AIX 5L Workload Manager (WLM)

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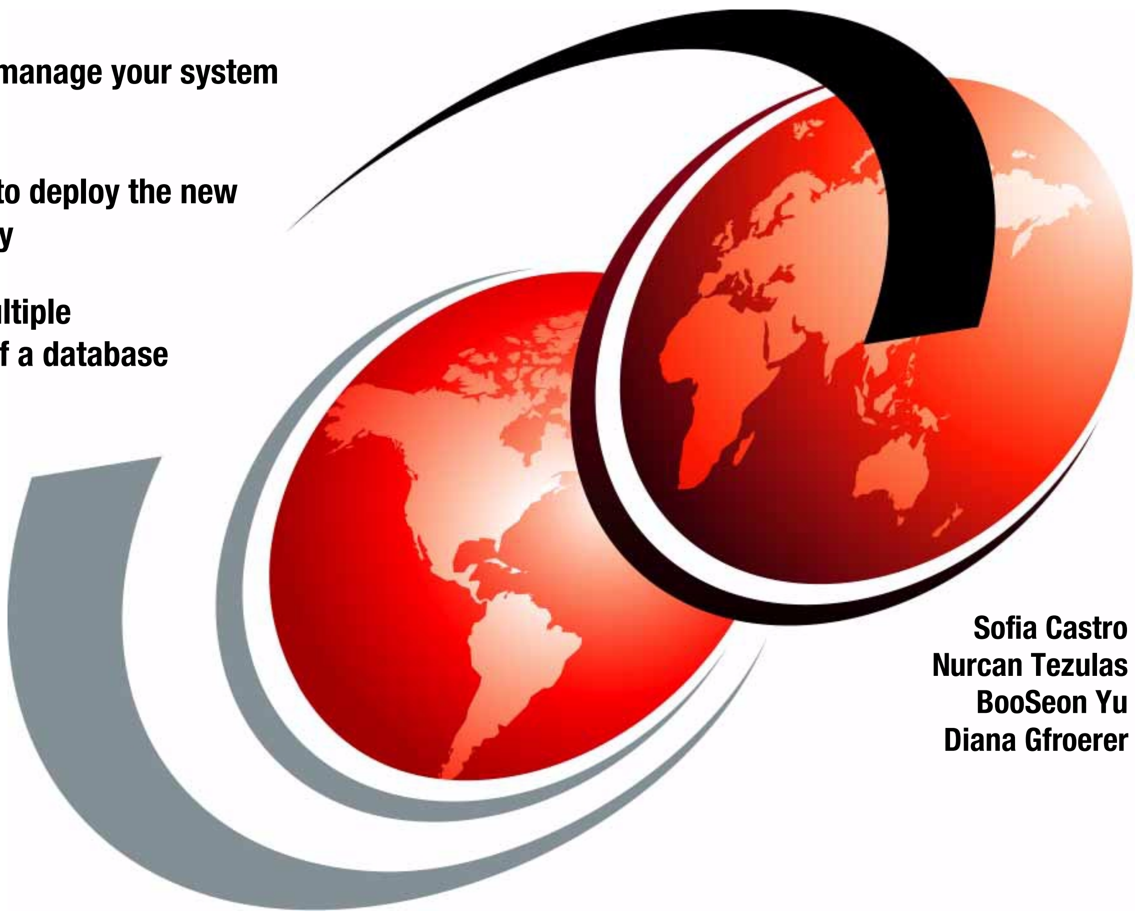
Learn how to deploy the new functionality

Manage multiple instances of a database



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AIX 5L Workload Manager (WLM)

November 2000

Take Note!

Before using this information and the product it supports, be sure to read the general information in Appendix G, “Special notices” on page 269.

First Edition (November 2000)

This edition applies to AIX Workload Manager for use with the AIX 5L for Power Version 5.0 Operating System.

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Contents

Preface

This IBM Redbook will help you work with AIX Workload Manager (WLM) by exploiting the whole spectrum of functionality provided by WLM. It contains the WLM features, including the WLM performance tools, introduced in the Fall of 2000 and is intended to be a workbook and reference that helps system administrators and technical support and service professionals gain a deeper understanding of AIX WLM.

This redbook contains a detailed description of how to configure WLM, explains the use of new features, such as manual assignment, the WLM API, and the WLM performance tools, and provides hints and tips gained from practical experience. A chapter for guidance on system sizing with WLM, primarily in Server Consolidation environments, has been included.

The Appendixes describe the test programs that were used during the creation of this redbook, and they contain sample scripts for manual assignment that can help you use the new features in your environment. They also contain an exhaustive explanation of the WLM API routines as well as a sample program for application tagging to be used with the WLM API.

The shell scripts and sample program are included on a floppy disk at the back of this book.

The team that wrote this redbook

This redbook was produced by a team of specialists from around the world working at the International Technical Support Organization, Austin Center.

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Chapter 1. The need for workload management

This chapter describes the differences between physical partitioning, logical partitioning, and workload management based on the AIX Workload Manager.

First, it is important to understand why workload management becomes vital. The conflicting pressures of costs, a lack of skilled support people, fast-growing server farms, and the need for competitive advantage are forcing customers to look for proactive solution designs. Solutions that are not scalable or flexible enough to handle or that cannot avoid increased architectural complexity lead directly to administrator overhead and solution downtime. The consequences are much larger and longer-term problems:

- Increased Total Cost of Ownership (TCO), such as increased hardware, software, and maintenance costs, and costs of excess administrators
- Increasing fragmentation of data and applications across the enterprise
- Reduced ability to exercise financial oversight
- Increased business costs due to outages

Server consolidation is one solution. It helps customers deliver higher IT service levels in a more cost-effective fashion by optimizing both the quantity and distribution of servers supporting their mission-critical IT functions.

However, server consolidation does not only mean physical consolidation of many small servers into fewer, more powerful servers. Administrators must go beyond simply moving department applications onto a single system. They must:

- Understand how applications behave under loads and be able to realize what expected loads will be
- Guarantee service levels, such as faster response times, continuous availability, and increased access to data
- Gather detailed information on usage and capacity
- Maximize their ability to make system changes flexibly
- React to changes in workload

Workloads from many different server systems are combined into a single, large system. The most frequent different server systems to be combined are OLTP, batch, print, and general user processing systems. These workloads often interfere with each other and have different goals and service agreements.

The ability to change resource allocation very rapidly with minimal operator intervention but maximum precision utilizing scripts, traditional system management tools, and other components of their IT infrastructure becomes very necessary.

1.1 Architectural differences

The demand for advanced management functionality has caused some confusion about the differences between physical partitioning and workload management.

These two functions are successfully merged in mainframe environments. Current UNIX offerings for physical partitioning and workload management have clear architectural differences. While physical partitioning creates isolation between multiple applications running on a single server, workload management supplies effective management of multiple, diverse workloads to efficiently share a common pool of resources.

1.1.1 Physical partitioning

Mainframes first addressed the need to isolate application environments from each other through physical partitioning. A certain degree of operator intervention was involved when resizing the physical partitions, and applications had to be quiesced before boundaries could be shifted. This explicit management burden limited the use of physical partitions as a tool to respond to fluctuating workload needs.

About 15 to 20 years ago, mainframe developers replaced physical partitions with logical partitions (LPARs). LPARs are virtual-machine-like and can be configured only at IPL time. They also created an additional layer of resource management across partitions by specifying of time-slicing parameters. With these functions, logical partitions provided a much finer degree of granularity than physical partitions.

At the same time, mainframe developers produced workload management tools. Systems were now able to respond dynamically to fluctuating loads. These tools were implemented as a kernel function within each of the mainframe’s SMP partitions.

1.1.2 Logical partitioning (LPAR)

In current UNIX environments, logical partitioning (LPAR) means splitting a hardware system on specific hardware boundaries and then running a separate operating system on each piece of hardware. Each physical partition can run a different level of operating system. This can be done on SMP systems or NUMA nodes.

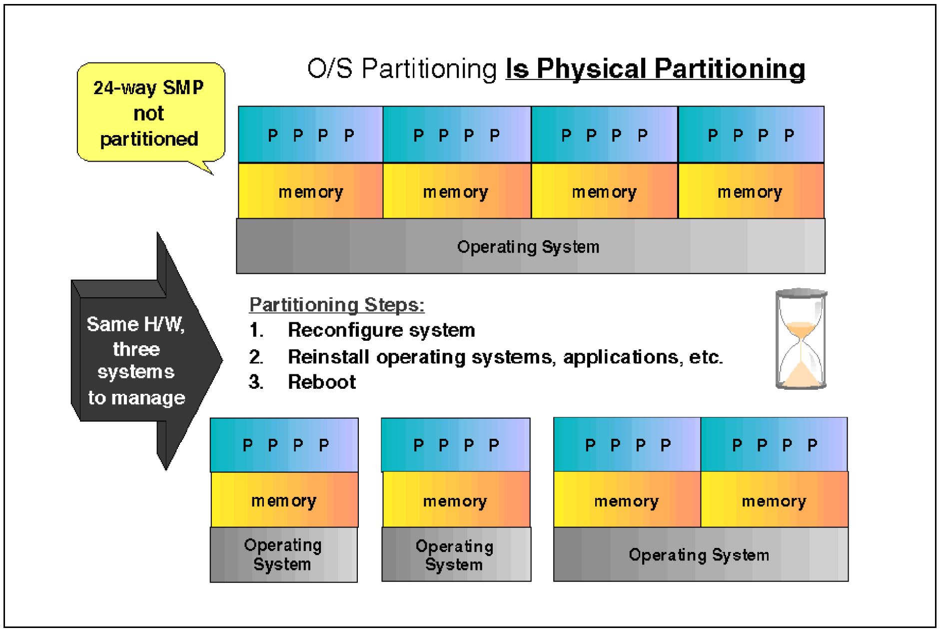


Figure 1. LPAR

Each partition has its own memory and processors.

Partitioning can be used to solve several problems, such as running production and test versions of an application or operating system on different partitions for verification or certification purposes. It can also be used for operating system fault isolation. It does not solve hardware or application faults.

Extra resources are needed due to the fact that each partition requires its own operating system that has to be managed as an individual system.

Resources may be wasted because the granularity of control is done on hardware boundaries, such as individual processors. Since resources cannot easily be switched from one partition to another, free resources on one partition will be wasted if they are not used by any application on that particular partition.

A more flexible solution to this problem is provided by various workload management products, such as the AIX Workload Manager (WLM).

1.1.3 Workload management

Workload management allows the system administrator to divide resources between jobs without having to partition the system as shown in Figure 2.

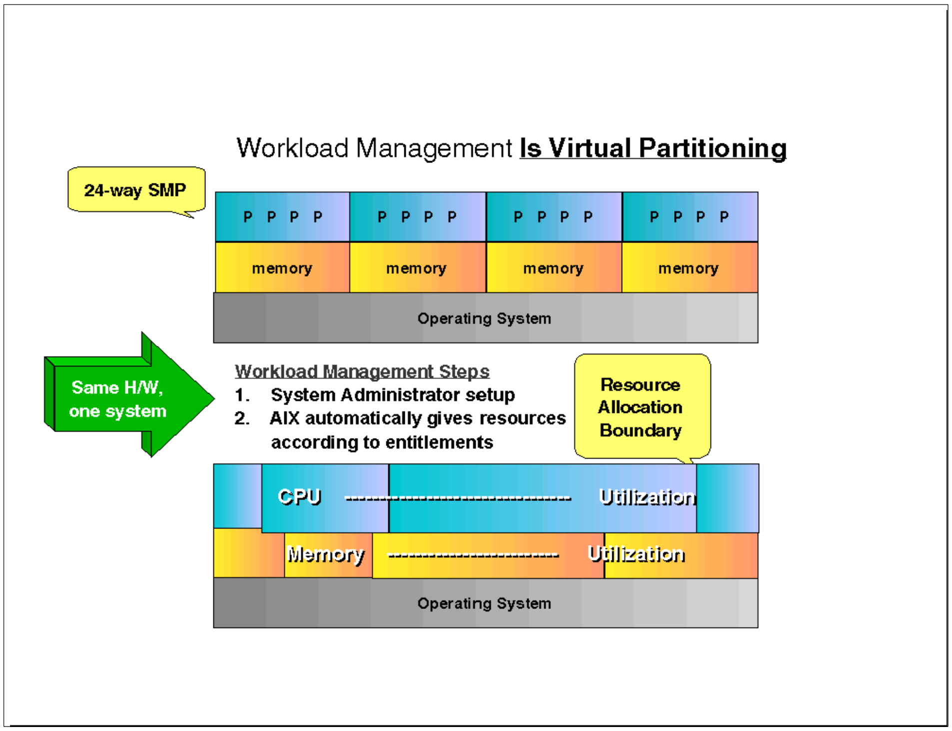


Figure 2. Workload Management

WLM provides isolation between user communities with very different system behaviors. This can prevent effective starvation of workloads with certain characteristics, such as interactive or low CPU usage jobs by workloads with other characteristics, such as batch or high memory usage jobs.

The setup of WLM is much simpler than partitioning where reinstallation and reconfiguration are required. With WLM, a single operating system manages the entire system and all jobs; so, only one system has to be administered.

WLM manages percentages of CPU time rather than CPUs. This allows control over CPU resources at a finer granularity.

CPU time, memory, and I/O bandwidth are managed separately. Therefore, different styles of applications can be managed.

AIX Workload Manager (WLM) is an operating system feature introduced in AIX Version 4.3.3. It is part of the operating system kernel at no additional charge.

AIX WLM delivers the basic ability to give system administrators more control over how scheduler, Virtual Memory Manager (VMM), and device driver calls allocate CPU, physical memory, and I/O bandwidth to classes-based user, group, application path, process type, or application tag.

It allows a hierarchy of classes to be specified, processes to be automatically assigned to classes by the characteristics of a process, and manual assignment of processes to classes.

Classes can be superclasses or subclasses.

AIX WLM self-adjusts when there are no jobs in a class or when a class does not use all the resources that are allocated for it. The resources will automatically be distributed to other classes to match the policies of the system administrator.

Since the scheduling is done within a single AIX operating system, system management is less complex.

Unlike LPAR, workload management does not allow multiple operating systems that may be useful for testing and certification purposes on one hardware system.

1.2 The purpose of AIX WLM

Customers, system administrators, performance consultants, and managers should be aware that Workload Manager is not a tuning tool. AIX WLM is a resource management tool that specifies the relative importance of each workload by classes, tiers, limits, shares, and rules.

WLM is ideally suited to balance the demands or requests of competing workloads when one or more resources are constrained.

It prevents a relatively uncontrolled way of resource scheduling for different applications on the system. Administrators are spared the requirement of writing complex scripts.

Before sizing a consolidated system (see Chapter 7, “Sizing recommendations for Workload Manager” on page 199) by putting two or more systems on a single, more powerful server, one thing is vital: *Know your* *workload*. It is very important that you understand the requirements of the workloads on each individual server that you are planning to incorporate onto the consolidated server.

Your application vendor might provide you with recommendations for system sizing. It is more important is, however, that you create application documentation based on your actual workloads in addition to that, which means gathering detailed information on usage and capacity for your individual systems. This can be done by performance monitoring.

Document the workload behavior in a standalone situation, that is, on each traditional single workload server. After migrating from the standalone servers to the consolidated server, which might have improvements in CPU performance or internal and external bus bandwidth, the workload behavior should again be documented so that you can compare future changes to this relative load. After this, you can start implementing different WLM configurations and testing what works best for you.

The same applies if WLM is used on a server that already has several different workloads running. Get a baseline first by monitoring the system performance without WLM; then, implement different WLM configurations, and monitor each of them in order to decide which one works best in your environment. Chapter 8, “Practical experience” on page 183, provides helpful examples on how this can be done.

Chapter 2. AIX Workload Manager functionality

AIX Workload Manager (WLM) is an operating system feature released with AIX V4.3.3. With AIX maintenance level 2 (APAR IY06844), additional features were added to the first release of WLM. These were:

- Classification of existing processes to avoid stopping and starting applications when stopping and starting WLM
- Passive mode to allow “before” and “after” WLM comparisons
- Management of application file names, which allowed WLM to start even if some applications listed in the rules file could not be accessed

In this chapter, we first focus on WLM’s functionality, which is available with AIX 5L, by outlining the enhancements it offers over its earlier release:

- Management of disk I/O bandwidth in addition to the already-existing CPU cycles and real memory
- Graphical display of resource utilization
- Performance Toolbox integration with WLM classes enabling the toolbox to display WLM performance statistics
- Fully-dynamic configuration including setup of new classes without restarting WLM
- Application Programming Interface (API) to enable external applications to modify the system’s behavior
- Manual reclassification of processes, which provides the ability to have multiple instances of the same application in different classes
- More application isolation and control:
  - New *subclasses* add ten times the granularity of control (from 27 to 270 controllable classes).
  - Administrators can delegate subclass management to others users and groups rather than root or system.
  - Possibility of inheritance of classification from parent to child processes.
- Application path name wildcard flexibility extended to user name and group name
- Tier separation enforced for all resources, enabling a deeper prioritization of applications

2.1 Overview

WLM gives the system administrator the ability to create different classes of service for jobs and to specify attributes for those classes. These attributes specify minimum and maximum amounts of CPU, physical memory, and disk I/O throughput to be allocated to a class. WLM then classifies jobs automatically to classes using class assignment rules provided by a system administrator. These assignment rules are based on the values of a set of attributes of a process. The system administrator or a privileged user can also manually assign jobs to classes, thereby, overriding the automatic assignment. The basic WLM elements are depicted in Figure 3.

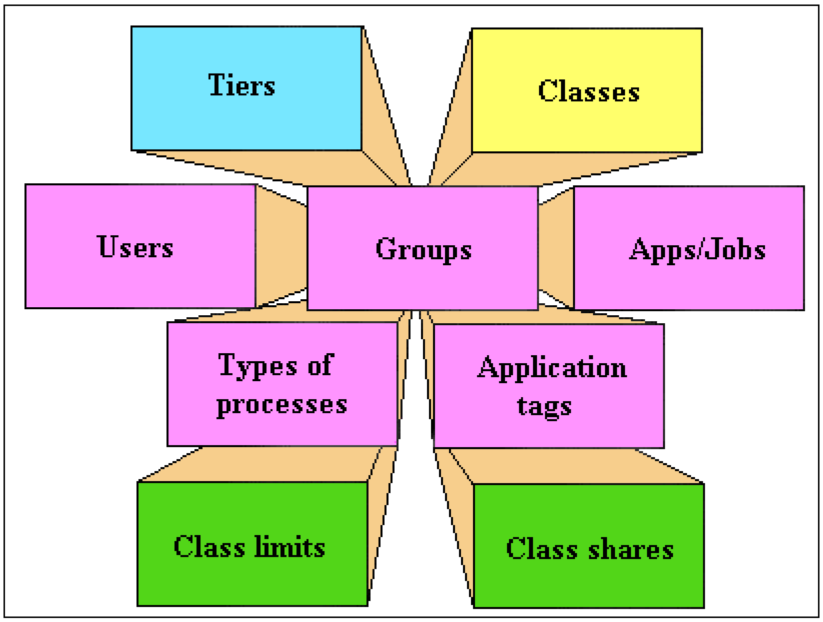


Figure 3. Basic WLM elements

This way, WLM monitors and regulates the CPU utilization of threads, physical memory consumption, and disk I/O bandwidth use of processes active on the system. The manner in which the resources are regulated is dependent on the WLM configuration defined by the system administrator.

There are a number of controlling variables in WLM that facilitate managing classes of jobs to achieve the automatic application of resource entitlement policy you define (see Figure 3). The primary concept to remember is that classes are what you manage in WLM, and there are five job attributes available for process identification: *users*, *groups*, *application path names*, *process types,* and *application tags* (application tags are set by the WLM API). Class resource shares and class resource limits allow you to define resource entitlements for each class. Tiers allow you to prioritize groups of classes.

WLM configuration can be performed through direct editing of the configuration files and AIX commands or through the AIX administration tools, SMIT, or Web-based System Manager (WSM) graphical user interface.

In the following sections, these points will be covered in greater detail.

2.2 Classes

The central concept of WLM is the class. A class is a collection of processes (jobs) that has a single set of resource limits applied to it. WLM assigns processes to the various classes and controls the allocation of system resources among the different classes. For this purpose, WLM uses class assignment rules and per-class resource shares and limits set by the system administrator. The resource entitlements and limits are enforced at the class level. This is a way of defining classes of service and regulating the resource utilization of each class of applications to prevent applications with very different resource utilization patterns from interfering with each other when they are sharing a single server.

2.2.1 A hierarchy of classes

WLM allows system administrators to set up a hierarchy of classes with two levels by defining superclasses and subclasses. The main difference between superclasses and subclasses is the resource control (shares and limits):

- At the superclass level, the determination of resource entitlement based on the resource shares and limits is based on the total amount of each resource managed by WLM available on the machine.
- At the subclass level, the resource shares and limits are based on the amount of each resource allocated to the parent superclass.

The system administrator can delegate the administration of the subclasses of each superclass to a *superclass administrator*, thus, having the option of allocating a portion of the system resources to each superclass and then letting superclass administrators distribute the allocated resources among the users and/or applications they manage.

WLM supports 32 superclasses (27 user defined plus five predefined). In turn, each superclass can have 12 subclasses (10 user-defined and two predefined). Depending on the needs of the organization, a system administrator can decide to use only superclasses or both superclasses and subclasses. He or she can also use subclasses only for some of the superclasses.

Each class is given a name by the WLM administrator who creates it. A class name is up to 16 characters long and can contain only uppercase and lowercase letters, numbers, and underscores (_). For a given WLM configuration, the names of all the superclasses must be different from one another, and the names of the subclasses of a given superclass must be different from one another. Subclasses of different superclasses can have the same name. The fully-qualified name of a subclass is *superclass_name.subclass_name*.

In the remainder of this chapter, whenever the term *class* is used, it is applicable to both subclasses and superclasses. The following sections describe both super and subclasses in greater detail as well as the backward compatibility WLM provides to configurations of its first release.

2.2.2 Superclasses

A superclass is a class with subclasses associated with it. No processes can belong to the superclass without also belonging to a subclass, either predefined or user-defined. A superclass has a set of class assignment rules that determines which processes will be assigned to it. A superclass also has a set of resource limitation values and resource target shares that determine the amount of resources that can be used by processes belonging to it. These resources will be divided among the subclasses based on the resources limitation values and resource target shares of the subclasses.

Up to 27 superclasses can be defined by the system administrator. In addition, five superclasses are automatically created to deal with processes, memory, and CPU allocation as follows:

- *Default* superclass: The default superclass is named Default and is always defined. All non-root processes that are not automatically assigned to a specific superclass will be assigned to the Default superclass. Other processes can also be assigned to the Default superclass by providing specific assignment rules.
- *System* superclass: This superclass is named System and will have all privileged (root) processes assigned to it if they are not assigned by rules to a specific class, plus the pages belonging to all system memory

segments, kernel processes, and kernel threads. Other processes can also be assigned to the System superclass. The default is for this superclass to have a memory minimum limit of one percent.

- *Shared* superclass: This superclass receives all the memory pages shared by processes in more than one superclass. This includes pages in shared memory regions and pages in files that are used by processes in more than one superclass (or in subclasses of different superclasses). Shared memory and files used by multiple processes that belong to a single superclass (or subclasses of the same superclass) are associated with that superclass. The pages are placed in the Shared superclass only when a process from a different superclass accesses the shared memory region or file. This superclass can have only physical memory shares and limits applied to it. It cannot have shares or limits for the other resource types, subclasses, or assignment rules specified.
- *Unclassified* superclass: The processes in existence at the time WLM is started are classified according to the assignment rules of the WLM configuration being loaded. During this initial classification, all the memory pages attached to each process are charged either to the superclass to which the process belongs (when not shared or shared by processes in the same superclass) or to the Shared superclass when shared by processes in different superclasses. However, there are a few pages that cannot be directly tied to any processes (and, thus, to any class) at the time of this classification, and this memory is charged to the Unclassified superclass. An example for that would be pages from a file that has been closed. The file pages will remain in memory, but no process really *owns* these pages; therefore, they cannot be charged to any specific class. Most of this memory will end up being correctly reclassified over time, when it is either accessed by a process or freed and reallocated to a process after WLM is started. There are only a few kernel processes, such as wait or lrud, in the Unclassified superclass. Even though this superclass can have physical memory shares and limits applied to it, WLM commands do not allow you to set shares and limits or specify subclasses or assignment rules on this superclass.
- *Unmanaged* superclass: A special superclass, named Unmanaged, will always be defined. No processes will be assigned to this class. This class will be used to accumulate the memory usage for all pinned pages in the system that are not managed by WLM. The CPU utilization for the waitprocs is not accumulated in any class. This is done deliberately; otherwise, the system would always seem to be at 100 percent CPU utilization, and it could be misleading for users when looking at the WLM or system statistics. This superclass cannot have shares or limits for any resource types, subclasses, or assignment rules specified.

2.2.3 Subclasses

A subclass is a class associated with exactly one superclass. Every process in the subclass is also a member of the superclass. Subclasses only have access to resources that are available to the superclass. A subclass has a set of class assignment rules that determine which of the processes assigned to the superclass will belong to it. A subclass also has a set of resource limitation values and resource target shares that determine the resources that can be used by processes in the subclass. These resource limitation values and resource target shares indicate how much of the superclass' target (the resources available to the superclass) can be used by processes in the subclass.

Up to 10 subclasses can be defined by the system administrator or by the superclass administrator for each superclass. In addition, two special subclasses, Default and Shared, are always defined in each superclass as follows:

- *Default* subclass: The default subclass is named Default and is always defined. All processes that are not automatically assigned to a specific subclass of the superclass will be assigned to the Default subclass. You can also assign other processes to the Default subclass by providing specific assignment rules.
- *Shared* subclass: This subclass receives all the memory pages used by processes in more than one subclass of the superclass. This includes pages in shared memory regions and pages in files that are used by processes in more than one subclass of the same superclass. Shared memory and files used by multiple processes that belong to a single subclass are associated with that subclass. The pages are placed in the Shared subclass of the superclass only when a process from a different subclass of the same superclass accesses the shared memory region or file. There are no processes in the Shared subclass. This subclass can have only physical memory shares and limits applied to it. It cannot have shares or limits for the other resource types or assignment rules specified.

2.2.4 Backward compatibility considerations

System administrators have the option of using only superclasses or both superclasses and subclasses in their WLM configurations. The system administrator can also choose to create subclasses only for some superclasses. So, when starting AIX 5L's WLM with configurations created in its first or AIX V4.3.3 release, only superclasses will be used. The default output of the `wlmstat` command, in this case, will show just the superclasses and will be similar to the one users of the first release are familiar with.

Note the following example:

```
# wlmstat
CLASS           CPU    MEM    DKIO
Unclassified    0      0      0
Unmanaged       0      0      0
Default         0      0      0
Shared          0      2      0
System          2      12     0
db1             0      0      0
db2             0      0      0
devlt           0      4      2
```

If some of the superclasses have subclasses defined by a WLM administrator, the subclasses will be shown in `wlmstat` output as the following:

```
# wlmstat
CLASS           CPU    MEM    DKIO
Unclassified    0      0      0
Unmanaged       0      0      0
Default         0      0      0
Shared          0      2      0
System          3      11     7
db1             46     0      0
db2             48     0      0
devlt           50     0      0
devlt.Shared    0      0      0
devlt.editors   18     0      0
```

The same thing happens with the output of the `ps` command. For processes in a superclass without any subclasses, `ps` will show the superclass name as the process' class name:

```
# ps -ae -o pid,user,class,args
PID   USER        CLASS            COMMAND
1     root        System           /etc/init
5614  dbadmin     db1              /etc/ora_db_writer
5750  dbadmin     db2              /etc/ora_db_writer
5980  jim         devlt.editors    /bin/vi
6714  sue         devlt.build      /bin/cc
```

2.3 Tiers

Tier configuration is based on the importance of a class relative to other classes in WLM. There are 10 available tiers from 0 through to 9. Tier value 0 is the most important and the value, 9, is the least important. As a result, classes belonging to tier 0 will get resource allocation priority over classes in tier 1; classes in tier 1 will have priority over classes in tier 2, and so on. The default tier number, if the attribute is not specified, is 0.

The tier applies at both the superclass and subclass levels. Superclass tiers are used to specify resource allocation priority between superclasses, and subclass tiers are used to specify resource allocation priority between subclasses of the same superclass. There is no relationship between tier numbers of subclasses of different superclasses.

Tier separation in terms of prioritization is much more enforced in AIX 5L than what was observed in the previous release. A process in tier 1 will never have more priority than a process in tier 0 since there is no overlapping of priorities in tiers. It is most unlikely that classes in tier 1 will get hold of any resources if processes in tier 0 are using up all the resources. This occurs because the control of *leftover resources* is much more restricted than what was happening in WLM's first AIX V4.3.3 release.

2.4 Class attributes

The attributes of a class are as follows:

- *Class name*: Up to 16 characters long. Can contain only uppercase and lowercase letters, numbers, and underscores (_).
- *Tier*: Number between 0 and 9 for class priority ranking.
- *Inheritance*: Specifies whether or not a child process inherits the class assignment from its parent.
- *Adminuser*, *admingroup* (superclass only): Used to delegate the administration of a superclass.
- *Authuser*, *authgroup*: Used to delegate the right to manually assign a process to a class.
- *Resource Set*: Used to limit the set of resources to which a given class has access in terms of CPUs (processor set).

Tier

This attribute holds the tier number to which the class belongs. It is used to prioritize resource allocation between classes. Refer to Section 2.3, "Tiers" on page 13, for further details on tiers.

Inheritance

The inheritance attribute indicates whether or not a child process should inherit its parent's class or be classified according to the automatic assignment rules upon `exec`. The possible values are *yes* or *no*, and the default if the attribute is not specified is *no*. This attribute can be specified at both the superclass and subclass level. For a subclass of a given superclass:

Table 1. Inheritance attribute at superclass and subclass level meaning

Superclass level inheritance value	Subclass level inheritance value	Meaning
yes	yes	A child of a process in the subclass will remain in the same subclass upon `exec`.
yes	no or unspecified	A child of a process in the subclass will remain in the same superclass and will be classified in one of its subclasses according to the assignment rules for the superclass upon `exec`.
no or unspecified	yes	A child of a process in the subclass will be submitted to the automatic assignment rules for the superclasses upon `exec`. If the process is classified by the rules in the same superclass, it will remain in the subclass (it will not be submitted to the subclasses assignment rules). If the process is classified by the superclass rules in a different superclass, the subclass assignment rules of the new superclass are applied to determine the subclass of the new superclass to which the process will be assigned.
no or unspecified	no or unspecified	A child of a process in the subclass will be submitted to the standard automatic assignment upon `exec`.

The inheritance attribute has a different reading when manual assignment is being used. This feature is fully-described in Section 5.1.3, "Interaction with inheritance" on page 143. Additionally, there is also the concept for tag inheritance from parent to child processes when application tagging is being used. This subject is covered in Section 6.1, "Application tag" on page 157.

Adminuser, admingroup

These attributes are valid only for superclasses. They are used to delegate the superclass administration to a user and/or group of users:

- *Adminuser* specifies the name of the user (as listed in /etc/passwd) authorized to perform administration tasks on the superclass. This can also be an NIS user.
- *Admingroup* specifies the name of the group of users (as listed in /etc/group) authorized to perform administration tasks on the superclass. This can also be an NIS group.

Only one value (user/group name) is allowed for each attribute. Any one of them, none, or both can be specified. The user and/or group has authority to create/delete subclasses, change the attributes and resource shares and limits for the subclasses, define, remove, or modify subclass assignment rules, and refresh (update) the active WLM configuration for the superclass. In addition, root always has authority on any superclass.

Authuser, authgroup

These attributes are valid for all the classes. They are used to specify the user name and/or the group name of the user and/or group authorized to manually assign processes to the class. When manually assigning a process (or a group of processes) to a superclass, the assignment rules for the superclass are used to determine which subclass of the superclass each process will be assigned to.

- *Authuser* specifies the name of the user (as listed in /etc/passwd) authorized to manually assign processes to the class.
- *Authgroup* specifies the name of the group of users (as listed in /etc/group) authorized to manually assign processes to the class.

Only one value (user/group name) is allowed for each attribute. Any one of them, none, or both can be specified. In addition, root and the administrators of a superclass specified by adminuser/admingroup can always manually assign processes to a superclass or to a subclass of the superclass.

Resource set (rset)

This attribute is valid for all the classes. Resource sets are an operating system feature introduced in AIX 5L. This feature allows the system administrator to define subsets of system resources through SMIT or WSM and give them a name using a new registry service.

WLM uses the concept of resource sets (or rsets) to restrict the processes in a given class to a subset of the system's physical memory and processors. A valid resource set is composed of memory (currently only one domain shared by all resource sets) and at least one processor.

Using SMIT or Web-based System Manager, a system administrator has the ability to define and name resource sets containing a subset of the resources available on the system. Then, using the WLM administration interfaces, root or a designated superclass administrator can use the name of the resource set as the *rset* attribute of a WLM class. From then on, every thread assigned to this WLM class is only dispatched on one of the processors in the resource set. This is a very effective way of further separating workloads for the CPU resource. Refer to Section 3.3.6, “Working with resource sets” on page 86 for further information on resource sets.

Since all of the current systems have only one memory domain shared by all the resource sets, this method does not allow the physical separation of workloads in memory.

2.5 Classification process

There are two ways to classify processes in WLM:

- Automatic assignment when a process calls the system call, `exec`, using assignment rules specified by a WLM administrator. This automatic assignment is always in effect (cannot be turned off) when WLM is active. This is the most common method of assigning processes to the different classes.
- Manual assignment of a selected process or group of processes to a class by a user with the required authority on both the process and the target class. This manual assignment can be done either by a WLM command, which can be invoked directly or through SMIT or WSM, or by an application, using a function of the WLM Application Programming Interface. Manual assignment overrides automatic assignment.

2.5.1 Automatic assignment

The automatic assignment of processes to classes uses a set of class assignment rules specified by a WLM administrator. There are two levels of assignment rules:

- A set of assignment rules at the WLM configuration level used to determine which superclass a given process should be assigned to.
- A set of assignment rules at the superclass level used to determine which subclass of the superclass the process should be assigned to.

The assignment rules at both levels have exactly the same format.

When a process is created (`fork`), it remains in the same class as its parent (for more information on inheritance, see Section 5.1.3, “Interaction with inheritance” on page 143). Usually, reclassification happens when the new process calls the system call `exec`. In order to classify the process, WLM starts by examining the top level rules list for the active configuration to find out which superclass the process should belong to. For this purpose, WLM takes the rules one at a time in the order in which they appear in the file and checks the current values for the process attributes against the values and lists of values specified in the rule. When a match is found, the process will be assigned to the superclass named in the first field of the rule. Then, the rules list for the superclass is examined in the same way to determine which subclass of the superclass the process should be assigned to. For a process to match one of the rules, each of its attributes must match the corresponding field in the rule. The rules to determine whether the value of a process attribute matches the values in the field of the rules list are as follows:

- If the field in the rule has a value of hyphen (-), any value of the corresponding process attribute is a match.
- If the value of the process attribute (for all the attributes except *type)* matches one of the values in the list in a rule and it is not excluded (prefaced by a (!)), it is considered a match.
- When one of the values for *type* attribute in the rule is comprised of two or more values separated by a plus (+) sign, a process will be a match for this value only if its characteristics match all the values mentioned above.

As stated before, at both the superclass and subclass levels, WLM goes through the rules in the order in which they appear in the rules list and classifies the process in the class corresponding to the first rule for which the process is a match. This means that the order of the rules in the rules list is extremely important, and caution must be applied when modifying it in any way.

2.5.2 Manual assignment

In addition to automatic class assignment, a user with the proper authority can manually assign processes or groups of processes to a specific superclass or subclass. This feature is described in greater detail in Chapter 5, “Manual assignment” on page 141.

2.5.3 Class assignment rules

After the definition of a class, it is time to set up the class assignment rules so that WLM can perform its automatic assignment. The assignment rules are used by WLM to assign a process to a class based on the user, group, application pathname, type of process, and application tag or a combination of these five attributes.

Note

WLM class assignment rules or process classification attributes:

- User
- Group
- Application path name
- Process type
- Application tag

The next sections describe all attributes that constitute a class assignment rule. All these attributes can contain a hyphen (-), which indicates that they are not specified.

Class name

This field must contain the name of a class that is defined in the class file corresponding to the level of the rules file we are configuring (either superclass or subclass). Class names can contain only uppercase and lowercase letters, numbers, and underscores (_) and can be up to 16 characters in length. No assignment rule can be specified for the system defined classes *Unclassified*, *Unmanaged*, and *Shared*.

Reserved

Reserved for future use. Its value *must* be a hyphen (-), and it must be present in the rule.

Users

The user name (as specified in the /etc/passwd file or in NIS) of the user owning a process can be used to determine the class to which the process belongs. This attribute is a list of one or more user names separated by a comma (,). Users can be excluded by using an exclamation point (!) prefix. Patterns can be specified to match a set of user names using full Korn shell pattern matching syntax.

Applications that use the `setuid` permission to change the *effective* user ID under which they run are still classified according to the user that invoked them. The processes are only reclassified if the change is done to the *real* UID.

Groups

The group name (as specified in the /etc/group file or in NIS) of a process can be used to determine the class to which the process belongs. This attribute is a list composed of one or more groups separated by a comma (,). Groups can be excluded by using an exclamation point (!) prefix. Patterns can be specified to match a set of group names using full Korn shell pattern matching syntax.

Applications that use the `setgid` permission to change the *effective* group ID under which they run are still classified according to the group that invoked them. The processes are only reclassified if the change is done to the *real* GID.

Application pathnames

The full pathname of the application for a process can be used to determine the class to which a process belongs. This attribute is a list composed of one or more applications and separated by a comma (,). The application pathnames will be either full pathnames or Korn shell patterns that match pathnames. Application pathnames can be excluded by using an exclamation point (!) prefix.

Process types

In AIX 5L, the process type attribute is introduced as one of the ways to determine the class to which a process belongs. This attribute is a comma (,)-separated list of single values or combinations of two or more single values joined with plus signs (+). A plus sign (+) means *AND*, and a comma (,) means *OR*. For example:

- 64bit,plock+fixed
- plock+fixed+64bit,32bit
- plock,fixed,64bit

The list of values that can figure on this attribute is shown in the following section. 32 bit and 64 bit are mutually exclusive:

Attribute value	**Process type**
32bit	The process is a 32 bit process.
64bit	The process is a 64 bit process.
plock	The process called plock() to pin memory.
fixed	The process is a fixed priority process (SHED_FIFO or SCHED_RR).

Application tags

In AIX 5L, the application tag attribute is introduced as one of the forms of determining the class to which a process belongs. This is an attribute meant to be set by WLM's API as a way of further extending the process classification possibilities. This was created with the main purpose of allowing differentiated classification for different instances of the same application. This attribute can have one or more application tags separated by commas (,). An application tag is a string of up to 30 alphanumeric characters.

The classification is done by comparing the value of the attributes of the process at `exec` time against the lists of class assignment rules to determine which rule is a match for the current value of the process attributes. The class assignment is done by WLM:

- When WLM is started for all the processes existing at that time.
- Every time a process calls, the system calls `exec`, `setuid (and related calls)`, `setgid (and related calls)`, `setpri`, and `plock`, once WLM is started.

There are two *default* rules that are always defined (that is, hardwired in WLM). These are the default rules to assign all processes started by the user root to the System class, and all other processes to the Default class. If WLM does not find a match in the assignment rules list for a process, these two rules will be applied (the rule for System first), and the process will go to either System (uid root) or Default. These default rules are the only assignment rules in the standard configuration installed with AIX. In the example of Table 2, the rule for Default class is omitted from display, though this class' rule is always present in the configuration.

Table 2. Examples of class assignment rules

Class	Reserved	User	Group	Application	Type	Tag
System	-	root	-	-	-	-
db1	-	-	-	/usr/oracle/bin/db*	-	_db1
db2	-	-	-	/usr/oracle/bin/db*	-	_db2
devlt	-	-	dev	-	32bit	-
VPs	-	bob,sally	-	-	-	-
acctg	-	!ted	acct*	-	-	-

The rule for System is explicit and has been put first in the file. This is done deliberately so that *all* processes started by root will be assigned to the System superclass. By moving the rule for the System superclass further down in the rules file, the system administrator could have chosen to assign to System only the root processes that would not be assigned to another class (because of the application executed, for instance). In the example shown in Table 2, with the rule for System on top, if root executes a program in /usr/oracle/bin/db* set, the process will be classified as System. If the rule for the System class were after the rule for the db2 class, the same process would be classified as db1 or db2 depending on the tag.

These examples show that the order of the rules in the assignment rules file is very important. The more specific assignment rules should appear first in the rules file, and the more general rules should appear last. An extreme example would be putting the default assignment rule for the Default class, for which every process is a match, first in the rules file. That would cause every process to be assigned to the Default class. Then, the other rules would, in effect, be ignored.

You can define multiple assignment rules for any given class. You can also define your own specific assignment rules for the System and/or Default classes. The default rules mentioned above for these classes would still be applied to processes that would not be classified using any of the explicit rules.

2.6 Resources

WLM monitors and regulates the resource utilization of the threads and processes active on the system. The monitoring and regulation is done per class. You can set minimum or maximum limits per class for each resource type managed by WLM. In addition, a target value for each resource per class may be given. This target, named share, is representative of the amount of the resource that would be optimal for the jobs in the class.

The shares and limits at the superclass level refer to the total amount of each resource available on the system. At the subclass level, they refer to the amount of each resource made available to the superclass the subclass is in (superclass' target). The hierarchy of classes is, thus, a way for a system administrator to divide up the system resources between groups of users (superclasses) and delegate the administration of this share of the resources to superclass administrators. Each superclass administrator can then redistribute this amount of resources between the users in the group by creating subclasses and defining resource entitlements.

2.6.1 Resources managed by WLM

WLM manages three types of resources:

- The CPU utilization of the threads in a class. This is the sum of all the CPU cycles consumed by every thread in the class.
- The physical memory utilization of the processes in a class. This is the sum of all the memory pages that belong to the processes in the class.
- The disk I/O bandwidth of the class. This is the bandwidth (in 512 byte blocks per second) of all the I/Os started by threads of the class on the disk devices accessed.

Once a second WLM calculates the per-class utilization for each resource during the last second as a percentage of the total resource available.

CPU

The total amount of CPU time available every second is equal to one second times the number of CPUs on the system. For instance, on an eight-way SMP, if all the threads of a class combined consumed two seconds of CPU time during the last second, this represents a percentage of 2/8 = 25 percent. The percentage used by WLM for regulation is a decayed average over a few seconds of this *instantaneous* per-second resource utilization.

Physical memory

The total amount of physical memory available for processes at any given time is the total number of memory pages physically present on the system minus the number of pinned pages. The pinned pages are not managed by WLM since these pages cannot be stolen from a class to give them to another class in order to regulate memory utilization. The memory utilization of a class is simply the ratio of the number of (non-pinned) memory pages being used by all the processes in the class to the number of pages available on the system, as defined above, expressed as a percentage.

Disk I/O

For the disk I/O, the main difficulty is to determine a meaningful available bandwidth for a device. When a disk is 100 percent busy, its throughput (in blocks per second) will be very different if one application is doing sequential I/Os than if several applications are doing random I/Os. If the maximum throughput measured for the sequential I/O case was used as a value of the I/O bandwidth available for the device to compute the percentage of utilization under random I/Os, statistical errors would be created. It might lead one to think that the device is, for instance, 20 percent busy, while it is, in fact, at 100 percent utilization.

In order to get more accurate and reliable percentages of per-class disk utilization, WLM uses the data provided by the disk drivers (which are displayed with the AIX `iostat` command) giving, for each disk device, the percentage of the time the device has been busy during the last second. WLM knows how many blocks in total have been read/written on a device during the last seconds by all the classes accessing the device, how many blocks have been read/written by each class, and what was the percentage of utilization of the device and can easily calculate what percentage of the disk throughput was consumed by each class. For instance, if the total number of blocks read or written during the last second was 1000 and the device had been 70 percent busy, it means that a class reading/writing 100 blocks used seven percent of the disk bandwidth. Similarly, to the CPU time (another renewable resource), the values used by WLM for its disk I/O regulation are also a decayed average over a few seconds of these per-second percentages.

For the disk I/O resource, the shares and limits apply to each disk device accessed by the class individually, and the regulation is done independently for each device.

2.6.2 Class resource shares

The number of shares of a resource for a class determine the proportion of the resource that is allocated to the processes assigned to the class. In simple terms, the resource shares are specified as relative amounts of usage between different classes in the same tier. One way of thinking about shares is as a self-adapting percentage.

For example, a system has three classes defined, A, B, and C, whose targets are 50, 30, and 20 respectively.

- If all three classes are active, the total number of shares for the active classes is 100. Their targets, expressed as percentages, are 50 percent, 30 percent, and 20 percent.
- If A is not active, the total number of shares is 50 (so, each share represents two percent). The target percentages for B and C are 60 percent and 40 percent.
- If only one class is active, its target is 100 percent.

A class is considered active (regardless of its resource consumption) when it has at least one process assigned to it.

In this example, the sum of the shares for the three classes was 100 simply to make the sample calculation easier. A target can be any number between 1 and 65535.

The preceding example implicitly supposes that:

- A, B, and C are either all superclasses or all subclasses of the same superclass.
- A, B, and C are in the same tier.

The relative share numbers of a subclass and a superclass, of two subclasses of different superclasses, or of classes in different tiers do not give any indication of their relative resource entitlements. As explained earlier, the shares are used by WLM to calculate for each class a percentage goal of resource utilization for each resource type. This goal represents a percentage of resources that can vary widely depending on how many classes are active at any given time. However, WLM makes sure that the dynamic value of this percentage goal remains compatible with the minimum and maximum limits for the class. If the calculated percentage is below the minimum, WLM uses the minimum as the target. If the percentage is above the maximum limit, WLM uses the maximum as the target. If the percentage is between the minimum and the maximum limit, WLM uses the calculated value.

The share number can be specified as a hyphen (-) for any resource type to indicate that the class' resource utilization for this resource type is not regulated by WLM. This is the default when no share value has been specified for a resource type. Note that this default is different from the default value of one share in the first version of WLM.

What exactly does it mean to have a resource type that is not regulated by WLM on a certain class? It means that the resource target for that class will always be 100 percent. WLM will never penalize this class for being above its target, for there is no such thing as the notion of *WLM target* for this resource for this class. The consequence is (as expected) that a class with a non-regulated resource in tier 0 is capable of starving all the other classes for this resource. It is, therefore, recommended to reserve this non-regulated value for notoriously well-behaved classes, such as System, for instance.

The example shown in Figure 4 on page 26 displays resource allocation before and after a new class is activated. Initially, there are three active classes that have been allocated five, seven, and two resource shares respectively. These resource shares in combination are allocated 100 percent of the resource in accordance with their relative share values. When the new class, which has three resource shares, is activated, there are four active classes with resource shares of five, seven, two, and three with the total active resource shares equal to 17. As a result, when all four classes are active, the class with five resource shares will be allocated five of the total of

17 shares or 29 percent of the system resource (29.4 percent will be rounded down to 29 percent).

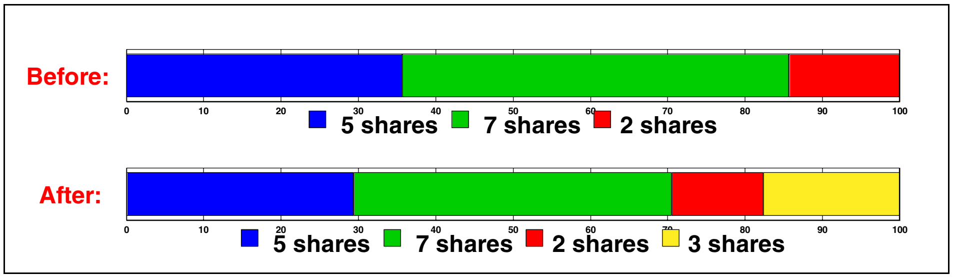


Figure 4. Example of share distribution automatically adjusting resources

2.6.3 Class resource limits

The class resource limits define the minimum and maximum amount of a resource that may be allocated to a class as a percentage of the total system resources. The different resources can be limited by the following values:

- The minimum percentage of the resource that must be made available when requested. The possible values are integers from 0 to 100. If unspecified, the default value is 0.
- The maximum percentage of a resource that can be made available when there is contention for the resource. If the contention no longer exists, this maximum limit can be surpassed. This is called a *soft* maximum, since it is possible for a class to get more resource than this soft maximum value if there is no contention. The possible values are integers from 1 to 100. If unspecified, the default value is 100.
- The maximum percentage of a resource that can be made available, *even* if there is no contention for the resource. This is called a *hard* maximum. A class will never get more resource than its hard maximum limit, even if it is the only one active on the system. The possible values are integers from 1 to 100. If unspecified, the default value is 100.

WLM does not impose hard constraints on the values of the resource limits. The following are the only constraints:

- The minimum limit must be less than or equal to the soft maximum limit.
- The soft maximum limit must be less than or equal to the hard maximum limit.
- The sum of the minimum of all the superclasses within a tier cannot exceed 100.

- The sum of the minimum of all the subclasses of a given superclass within a tier cannot exceed 100.
- WLM will not let users set a hard memory limit on the *System* class because of potential deadlock situations.

  For instance, consider the case in which performing file system I/Os involves a system daemon (a good example is NFS). If there is a hard maximum limit on the System class and the class reaches its maximum limit, the VMM page replacement algorithm (LRU) will be started and will initiate page-outs. No page will be given to processes in the System class until those page-outs complete, thus, bringing the System class below its maximum limit. Since there is intensive stealing of the pages belonging to the processes in the System class due to the maximum limit, it is entirely possible that the file system daemon needs a page to start processing the I/Os. So, VMM will not give it a page until the I/Os are complete, and the daemon will not process any I/O until it gets its page(s). From then on, no System process will ever be given a memory page, and the system will halt in a matter of seconds.

When a class (other than System) has reached its hard memory limit and requires more pages, the VMM page replacement algorithm (LRU) is initiated to steal pages from the class at limit, lowering its number of pages below the hard maximum before handing out new pages (the class pages against itself). This is, of course, the desired behavior, but this extra paging activity, which can take place even where there are plenty of free memory pages available, will impact the general performance of the system. Memory minimums for other classes should be used before imposing a memory hard maximum for any class.

This constraint about the sum of the minimum limits within a tier being less than or equal to 100 means that a class in the highest priority tier is always allowed to get resources up to its minimum limit. However, WLM cannot guarantee that the class will actually reach its minimum limit. This depends on how the processes in the class use their resources and on other limits that may be in effect. For example, a class may not be able to reach its minimum CPU entitlement because it cannot get enough memory.

For physical memory, setting a minimum limit gives some protection to the pages of the processes in the class (again, at least for the highest priority tier). Pages should not be stolen from a class below its minimum limit unless all the active classes are below their minimum limit and one of them requests more pages.

With this constraint, it means that pages should never be stolen from a class in the highest tier below its minimum limit. So, setting a memory minimum limit for a class of interactive jobs helps ensure that their pages will not all have been stolen between consecutive activations (even in cases where the memory is tight) and improves response time.

Note

Resource limits take precedence over class resource share values.

2.6.4 Backward compatibility considerations

As mentioned earlier, in the first release of WLM, the system default for the resource shares was one share. In AIX 5L it is (-), which means that the resource consumption of the class for this particular resource is not regulated by WLM. This changes the semantics quite a bit, and it is advised that system administrators review their existing configurations and consider if the new default is good for their classes or if they would be better off either setting up a default of one share to go back to the previous behavior or setting explicit values for some of the classes.

For the limits, the first release of WLM only had one maximum, not two. This maximum limit was, in fact, a *soft* limit for CPU and a *hard* limit for memory. Limits specified with the old format, *min percent-max percent*, will have, in AIX 5L, the max interpreted as a softmax for CPU, and a max that was set for memory will become both hardmax and softmax for memory in AIX 5L (which will give hardmax and softmax an equal value in this case). All interfaces (SMIT, AIX commands, and WSM) will convert all data existing from its old format to the new one.

The disk I/O resource is new for the current version; so, when activating AIX 5L's WLM with configuration files of the first WLM release, the values for the shares and the limits will just be the default ones for this resource. The system defaults are as follows:

- shares = -
- min = 0 percent, softmax = 100 percent, hardmax = 100 percent.

So, for existing WLM configurations, the disk I/O resource will not be regulated by WLM, which should lead to the same behavior for the class as with the first version.

2.7 WLM interaction with the kernel

WLM's management of system resources interacts with the already-existing kernel control mechanisms. These mechanisms are the scheduler for the CPU, the Virtual Memory Manager for memory, and device driver calls for the disk I/O bandwidth. They all use the allocation priority value calculated by WLM for each resource for each WLM class. This value is called Uniform Resource Access Priority (URAP).

2.7.1 Uniform Resource Access Priority (URAP)

URAP is a generic mapping of resource usage mechanisms. Each resource allocation mechanism (CPU, memory, and disk I/O) determines what will be the input to the URAP computation, named *resource usage*. It may be decayed CPU ticks, a number of memory pages, or a time-decayed amount of disk I/O blocks. In return, the URAP value will allow the subsystem to take decisions regarding the regulation of the resource. There is one URAP value independently computed for each resource in each class. The URAP value represents the priority of access to resources.

2.7.2 Interaction with the scheduler

AIX scheduler calls a WLM routine to inquire about the scheduling priority of each thread. This priority is determined by WLM using the URAP algorithm, which calculates the allocation priority for CPU for the class of the thread in question.

In a WLM environment, the `nice` command will cause a process to have its CPU usage selectively favored or penalized with respect to other processes in the same class as the process in question. The `nice` command will not affect the CPU utilization of processes in other classes because WLM will work to have the class' resources meet the requested number of resource shares and resource limits.

The `schedtune` command can be used to modify the behavior of the scheduler. All options to `schedtune` continue to work in a WLM environment. The use of `schedtune` options will not significantly impact the ability of WLM to manage CPU usage.

Note

It is recommended that any tuning with `schedtune` be done prior to using WLM.

2.7.3 Interaction with VMM

WLM controls the memory used by each class according to the tier where the class resides and the minimum, share, and maximum thresholds defined for the class. Regulation is based on memory URAPs computed from class consumption rates each second by `wlmsched`. This value is then used by VMM to control memory allocation to threads.

The `vmtune` command can be used to modify the behavior of VMM. All vmtune options work in a WLM environment. Some of the options to vmtune, particularly minperm, maxperm, minfree and maxfree, can hamper WLM's ability to achieve the specified physical memory usage goals.

> **Note**
>
> It is recommended that any tuning with `vmtune` be done prior to using WLM.

2.7.4 Interaction with disk device drivers

WLM intercepts the call to `devstrat` and executes its own algorithm for the regulation of disk I/O bandwidth:

- For I/O to a disk device, WLM updates the class per device statistics.
- If the class needs to be restricted (over target, for example), WLM delays the I/O. The delay is adjusted to regulate the I/O throughput utilization of the class (on a per-device basis).
- Each second, WLM calculates the percentage of disk utilization contributed by each class. For this purpose, WLM uses the statistics given by the device drivers (through `iostat` and `dkstat`), which contain the percentage of time the device was busy during that same time interval.
- Based on these statistics and on the allocation priority value calculated for disk I/O bandwidth for the class of the thread being controlled, WLM regulates the resource allocation for the thread.

2.8 WLM Application Programming Interface (API)

The WLM API supplies applications with the ability to perform every task a system administrator does through WLM commands. The API is described in Chapter 6, “WLM Application Programming Interface (API)” on page 157.

Chapter 3. AIX Workload Manager administration

WLM can be administered using three different methods:

- Command line and file editing
- System Management Interface Tool (SMIT), initiated with the AIX command `smit wlm` or `smitty wlm`
- Web-based System Manager (WSM) graphical user interface, initiated with the AIX command `wsm`

Throughout this chapter, you will find descriptive examples of each of these methods' functionality. These examples differ from method to method, even when they are outlined within the same section, in order to give you a broader perspective on the functionality.

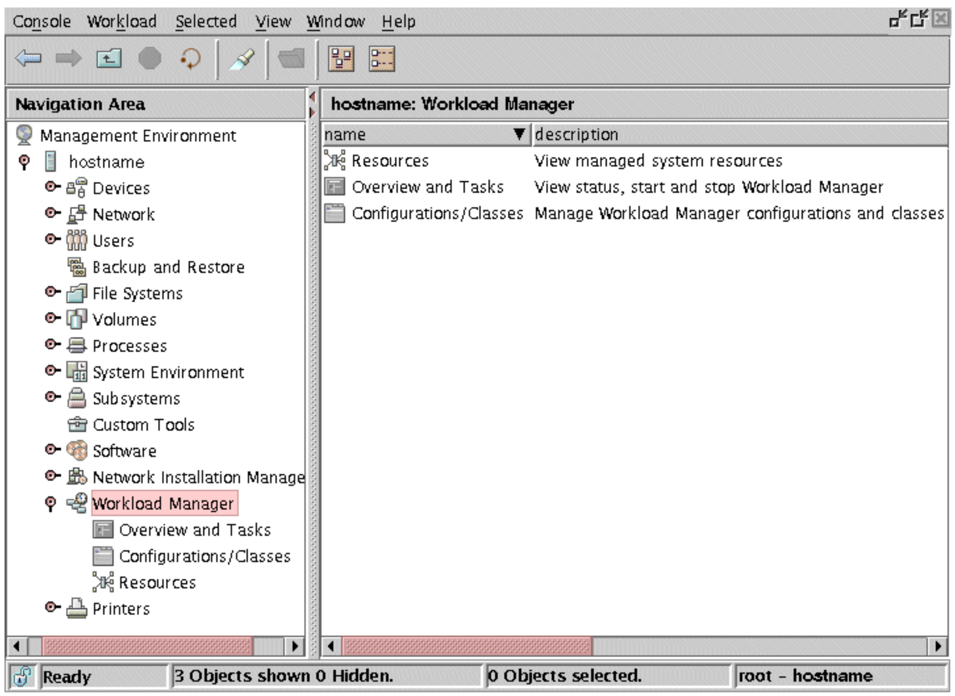


Figure 5. WLM screen in WSM

WLM commands can also be initiated through crontab entries to take advantage of WLM's various configuration capabilities. This way, job rankings can be changed at specific times of day and/or days of the week.

3.1 Property files

The WSM and SMIT interfaces record the configuration information in the same flat text files. These files are called the WLM *property files* and reflect WLM's two-layered class configuration.The various WLM configurations are placed in subdirectories of /etc/wlm. A symbolic link, /etc/wlm/current, points to the directory containing the current configuration files. For example, the current running rules file is stored in a file, /etc/wlm/current/rules. This link is updated by the `wlmcntrl` command when WLM starts with a specified set of configuration files. The sample configuration files shipped with AIX are in the /etc/wlm/standard directory.

The example in Figure 6 shows a configuration, called *Config*, which is, therefore, placed in /etc/wlm/Config.

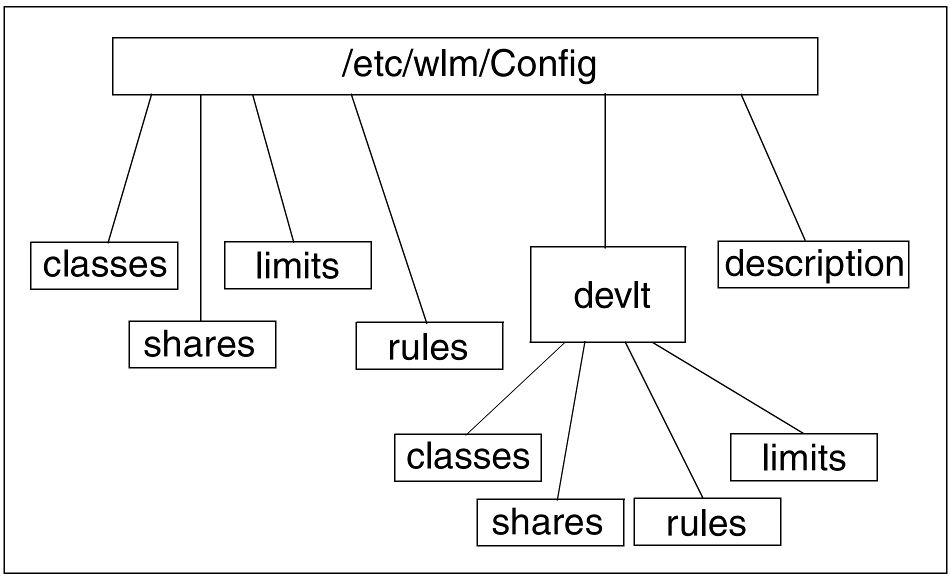


Figure 6. WLM's property files

The various files are explained below:

- *description* contains the description of the configuration.
- *classes* contains the class definitions of the configuration.
- *shares* contains the resource entitlements of the configuration.
- *limits* contains the resource limits of the configuration.
- *rules* contains the assignment rules of the configuration.

The configuration, *Config*, has a superclass, named *devlt*. Each superclass is represented by a subdirectory in the configuration directory named after the superclass. For each superclass, this subdirectory contains the *classes*, *shares*, *limits*, and *rules* files corresponding to the superclass's subclasses, resource entitlements, limits, and assignment rules.

The WLM property files for a WLM configuration must have write permission only for root. The WLM property files for superclasses must have write permission for the adminuser and admingroup for the superclass. If there is no adminuser for the superclass, the files should be owned by root. If there is no admingroup for a superclass, the WLM property files for the superclass should be the group *system*, and have no write permission for the group.

classes file

This file contains the definition of WLM superclasses or subclasses for a given configuration. This file is organized into stanza names, which are WLM class names, and contents, which are attribute-value pairs specifying characteristics of the class. Each stanza names a WLM class. The only names that have a special meaning to the system are Default, Shared, Unclassified, Unmanaged, and System. Unclassified and Unmanaged cannot appear as class names in this file. The superclasses, Default, Shared, and System, are always defined. The subclasses, Default and Shared, are always defined. The class attributes that can be defined in the *classes* file are tier, inheritance, adminuser, admingroup, authuser, authgroup, and resource set (rset). Refer to Section 2.4, "Class attributes" on page 14, for further details about these attributes. The attributes that have not been explicitly set by the system administrator are omitted from this file. The default values for these attributes can be changed using a special *default* stanza at the very top of this file. Be extra careful when using this default stanza because it can lead to starvation of your *System* superclass.

The following is part of a typical /etc/wlm/Config/classes file for the example in Table 2 on page 21. In this example, the tier for db2 would have to be set to 1 because the default value, specified for the tier attribute in the special *default* stanza at the top of this file, has been set to tier 0:

```
* This is the default special stanza, valid for all classes
* if not specified otherwise:
*
default:
        tier=0

* System defined classes
* All attributes to default value
* Attribute values can be specified
```

```
Default:

System:

Shared:

* User defined classes
*
db1:
        inheritance     = "yes"
        adminuser       = "bob"
        authgroup       = "devlt"

db2:
        tier            = 1
        admingroup      = "sales"
        authuser        = "sally"
        rset            = "part1"
```

Note

The asterisk (*) is the comment character used in the classes file.
The example shows comments in the classes file for clarity only. Comments can be added by directly editing the file. However, users should be aware that all other interfaces to create/modify/delete classes (command line, SMIT, WSM) will remove the comments when updating the file.

shares file

This file contains the definition of the number of shares of all the resources allocated to superclasses or subclasses for a given configuration. This file is organized into stanza names, which are WLM class names, and contents, which are attribute-value pairs specifying the number of shares allocated to the class for the various resources. The attribute names identify the resource. The shares value is either an integer between 1 and 65535 or a hyphen (-) to indicate that WLM does no regulation for the class for the given resource. This is the system default. Each stanza names a WLM class, which *must* exist in the classes file at the corresponding level (superclass or subclass). The class attributes defined in the *shares* file are CPU, memory, and disk I/O. Refer to Section 2.6.1, “Resources managed by WLM” on page 22, for further detail on these attributes. The values just mentioned as being the system default can be modified using a special stanza, called *default*, at the very top of the shares file. Be extra careful when using this default stanza because it can lead to starvation of your *System* superclass.

The following is part of a typical /etc/wlm/Config/shares file for the example in Table 2 on page 21. In this example, *System*, *Shared*, and *db2* would get four shares of CPU as specified by the *default* special stanza:

```
* This is the default special stanza, valid for all classes
* if not specified otherwise:
*

default:
        CPU             = 4
*
* System Defined Classes
* In this example, the system administrator uses
* only default values for the System and Shared
* superclasses, which are omitted in the file.
* The system administrator gives non default values
* only for the Default class:

Default:
        CPU             = 2
        memory          = 10

*
* User defined classes
*
db1:
        CPU             = 8
        memory          = 20
        diskIO          = 6

db2:
        memory          = 12
        diskIO          = 6
```

Note

The asterisk (*) is the comment character used in the shares file.

The example shows comments in the shares file for clarity only. Comments can be added by directly editing the file. However, users should be aware that all other interfaces to create/modify/delete shares (command line, SMIT, WSM) will remove the comments when updating the file.

limits file

Contains the specification of the minimum and maximum limits for the resources allocated to superclasses or subclasses of a given configuration. Although the limits at the superclass level represent a percentage of the total amount of resource available on the system, and the limits at the subclass level represent a percentage of the target usage configured for the superclass, the description of resource limits for the superclasses and subclasses have the same format. This file is organized into stanza names, which are WLM class names, and contents, which are attribute-value pairs specifying the minimum and maximum resource allocated to the class for the various resources. The attribute names identify the resource. For each resource, three values must be provided: The minimum limit (m), a soft maximum limit (SM), and a hard maximum limit (HM). Refer to Section 2.6.3, “Class resource limits” on page 26, for further details about these values. The limits are expressed as percentages. The minimum limit is a number between 0 and 100, and the maximum limits are numbers between 1 and 100. The hard maximum must be greater than or equal to the soft maximum, which must be greater than or equal to the minimum. The system default values, when the limits are not specified for a class or a resource type, are 0 for the minimum and 100 for both the soft and hard maximum.

The syntax is:

```
attribute     = m%-SM%;HM%
```

Each stanza names a WLM class, which *must* exist in the classes file at the corresponding level (superclass or subclass). The class attributes defined in the *limits* file are CPU, memory and disk I/O. Refer to Section 2.6.1, “Resources managed by WLM” on page 22, for further details about these attributes. The values mentioned above as being the system default can be modified using a special stanza, called *default*, at the very top of the limits file. Be extra careful when using this default stanza because it can lead to starvation of your *System* superclass.

The following is part of a typical /etc/wlm/Config/limits file for the example in Table 2 on page 21. In this example, *db2* and *Default* would be assigned a minimum of zero percent, a soft maximum of 50 percent, and a hard maximum of 70 percent for CPU resource because of the special *default* stanza:

```
* This is the default special stanza, valid for all classes
* if not specified otherwise:

* default:
       CPU     = 0%-50%;70%

* System Defined Classes
* In this example, the system administrator uses
* default values for the Shared
* superclass (memory only).
```

```
* The system administrator gives non default values
* for the Default and System classes. The System class
* has a memory minimum of 1% by default. This value
* can be increased by system administrator:
*
System:
        CPU    =  0%-100%;100%
        memory =  1%-100%;100%

Default:
        memory =  0%-25%;50%
*
* User defined classes
*

db1:
        CPU    =  10%-100%;100%
        memory =  20%-100%;100%
        diskIO =  0%-33%;50%

db2:
        memory = 0%-20%;50%
        diskIO = 10%-66%;100%
```

Note

The asterisk (*) is the comment character used in the limits file.

The example shows comments in the limits file for clarity only. Comments can be added by directly editing the file. However, users should be aware that all other interfaces to create/modify/delete limits (command line, SMIT, WSM) will remove the comments when updating the file.

rules file

This file defines the automatic class assignment rules for the superclasses or subclasses of a given configuration. Each line of this file represents an assignment rule for a given class. There can be several assignment rules for the same class. Each rule lists the name of a class and a list of values for some attributes of a process that are used as classification criteria. The various fields of a rule are separated by blank spaces. Attributes whose values are not specified will be represented by a hyphen (-). The fields of an assignment rule, listed in the order in which they *must* appear in the *rules* file, are class name, reserved, user, group, application, type, and application tag. Refer to Section 2.5.3, “Class assignment rules” on page 19, for further detail on these attributes. The class name and the first two attribute fields (reserved and user) are mandatory. The other fields, if not present, will default to (-).

Remember, however, that WLM recognizes the fields by their position on the line. It is, therefore, not possible to omit one field in the middle of the line. For example, if you skip a group name and enter an application name, WLM will take the application name as a group name and give error messages about invalid groups.

WLM will scan this file from top to bottom, looking for the first rule that is a match for the set of process attributes (user, group, application, type, and tag) for each application:

- If the value in the rule is a hyphen (-), any value of the corresponding process attribute is a match.
- If the value of a process attribute other than *type* appears in the list of values specified in the corresponding field in the rule and is not preceded by the exclusion character (!), this is a match for the specified attribute.
- If the values of the process *type* attribute (32bit/64bit, plock, fixed) match all the values (separated by (+) signs) provided in the list of one or more comma-separated values for the *type* field in the rule, this is a match for the process type. For example, for *32bit,plock+fixed*, it had to match either *32bit* or *plock and fixed*.
- The process will be classified in the class specified in the *class* field of the rule if all the values of the process attributes in the table above match the values in the corresponding field of the rule.

When classifying a process, WLM will first scan the rules file for the superclasses of the current configuration to determine which superclass the process will be assigned to, and then, WLM scans the rules file for this specific superclass to determine which subclass of the superclass the process will be assigned to.

There are implicit rules for the Default superclass and the Default subclass of all superclasses (whether or not they are present in the *rules* files), which will classify all processes that did not match any of the other rules.

The following is an example of a /etc/wlm/Config/rules file for the configuration given in the example in Table 2 on page 21:

```
* This file contains the rules used by WLM to
* assign a process to a superclass
*
* class   resvd user      group   application          type    tag
  System  -     root      -       -                    -       -
  db1     -     -         -       /usr/oracle/bin/db*  -       _db1
  db2     -     -         -       /usr/oracle/bin/db*  -       _db2
  devlt   -     -         dev     -                    32bit   -
```

```
  VPs     -     bob,sally -       -                    -      -
  acctg   -     !ted      acct*   -                    -      -
```

The following is an example of the rules file for the *devlt* superclass in /etc/wlm/Config/devlt/rules of the previous example:

```
* This file contains the rules used by WLM to
* assign a process to a subclass of the
* superclass devlt
*
* class   resvd user      group   application       type         tag
  hackers -     jim,liz   -       -                 -            -
  hogs    -     -         -       -                 32bit+plock  -
  editors -     !sue      -       /bin/vi,/bin/emacs -           -
  build   -     -         -       /bin/make,/bin/cc -            -
  Default -     -         -       -                 -            -
```

Note

The asterisk (*) is the comment character used in the rules file.

The example shows comments in the rules file for clarity only. Comments can be added by directly editing the file. However, users should be aware that all other interfaces to create/modify/delete rules (command line, SMIT, WSM) will remove the comments when updating the file.

In the */etc/wlm/.running* directory, the system administrator can find an image of what is exactly the currently-running configuration in the kernel.

The class definitions, shares, and limits in effect at a given time (that is, known to the kernel at this time), may be different from the class definitions, shares, and limits in the *current* configuration (the set of files in the directory pointed to by /etc/wlm/current) for several reasons:

1. The configuration files could have been modified, but WLM has not been refreshed yet.
2. Classes have been created and/or shares and limits were changed directly into the kernel (without updating the configuration files) either by an application using the API, or the command line interface (by specifying an empty string as the configuration name (`-d ""`).

This is why WLM keeps a set of configuration files in a special directory, /etc/wlm/.running, which, at any given time, reflects the class definitions, shares, limits, and rules exactly as they are known to the kernel.

3.2 WLM operation

Operating WLM consists, basically, of turning it on, off, or refreshing its running configuration for any changes made. The main issue when operating WLM is the two different modes in which it can be started. The following sections focus on all these points.

3.2.1 Modes of operation

WLM can be turned on in one of two modes:

- In the *active* mode, WLM classifies new and existing processes and regulates their resource usage according to the class shares and resource limits defined in the active WLM configuration. This is the normal mode of operation.
- A *passive* mode is provided to help system administrators understand what the resource requirements of their applications on a system are, thus, helping them better tune their WLM configurations.

  In this mode, WLM classifies new and existing processes and gathers statistics about their resource usage but does not try to regulate this usage. In this mode, the processes compete for resources exactly as they would if WLM was off. The `wlmstat` command can then be used to get snapshots of the resource usage for the different classes.

The `wlmcntrl` command lets you switch from passive to active mode or from active to passive mode at any time. In addition, rset binding can be turned on or off, so that all classes have access to the whole resource set of the system use (use `wlmctrl -g` to turn it off). All possible combinations are allowed, as follows:

- active mode + rset on
- active mode + rset off
- passive mode + rset on
- passive mode + rset off

The *passive* mode can be used for various purposes. Here are a few examples:

- Before fully-enabling WLM on a production system, the system administrator could use the passive mode to check the assignment rules.

  With WLM started in the passive mode, all the processes would be classified according to the assignment rules, and the system administrator could use `ps` to check that the various applications are classified in the correct class. Since there is no regulation in this mode, this has virtually no impact for the users of the system.

- When the system administrator is satisfied with the classification, the system can be allowed to run for some time in *passive* mode to gather base line resource usage statistics with the `wlmstat` command. These statistics provide a reference that can be used to determine how to apply the shares and, if necessary, resource limits to favor critical applications and/or restrain less important work to match the business goals.

3.2.2 Start/Stop/Update WLM - wlmcntrl

WLM is not enabled at system installation and must be activated by the system administrator. This may be performed from the command line with the `wlmcntrl` command or from the administration tools, SMIT or WSM. Either way, the `wlmcntrl` command does some very important processing of the WLM property files before passing the configuration information to the operating system. In particular:

- It converts all the user and group names into numerical user IDs and group IDs.
- It expands the wild cards (if applicable) in the users, groups, or application pathnames in the rules files and accesses all the target application files to transform the pathnames into information usable by the kernel, such as device identifiers and inode numbers.

The `wlmcntrl` command will issue an error message and *will not start* WLM if it cannot translate a user or group name in a rule. If one or more of the application file names cannot be accessed, the `wlmcntrl` command will issue warning messages identifying the files causing a problem, but it will still start WLM. The problem files' names will just be ignored. Even though this condition is not fatal, the system administrator should try to understand why some of the application files cannot be accessed and take corrective actions. The problem could be due to a file system that was not mounted or an NFS server being down, for example. If none of the application files listed in an assignment rule can be accessed, the entire rule is ignored.

The following describes the functionality of each of the aforementioned WLM operating methods.

Command line

From the command line, WLM can be started, updated, stopped, and queried by running the `wlmcntrl` command with the appropriate option.

The syntax for this command can take two forms:

```
wlmcntrl [[ -a | -p ] [ -g ] [ -d Config_dir ]] [ -o | -q ]
```

or

```
wlmcntrl -u [ -S Superclass | -d Config_dir ]
```

The options of the `wlmcntrl` command are:

`-a`	To start WLM in active mode or to switch from passive to active mode. This is the default when no option other than `-d` is specified.
`-p`	To start WLM in passive mode or to switch from active to passive mode.
`-d Config_dir`	To consider /etc/wlm/Config_dir as the directory to use for the classes, resource limits, resource shares, rules files and superclasses directories.
`-g`	To disable the enforcement of resource set bindings at WLM startup.
`-o`	To stop WLM.
`-u`	To send an update request to change the attributes of the running classes or to change the current configuration in use. Can be used alone or in conjunction with `-S` or `-d` options.
`-S Superclass`	To specify the running superclass whose attributes are to be updated. Can only be used in conjunction with the `-u` option.
`-q`	To query WLM state. Returns 0 if WLM is running in active mode, 1 if WLM is not started, or 2 if WLM is running in passive mode. A message indicating the current state of WLM is the output.

A system administrator has the option of modifying the current configuration files and making the changes active without stopping WLM by using:

```
# wlmcntrl -u
```

Any attributes of classes in the current configuration can be changed and are then used to reclassify the processes to which they apply.

Administrators also have the option of creating a new configuration with different classes, shares, limits, and/or tier numbers and making this new configuration active without stopping WLM by using:

```
# wlmcntrl -u -d <new_config>
```

This second option is interesting since it allows administrators to create different configurations, such as a *day_config* and a *night_config*, and flip from one to the other at given times using the AIX `cron` facility.

Starting WLM by a direct invocation of the `wlmcntrl` command, however, only causes WLM to be initialized at that moment, not on every system boot. To configure WLM to start automatically at system boot, manually edit /etc/inittab. Make sure the WLM entry is placed directly after the mounting of filesystems so that the maximum number of processes are classified.

The line to add to /etc/inittab is:

```
wlm:2:once:/usr/sbin/wlmcntrl > /dev/console 2>&1 #Start WLM
```

Note

Always perform tests in non-production environments.

SMIT

WLM can be started, stopped, updated or queried by accessing the SMIT *Start/Stop/Update WLM* screen, shown in Figure 7, or by using the following fastpath:

```
# smitty wlmmanage
```

```
                             Start/Stop/Update WLM

Move cursor to desired item and press Enter.

  Start Workload Management
  Update Workload Management
  Stop Workload Management
  Show WLM status

F1=Help             F2=Refresh          F3=Cancel           Esc+8=Image
Esc+9=Shell         Esc+0=Exit          Enter=Do
```

Figure 7. smitty wlmmanage

Under *Start Workload Management*, you will be able to specify the Management Mode (active or passive) if you want WLM to enforce resource set bindings and if WLM is supposed to start now, at the next boot, or both ways.

Under *Update Workload Management*, you will be asked to specify a superclass name that you can leave blank if you wish to do a general update) not bound to a specific superclass only. You cannot use the SMIT interface to change the currently-running configuration.

Under *Stop Workload Management*, you are able to stop WLM either now, at the next boot, or both ways.

Show WLM Status will give you information about WLM's mode of operation (active, passive, or inactive), as well as whether WLM was started with resource set bindings enforced. It will also display the currently-configured superclasses. Figure 8 shows the WLM status screen in SMIT.

```
                                 COMMAND STATUS

Command: OK            stdout: yes           stderr: no

Before command completion, additional instructions may appear below.

WLM is running in active mode, Rset bindings not active.
Checking classes and rules for 'current' configuration...
System
Default
Shared
db1
devlt
VPs
acctg
db2




F1=Help             F2=Refresh          F3=Cancel           F6=Command
F8=Image            F9=Shell            F10=Exit            /=Find
n=Find Next
```

Figure 8. Show WLM status screen in SMIT

WSM

WLM can be controlled from inside the *Overview and Tasks* screen of WSM shown in Figure 9 on page 45.

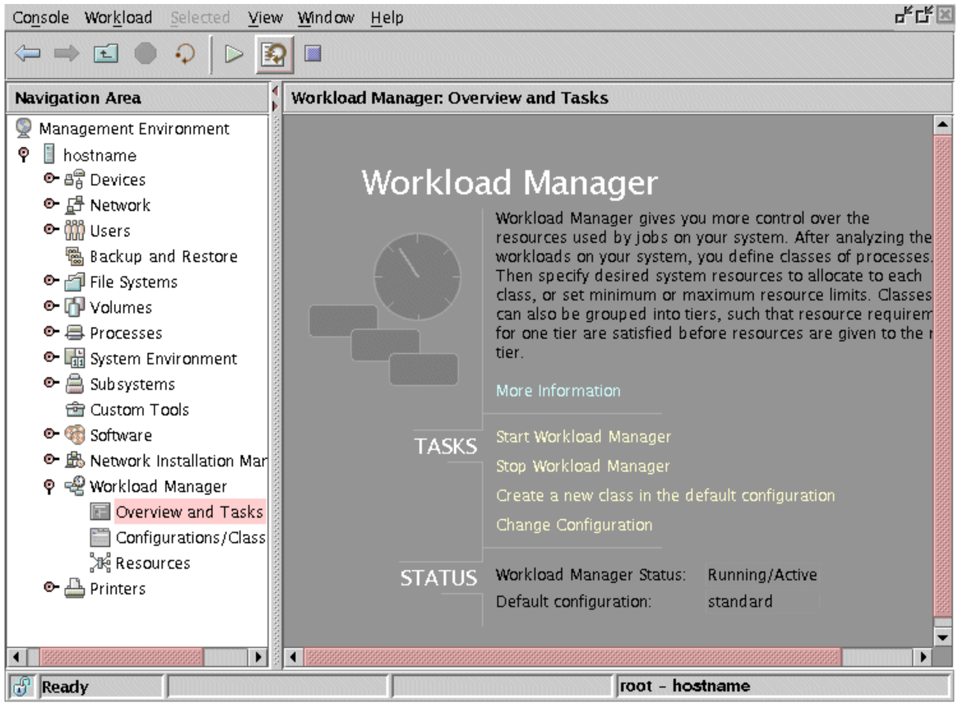


Figure 9. Overview and Tasks screen in WSM

The WLM status and currently-running configuration are shown as we enter the screen. In Figure 9, we can observe that WLM status is Started and Active, and the current configuration is Config. From this screen:

- WLM can be started in active or passive mode, now, at system boot, or both with or without resource set bindings (specifying the chosen configuration) by clicking on *Start Workload Manager*:. Figure 10 on page 46 shows the Start Workload Manager screen in WSM.

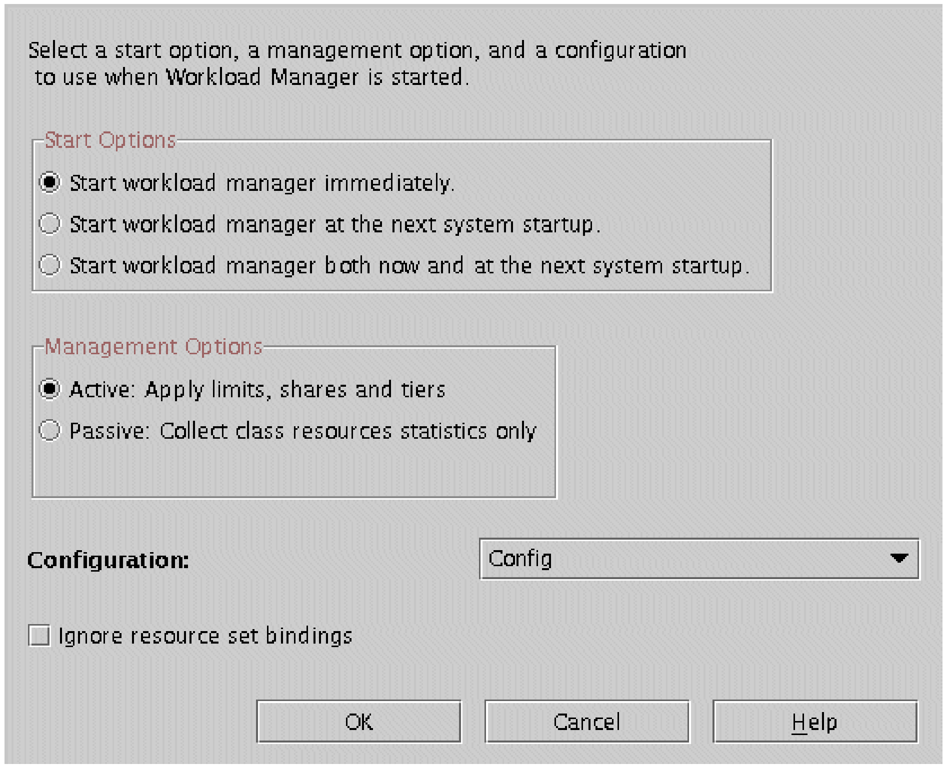


Figure 10. Start Workload Manager screen in WSM

- WLM can be stopped by clicking *Stop Workload Manager* (confirmation is requested)*:* Figure 11 shows the Stop Workload Manager screen in WSM.

Figure 11. Stop Workload Manager screen in WSM

- A new class for this configuration can be created by clicking *Create a new class in the default configuration* (the class management subject is discussed later).
- The currently running configuration can be modified by clicking *Change Configuration*:. The Change Configuration screen appears as shown in Figure 12 on page 47.

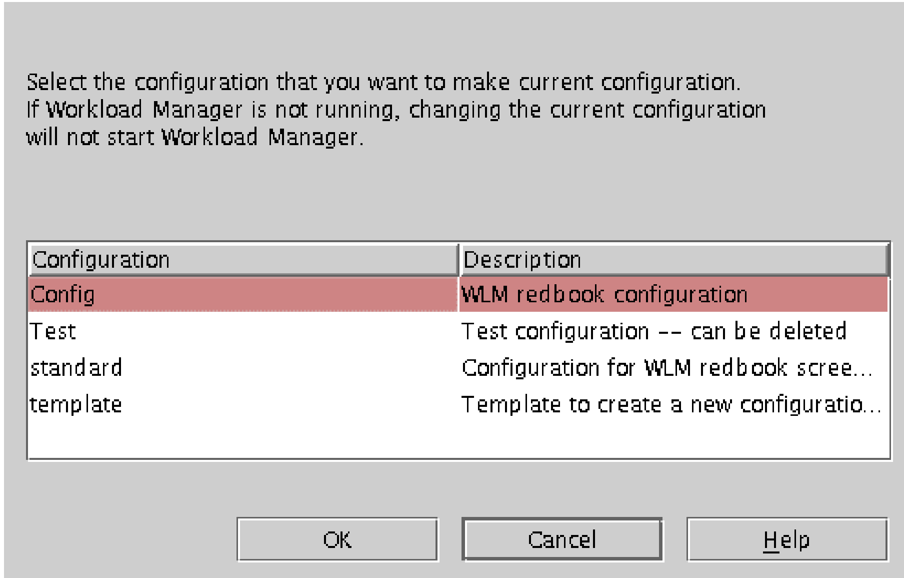
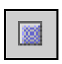


Figure 12. Change Configuration screen in WSM

Alternatively, inside the Configurations/Classes screen, some of the icons displayed at the top of the WSM window can be used for WLM management:

 *Start Workload Manager* (see Figure 10 on page 46)

 *Stop Workload Manager* (see Figure 11 on page 46)

As a third option, WLM can be managed in the *Configurations/Classes* screen by right clicking in a selected configuration and choosing any of the management options, shown in Figure 13 on page 48. In this section, only the options related to WLM management are mentioned. All others are described in later sections.

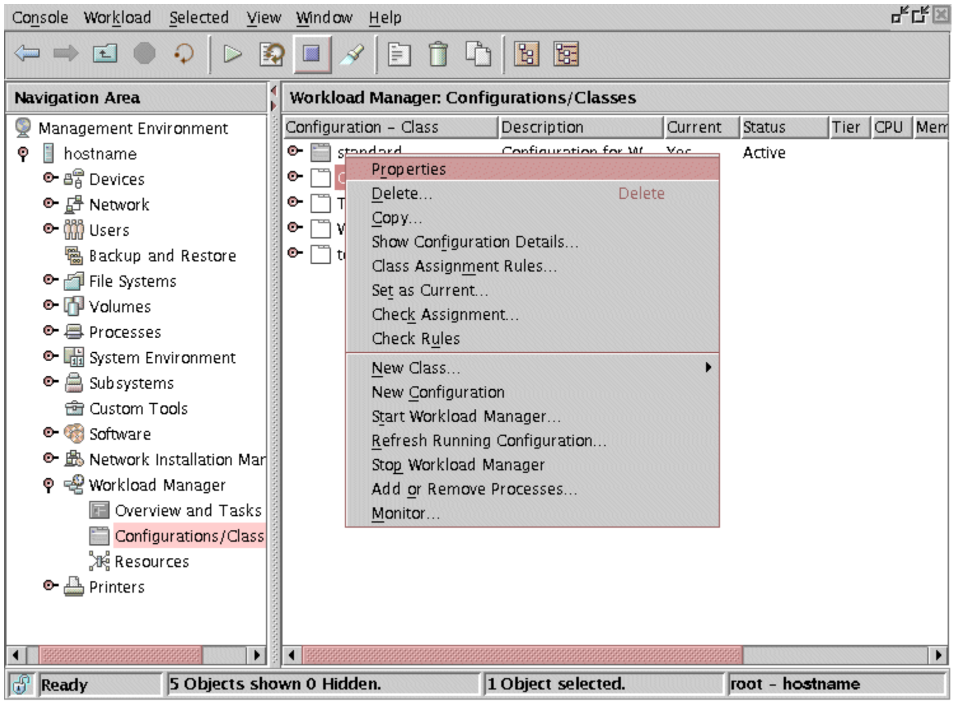


Figure 13. Configuration options in WSM

The WLM management options in the configuration options' screen are:

- *Start Workload Manager*
- *Stop Workload Manager*

3.3 WLM configuration

This section discusses some of the steps a system administrator needs to take to configure WLM on a system. First, it points out the method to follow to configure WLM in a manner that is easy to maintain and update. Afterwards, it shows how the configuration can be done in practice, using any of the three methods provided to configure WLM: Command line, SMIT, and WSM.

3.3.1 Steps for a WLM configuration

In order to successfully configure WLM on a system, it is recommended that the system administrator follow a set of steps described in the following sections.

Step 1 - Design your classification
The first step is to define your classes (superclasses first). In order to define which classes you need, you must know your users and their computing needs, the applications on your system and their resource needs and the requirements of your business (that is, which tasks are critical and which can be given a lower priority). This depends a lot on what you'll be using WLM for. If this is a case of server consolidation, you probably already know the applications and the users and their resource requirements, and you may be able to skip or shorten some of the steps.

WLM is very flexible, and allows you to classify processes by user/group, application (besides type and application tag), or any possible combination. Since WLM regulates the resource utilization among the classes, you should group in the same classes applications and/or users with the same resource utilization patterns. For instance, you generally want to separate the interactive jobs that typically consume very little CPU time but require quick response time when activated from batch type jobs that, typically, are very CPU- and memory-intensive. It is the same in a database environment where you probably need to separate the OLTP type traffic from the heavy queries of data mining, for example.

WLM cannot help much in this initial design phase. You will probably have to go through a few iterations to refine your classification and optimize your class definitions. At the end of this step, you should be able to set up your class definitions and the corresponding assignment rules.

Step 2 - Create the superclasses and assignment rules
This step is done using the WLM administration interfaces, WSM, SMIT, or command line interface. In the next sections, the process of configuring WLM using these tools will be covered. The first few times, it is probably a good idea to use WSM or SMIT. They will take you through the steps of creating your first WLM configuration including defining the superclasses and setting their attributes. For the first pass, you can set up only some of the attributes and leave the others at their default value. Same thing for the resource shares and limits. All these characteristics of the classes can be dynamically modified later on. The goal is to have a basic set of superclasses and the associated assignment rules defined. When that is done, you can start WLM in passive mode, check your classification, and start looking at the resource utilization patterns of your applications.

Step 3 - Use WLM to refine your class definitions
When Step 2 above is complete, you can check your configuration using the `wlmcheck` command or the corresponding SMIT or WSM menus and start WLM in passive mode on the newly-defined configuration. This means that WLM

will classify all the existing processes (and all processes created from then on) and start getting statistics on the CPU, memory, and disk I/O utilization of the various classes but will not try to regulate this resource usage. This is, basically, what needs to be accomplished at that point: check that the various processes are classified in the right class as expected by the system administrator (using the `-o class` option of the `ps` command). If some of the processes are not classified as you expect, you can modify your assignment rules and/or set the inheritance bit for some of the classes (if you want the new processes to remain in the same class as their parent) and update WLM. You can repeat the process until you are satisfied with this first level of classification (superclasses).

Running WLM in passive mode and refreshing WLM (always in passive mode) is a very low-risk, low-overhead operation and can be done safely on a production system without disturbing normal system operation.

Step 4 - Gather resource utilization data

For this purpose, WLM should be run in passive mode (using the class definitions resulting from Step 3) and gather statistics using the `wlmstat` command. This command can be started to display the per class resource utilization (as a percentage of the total resource available for superclasses) repeatedly and at regular time intervals. You can thus monitor your system for extended periods of time to look at the resource utilization of your main applications over time.

With this data and your business goals defined in Step 1 (which applications and/or system users are critical for your business and which are somewhat less important), you can start deciding (or refining) which tier number will be given to every superclass and what share of each resource should be given to the various classes.

Step 5 - Turn WLM on

You are now ready to start WLM in active mode and monitor the system again with the `wlmstat` command to check if the regulation done by WLM is in line with your goals and if applications are not unduly deprived of resources while others get more than they should. If this is the case, adjust the shares and refresh WLM.

For some specific cases, you may have to use minimum and/or maximum limits. If possible, try to adjust the shares (and potentially tier numbers) to get closer to your resource allocation goals first and reserve limits for cases that cannot be solved with shares only. Use minimum limits for applications that typically have low resource usage but need a quick response time when activated by an external event. One of the problems faced by interactive jobs in situations where memory becomes tight is that their pages get stolen during the periods of inactivity (waiting for user input, for instance). A memory minimum limit can be used to protect some of the pages of interactive jobs (up to the minimum limit) if the class is in tier 0. Use maximum limits to contain some resource-hungry, low-priority jobs. Again, unless you want to partition your system resources for other reasons, a hard maximum will make sense mostly for a non renewable resource, such as memory, because of the time it would take to write data out to the paging space if a higher priority class would suddenly need pages that this other class would have used. For CPU, you can use tiers or soft maximum to make sure that if a higher priority class needs the CPU, it gets it right away. Again, monitor and adjust the shares, limits, and tier numbers until you are satisfied with the system's behavior.

Step 6 - Fine tune your configurations
In this step, you can decide whether you need to use subclasses and, if you do, whether you want to delegate the subclasses administration for some or all of the superclasses. When creating and adjusting the parameters of subclasses, you can refresh WLM only for the subclasses of a given superclass without affecting users and applications in the other superclasses. The administrator of each superclass can repeat the same process described above (Steps 1 through 5) for the subclasses of the superclass. The only difference is that it is not possible to run WLM in passive mode at the subclass level only. The subclass configuration and tuning might have to be done with WLM in active mode. In this case, one way of not impacting users and applications in the superclass is to start with the tier number, the shares and limits for the subclasses at their default value ((-) for shares, 0 percent for min, and 100 percent for soft and hard max) so that WLM will not regulate the resource allocation between the subclasses. The administrator can then monitor and set up the subclasses shares, limits, and tier number as explained in the steps above.

Step 7 - Create other configurations as needed
When you are done with your initial configuration, you can repeat the process to define other configurations with different parameters for nights and weekends, for instance, according to the needs of the business. When doing so, you can, probably, take shortcuts for some of the steps since you will not be creating your configurations from scratch, but, rather, copying and modifying existing configurations.

3.3.2 Working with WLM configurations

WLM allows the setup of various configurations. They can be used interchangeably, for instance, manually or by configuring `cron` to change WLM into a particular configuration at a specific point of time (night time or weekends, for example).

Let us consider an example: A system runs an interactive job that is heavily used during daytime, a batch calculation job that must not interfere with the previous one, and a backup that must not interrupt or steal resources from any of the jobs mentioned previously. Nevertheless, all these jobs are to perform their tasks eventually. So, the system administrator might want to make sure the calculation job runs every night from 0:00h to 3:00h a.m. and the backup is done from 4:00 to 6:00 a.m. One way to set up all this is:

- Create a configuration, *daytime*, with classes for all these jobs: *interactive* in tier 0, *batch* in tier 1 and *backup* in tier 2.
- Create a second configuration, *nightime1*, with *batch* in tier 0, *interactive* in tier 1, and *backup* in tier 2.
- Create a third configuration *nightime2* with *backup* in tier 0, *batch* in tier 1 and *interactive* in tier 2.
- Setup `cron` to change WLM from *daytime* to *nightime1* at 0:00h and from *nightime1* to *nightime2* at 4:00h a.m.

This is only one of the ways this setup can be implemented. The idea here is to illustrate the use of WLM's various configurations capability.

Command line

Using command line, the way to create configurations in WLM is simply to create new directories under /etc/wlm, to copy the contents from one configuration already made to the new one (if this is the first configuration, use /etc/wlm/templates) and edit the files manually. The name of the configurations will be the subdirectory names under /etc/wlm.

So, if in our example, we already had the configuration, *daytime*, which could have been created by setting up the subdirectory, /etc/wlm/daytime, and creating the classes in it, we could now copy this configuration into newly-created /etc/wlm/nightime1 and /etc/wlm/nightime2 subdirectories and edit the files manually to alter the tier attribute of the classes. The `mkclass` command could be used to set up new classes (see also Section 3.3.3.2, “Adding a class - mkclass” on page 58), and the `lsclass` command could be used to list the contents of our new configurations (see also Section 3.3.3.4, “Listing the classes - lsclass” on page 71).

SMIT

To set up our example in SMIT, we could access the *Work on alternate configurations* screen, shown in Figure 14 on page 53, or we could use the following fastpath:

```
# smitty wlmconfig
```

```
                        Work on alternate configurations

Move cursor to desired item and press Enter.

  Show all configurations
  Copy a configuration
  Create a configuration
  Select a configuration
  Enter configuration description
  Remove a configuration









F1=Help             F2=Refresh          F3=Cancel           Esc+8=Image
Esc+9=Shell         Esc+0=Exit          Enter=Do
```

Figure 14. smitty wlmconfig

From this screen, the system administrator can:

- See all the existing configurations (*Show all configurations*).
- Copy an existing configuration into a new one (*Copy a configuration*).
- Create a brand new configuration (*Create a configuration*).
- Select a configuration to work with (*Select a configuration*). See also Figure 15 on page 54. The output of this option is the listing of the superclasses and subclasses of the selected configuration. All changes made from this option on (create, change, delete classes, or rules) will apply to the selected configuration, leaving the currently-running configuration unchanged. The scope is returned to the currently-running configuration if SMIT is exited and restarted.
- Enter a description for the configuration (*Enter configuration description*).
- Remove a configuration (*Remove a Configuration*).

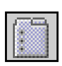
```
                              COMMAND STATUS

Command: OK            stdout: yes           stderr: no

Before command completion, additional instructions may appear below.

[TOP]
System
Default
Shared
db1
devlt
devlt.Default
devlt.Shared
devlt.hackers
devlt.hogs
devlt.editors
devlt.build
VPs
[MORE...3]

F1=Help             F2=Refresh          F3=Cancel           F6=Command
F8=Image            F9=Shell            F10=Exit            /=Find
n=Find Next
```

Figure 15. Select a configuration screen in SMIT

WSM

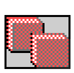
Configurations can be managed in WSM from the *Configurations/Classes* screen. As we enter this screen and all existing configurations are listed, we can right-click on the configuration to be updated, and all the configuration options will be listed in a pop-up window (see Figure 13 on page 48). Some of these options, namely, the ones related to WLM management, are described in Section 3.2.2, “Start/Stop/Update WLM - wlmcntrl” on page 41. Only the options regarding WLM *configurations* are described in this section.

- The *Properties* option allows the system administrator to visualize general characteristics of the configuration (name, description, and whether it is the currently-running configuration or not) and change the description. Alternatively, the properties icon in the upper part of the WSM window can be clicked:



Properties

- The *Copy* option allows the system administrator to create a new configuration out of an already-existing one. Alternatively, the copy icon at the top of the WSM window can be clicked:



Copy

- *Show Configuration Details* shows general characteristics of the configuration, such as its classes and theirs shares and limits. In Figure 16, you can see a possible output for the example in Table 2 on page 21.

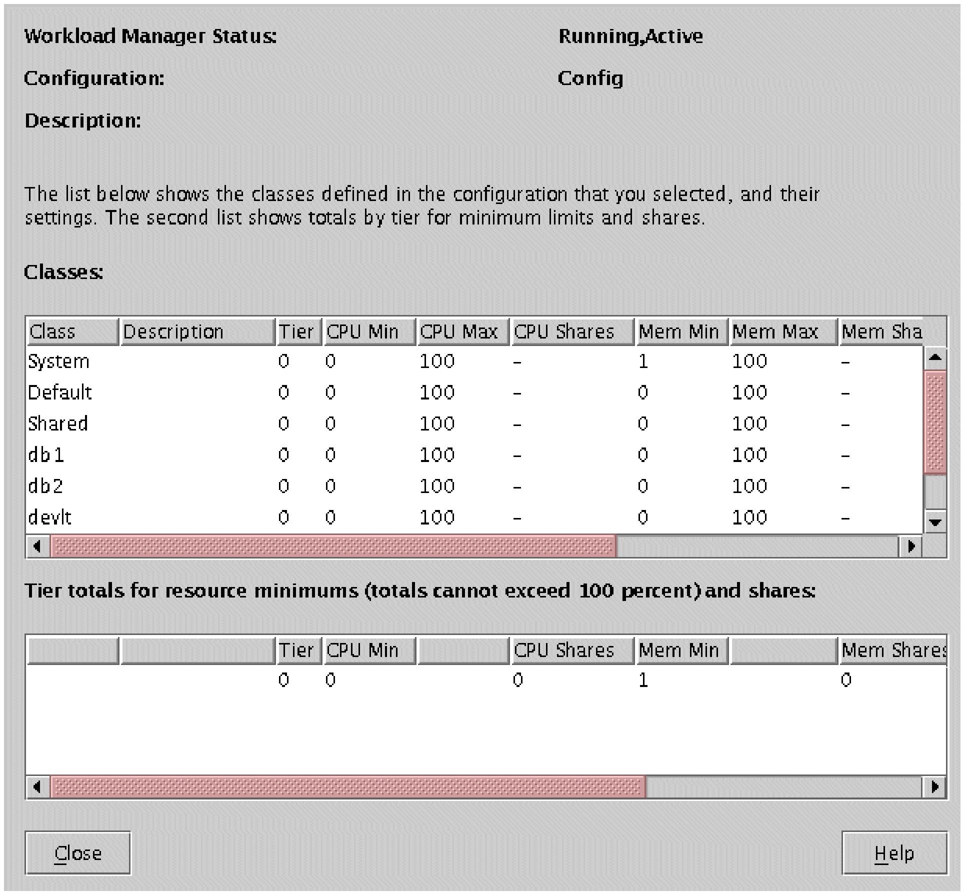


Figure 16. Show Configuration Details screen in WSM

- *New Configuration* allows the system administrator to setup a new configuration to work with.
- *Refresh Current Configuration* updates the configuration with the changes made. This screen is shown in Figure 17 on page 56.

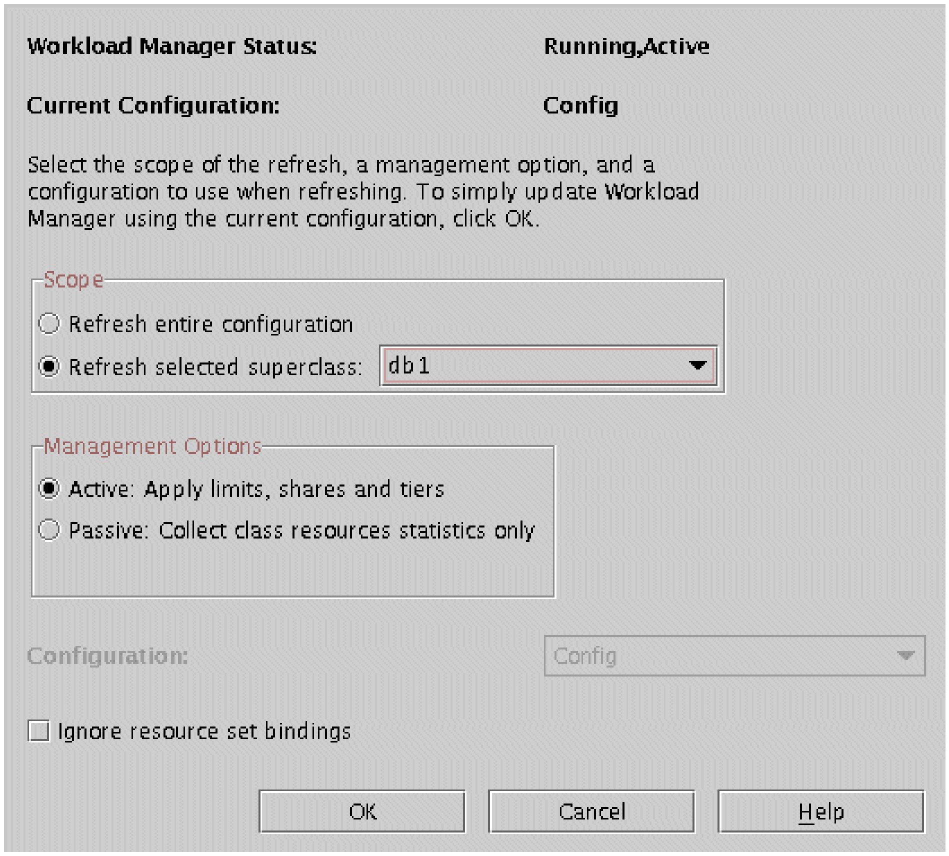
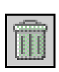


Figure 17. Refresh Current Configuration screen in WSM

Alternatively, one of the icons in the top of the WSM's window can be used to perform this task:

 *Refresh Current Configuration*

To remove a configuration, click on the configuration to be deleted and then press the delete icon in the top of the window:

 *Delete*

3.3.3 Working with classes

After defining the configuration name, superclasses must be added to it, and, then, subclasses can be configured. This section will show how the system administrator can deal with both superclasses and subclasses.

3.3.3.1 Working with sets of subclasses

This method of working with sets of subclasses is only applicable to SMIT. WSM uses a different approach to work with classes. It consists of changing the context we are currently working in into the superclass environment. This is the best way for a superclass administrator to work because he or she does not have any privileges to work in any other environment besides the scope of his or her own superclass. Once inside the context of a superclass A, every class that is listed, created, changed, or removed (even specifying only its short name) will always be treated as a subclass of superclass A.

The context to a specified superclass in SMIT can be changed through the *Work on a set of Subclasses* screen*.* After selecting the superclass to be worked on, the list of its subclasses is displayed. From this point on, any work in other SMIT screens in this same SMIT session is done *inside* this superclass environment.

To know in which context the current work is, the *Show current focus (Configuration, Class Set)* screen can be accessed in the SMIT session where the context was changed. The configuration shown in the output of this command is, by default, the currently-running one. However, you can work on other configurations (leaving the currently-running one untouched) if you select a configuration to work with inside the *Work on alternate configurations* screen (see Section 3.3.2, "Working with WLM configurations" on page 51, for further details on how to work with alternate configurations).

Note

After exiting SMIT and reentering it, the context is drawn back to the root of the currently-running WLM configuration.

So, if the context is changed into the *devIt* superclass in configuration *Config,* from the example in Table 2 on page 21, the *focus* is the output shown in Figure 18 on page 58. Note that, since the configuration focus has not been changed, the working configuration is presented as being the currently-running one.

```
                              COMMAND STATUS

Command: OK            stdout: yes           stderr: no

Before command completion, additional instructions may appear below.

Configuration: current
Class set: Subclasses of devlt/

current -> Config











F1=Help             F2=Refresh          F3=Cancel           F6=Command
F8=Image            F9=Shell            F10=Exit            /=Find
n=Find Next
```

Figure 18. Show current focus screen in SMIT

If the configuration focus had been changed into, for instance, a configuration named *Config_2*, and the class focus had been changed into the set of subclasses of superclass *OLTP*, then the:

- Configuration focus in Figure 18 was *Config_2*
- Class set was *Subclasses of OLTP*
- Currently-running configuration was *Config*

3.3.3.2 Adding a class - mkclass

To add a class (either superclass or subclass), any of the three methods mentioned earlier can be used:

Command line

The command to create classes in WLM is `mkclass`. The syntax of this command is as follows:

```
mkclass [ -a Attribute=Value  ...  ] [ -c | -m | -b KeyWord=Value ] [ -d
Config_Dir ] [ -S SuperClass ] Name
```

The `mkclass` command creates a superclass or a subclass identified by the Name parameter. The class must not already exist. The name parameter can contain only uppercase and lowercase letters, numbers, and underscores (_). The name is in the format, *supername* or *subname* (with the *-S supername* option) or *supername.subname*. Supername and subname are each limited to 16 characters in length. The names, Default, System, and Shared, are reserved. They refer to predefined classes. Any Attribute=Value or

KeyWord=Value argument will initialize the specified attribute or resource limit.

The options for this command are:

`-a Attribute=Value` To set up an attribute value. The valid names for attributes are *tier*, *inheritance*, *authuser*, *authgroup*, *rset*, *adminuser*, and *admingroup*.

`-b KeyWord=Value` Changes a limit or share value for disk I/O throughput. Possible KeyWords are *min*, *softmax*, *hardmax*, or *shares*.

`-c KeyWord=Value` Changes a limit or share value for a CPU. Possible KeyWords are *min*, *softmax*, *hardmax*, or *shares*.

`-d Config_dir` To use /etc/wlm/Config_dir as an alternate directory for the properties files. When this option is not used, `mkclass` uses the configuration files in the directory pointed to by /etc/wlm/current.

`-m KeyWord=Value` Changes a limit or share value for memory. Possible KeyWords are *min*, *softmax*, *hardmax*, or *shares*.

`-S Superclass` To specify the name of the superclass when creating a subclass. There are two ways of creating the subclass, *sub*, of the superclass, *Super*:

- Specify the full name of the subclass as *Super.Sub* for Name, and do not use `-S`.
- Use the `-S` option to give the superclass name, and use the short name for the subclass: `mkclass <options> -S Super Sub`

So, to set up the *devlt* superclass and the subclass, *hackers*, from the example in Table 2 on page 21, the following commands could be run:

```
# mkclass -a inheritance=yes -a tier=0 -a adminuser=bob devlt

# mkclass -a inheritance=no -a tier=0 -S devlt hackers
```

or

```
# mkclass -a inheritance=no -a tier=0 devlt.hackers
```

SMIT

To create a class through SMIT, simply access the *Add a class* screen, or use the following fastpath:

```
# smitty wlmaddclass
```

```
                        General characteristics of a class

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                        [Entry Fields]
* Class name                                         [devlt]
  Description                                        []
  Tier                                               [0]                     +#
  Resource Set                                                               +
  Inheritance                                        [Yes]                   +
  User authorized to assign its processes to this cl []                      +
  ass
  Group authorized to assign its processes to this c []                      +
  lass
  User authorized to administrate this class         [bob]                   +
  (Superclass only)
  Group authorized to administrate this class        []                      +
  (Superclass only)



F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 19. smitty wlmaddclass

In this screen, the system administrator can create a superclass by entering its name or a subclass by entering its *full* name (superclass.subclass). The superclass must already exist for this to be possible. Every other attribute works exactly the same for both superclasses and subclasses.

If the screen, *Work on a set of subclasses*, has been accessed to change into a superclass' context (see Section 3.3.3.1, "Working with sets of subclasses" on page 57, for further information about how to change the focus), the *Add a class* screen will operate on the superclass' environment of the chosen superclass. While operating under a superclass' scope, the short name can be specified when creating a subclass for that superclass.

Note

Remember that the scope will be returned to the root of the currently-running configuration if the SMIT session is exited and restarted.

WSM

To add a class in WSM, several paths can be taken.

The first way is to create a new class in the currently running configuration inside the *Overview and Tasks* screen (see Figure 9 on page 45). In this screen, click on the *Create a new class in the default configuration* link. This will guide you through the New Class Wizard (see Figure 20), which sets up a new class and its attributes (tier, inheritance, adminuser, admingroup, resource set, authuser, and authgroup). The class can be a superclass with the name, *supername*, or a subclass of an already-existing superclass with the name, *supername.subname*:

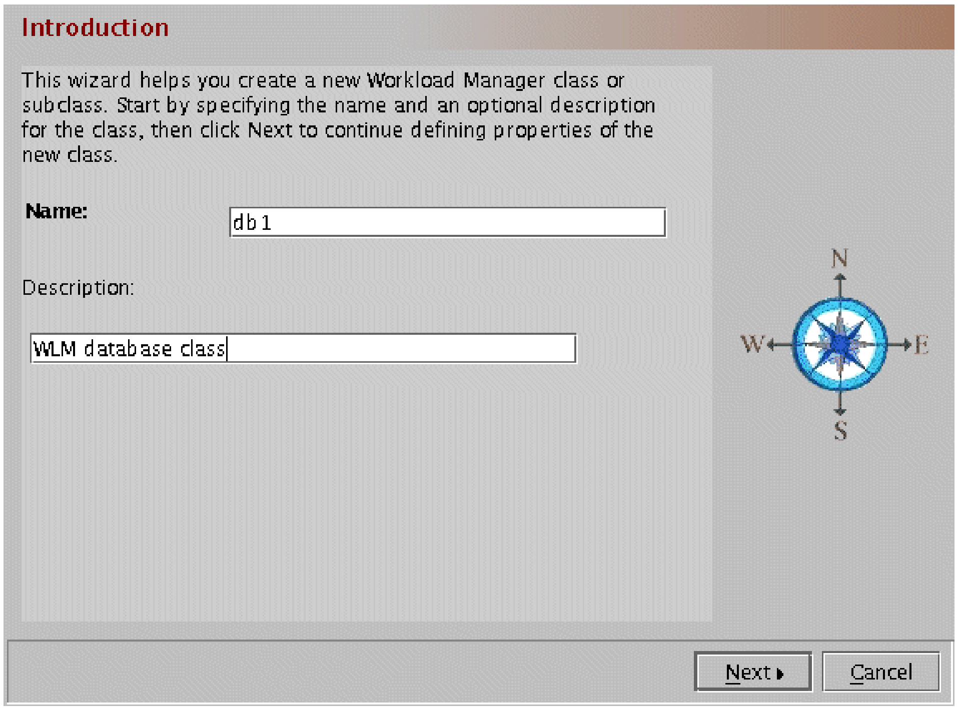


Figure 20. New Class Wizard in WSM

Another way to create a class is to right-click on the configuration to be altered (see Figure 13 on page 48) inside the *Configurations/Classes* screen, and choose the *New Class* option.

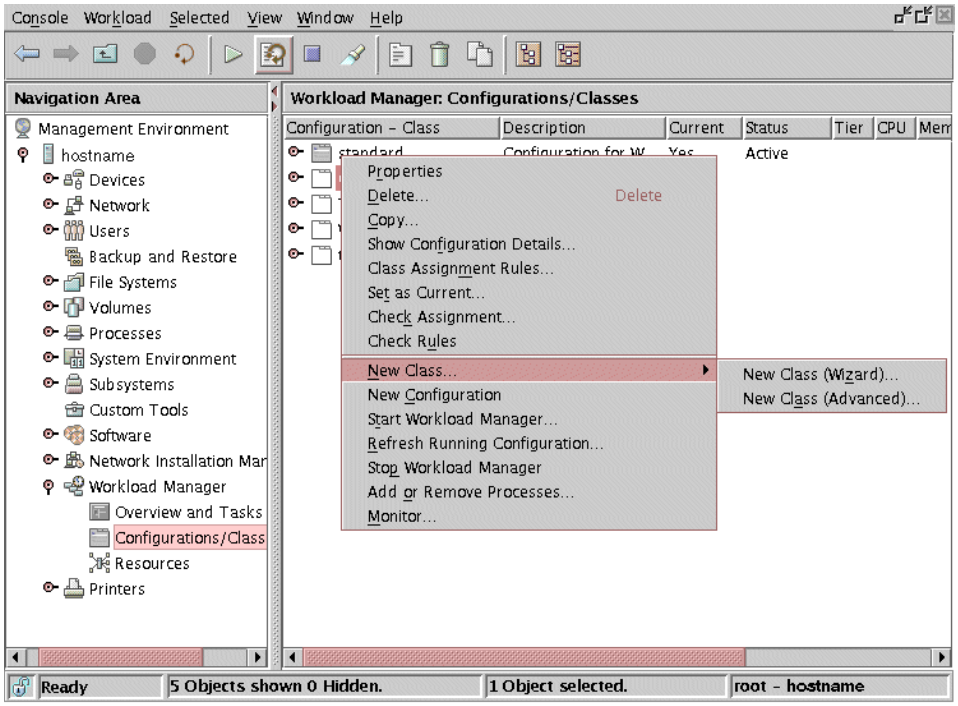


Figure 21. Create a class in Configurations/Classes screen in WSM

From here, you can choose to use the wizard mentioned earlier (see Figure 20 on page 61) or the Advanced configuration tool, which, in addition, allows other class attributes to set up shares and limits for the class being created. The class can be a superclass with the name, *supername*, or a subclass of an already-existing superclass with the name, *supername.subname*:

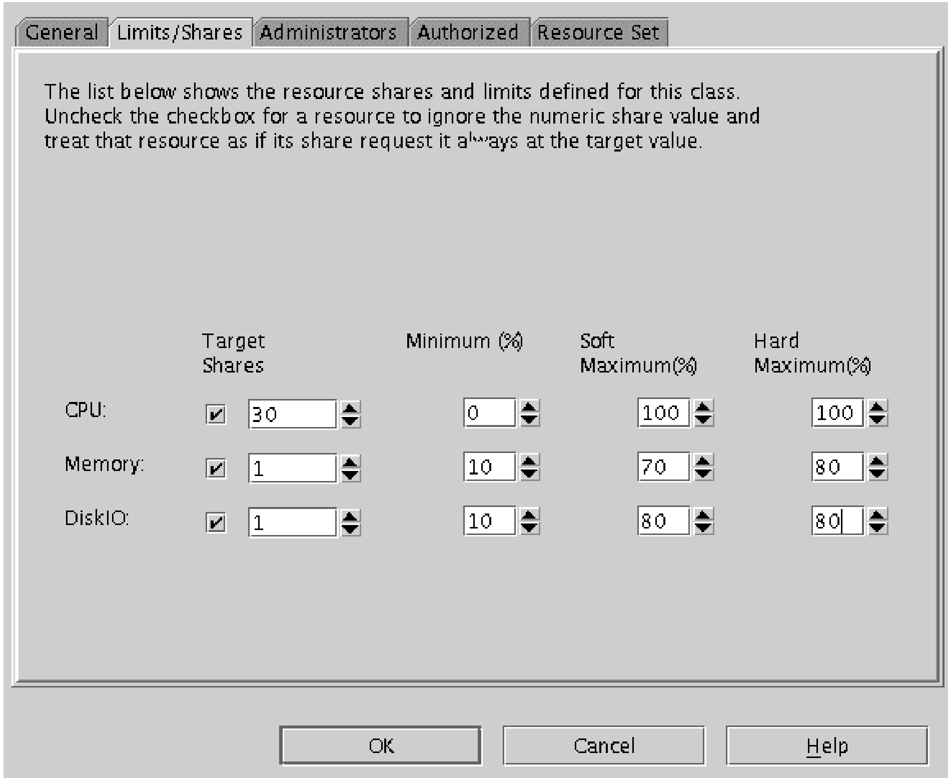
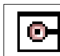


Figure 22. New Class advanced in WSM - Setting up limits and shares

The third way to create a class is to click the *expand* icon, found at the right hand side of the configuration selected, to expand the view to all the configured classes in that configuration.

 *Expand*

All the superclasses with subclasses will also be shown with an expand icon that can be selected to extend even further down the view into the subclass level. From this view, by right clicking the name of a class, the class options screen is displayed as shown in Figure 23 on page 64.

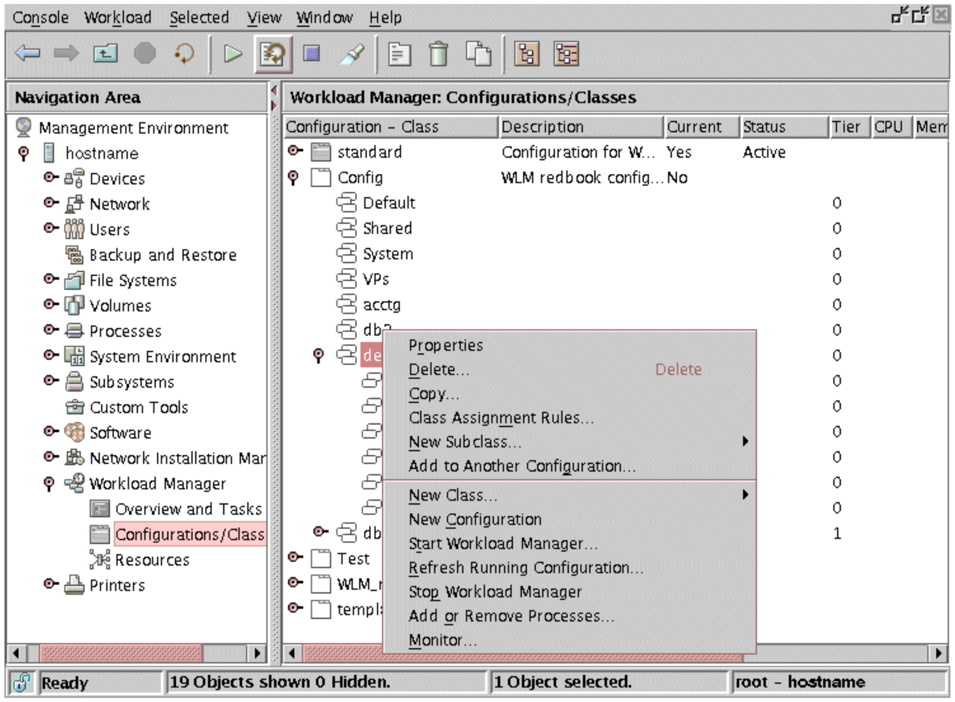
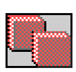


Figure 23. Class options screen in WSM

The bottom part of the class options screen is exactly equal to the bottom part of the configuration options screen; so, what has been (and will be) said about the latter also applies to the former. In this section, only the options of this screen that apply to creating classes are mentioned. All others are described in later sections.

From this screen, the system administrator can create a new class as follows:

- Copy the selected class attributes into a new class, making any necessary changes (*Copy*). Alternatively, the copy icon at the top of the WSM window can be pressed.



Copy

- Create a subclass for the selected superclass (*New Subclass*) using either the Wizard or the Advanced tool for that purpose as shown in Figure 24 on page 65.

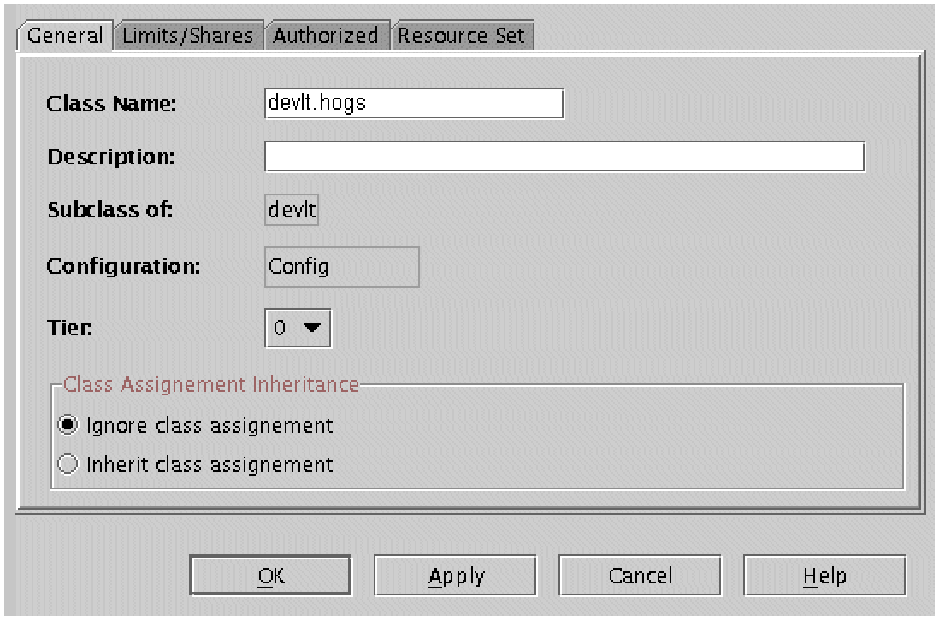


Figure 24. New Subclass Advanced in WSM

- Copy the selected class into another configuration (*Add to Another Configuration* as shown in Figure 25):

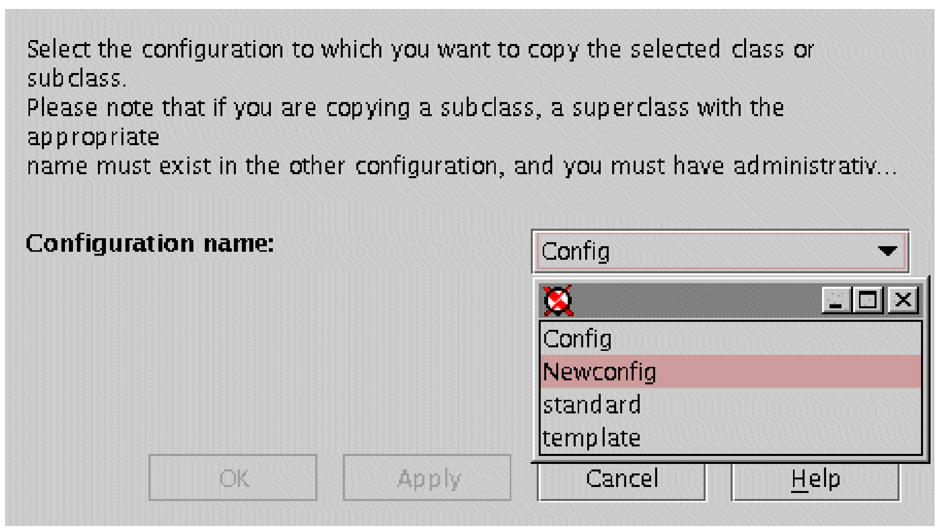


Figure 25. Add to another configuration screen in WSM

3.3.3.3 Updating a class - chclass

Updating a class can mean either changing or setting new values for the attributes that can be configured by the time the class is created or setting up shares or limits for it. To do this, the three methods mentioned earlier can be used:

Command line

The command to update a class is `chclass`. The syntax of this command is:

```
chclass -a Attribute=Value {[-a Attribute=Value]...} [-c|-m |-b
Keyword=Value] [-d Config_dir] [-S Superclass] Name
```

The `chclass` command changes attributes for the class identified by the Name parameter. The class must already exist. To change a class attribute (tier, inheritance, adminuser, admingroup, rset, authuser, and authgroup), specify the attribute name and the new value with the *-a Attribute=Value* option. To change/set a limit or shares value, use option -c for *cpu*, -m for *memory*, and -b for *disk I/O* (stands for *block I/O*), with the Keyword value in *min*, *softmax*, *hardmax*, or *shares*.

The options for this command are:

`-a Attribute=Value`	To change a class attribute (attribute in *tier*, *inheritance*, *adminuser*, *admingroup*, *rset*, *authuser,* and *authgroup*).
`-c Keyword=Value`	To change CPU resource limits or shares (keyword in min, softmax, hardmax, or shares).
`-m Keyword=Value`	To change memory resource limits or shares (keywordin min, softmax, hardmax, or shares).
`-b Keyword=Value`	To change Disk I/O resource limits or shares (keywordin min, softmax, hardmax, or shares).
`-d Config_dir`	To use /etc/wlm/Config_dir as an alternate directory for the properties files. If this option is not present, the current configuration files in the directory pointed to by /etc/wlm/current are used.
`-S Superclass`	To specify the name of the superclass when changing the attributes of a subclass. There are two ways of specifying that the change is to be applied to the subclass, *Sub*, of the superclass, *Super*: • Specify the full name of the subclass as *Super.Sub* and not use `-S`.

- Use the `-S` option to give the superclass name and use the short name for the subclass:

```
chclass <options> -S Super Sub
```

So, to change the *devlt* class from the example in Table 2 on page 21, we could run the following command to give it 20 CPU shares, change the administration user to *bob*, and set 10 percent as the memory minimum limit:

```
# chclass -a adminuser=bob -c shares=20 -m min=10 devlt
```

SMIT

In SMIT, the characteristics of a class can be changed in the *Change/Show Characteristics of a class* screen, shown in Figure 26, or with the following fastpath:

```
# smitty wlmchclass
```

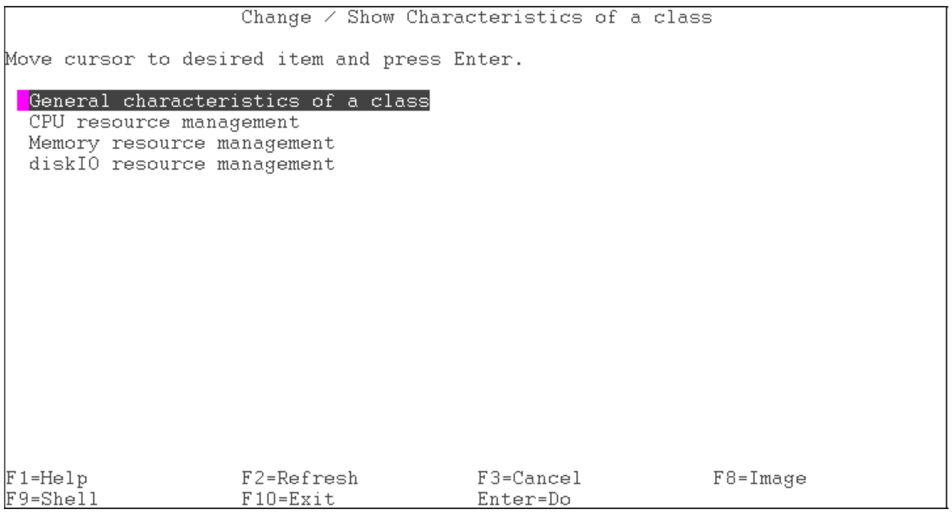


Figure 26. smitty wlmchclass

In the *General characteristics of a class* screen, shown in Figure 27 on page 68, the class attributes (tier, inheritance, adminuser, admingroup, rset, authuser, and authgroup) can be changed or set.

```
                         General characteristics of a class

    Type or select values in entry fields.
    Press Enter AFTER making all desired changes.

                                                          [Entry Fields]
      Class name                                          devlt
      Description                                        []
      Tier                                               [0]                  +#
      Resource Set                                                            +
      Inheritance                                        [No]                 +
      User authorized to assign its processes to this cl []                   +
      ass
      Group authorized to assign its processes to this c [dev]                +
      lass
      User authorized to administrate this class         []                   +
      (Superclass only)
      Group authorized to administrate this class        []                   +
      (Superclass only)



    F1=Help             F2=Refresh          F3=Cancel           F4=List
    F5=Reset            F6=Command          F7=Edit             F8=Image
    F9=Shell            F10=Exit            Enter=Do
```

Figure 27. General characteristics of a class screen in SMIT

Any of the resource relative attributes (shares and minimum and maximum limits) can be changed under the option referring to the required resource (CPU, memory, or disk I/O).

This way, to change CPU's shares to 20 in *devlt* class from the example in Table 2 on page 21, we need to access the *CPU resource management* screen, shown in Figure 28 on page 69.

```
                          CPU resource management

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                        [Entry Fields]
  Class name                                          devlt
  Shares                                             [20]                 #
  Minimum (%)                                        [0]                  #
  Maximum (%)                                        [100]                #
  Absolute Maximum (%)                               [100]                #








F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 28. CPU resource management screen in SMIT

To change the memory minimum limit to 10 percent, we need to access the *Memory resource management* screen shown in Figure 29.

```
                         Memory resource management

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                        [Entry Fields]
  Class name                                          devlt
  Shares                                             [-]                  #
  Minimum (%)                                        [10]                 #
  Maximum (%)                                        [100]                #
  Absolute Maximum (%)                               [100]                #








F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 29. Memory resource management screen in SMIT

If the *Work on a set of subclasses* screen has been accessed to change into a superclass' context (see Section 3.3.3.1, "Working with sets of subclasses" on page 57, for further information on how to change the focus), the *Change/Show Characteristics of a class* screen will operate on the subclasses of the chosen superclass. While operating under a superclass' scope, the short name can be specified when changing a subclass of that superclass.

Note

Remember that the scope will be returned to the root of the currently-running configuration if the SMIT session is exited and restarted.

WSM

In WSM, the classes attributes can be changed in the *Configurations/Classes* screen, in the classes view (or the subclasses view for a specific superclass) by right-clicking the name of the class to update and selecting *Properties.* This can also be done by simply double-clicking the name of the class.

An example of changes that can be made to shares and limits in this screen is shown in Figure 30.

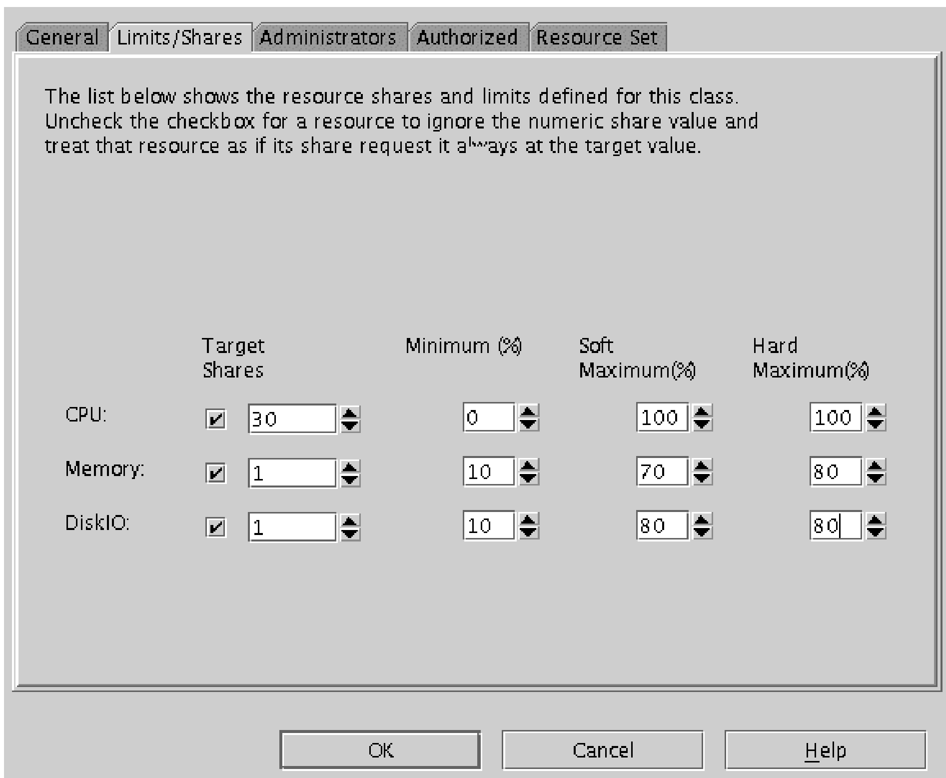
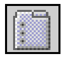


Figure 30. Changing class properties in WSM

Alternatively, the properties icon at the top of the WSM window can be clicked for the same purpose:

 *Properties*

3.3.3.4 Listing the classes - lsclass

To list the classes configured in our system, the three methods mentioned earlier can be used:

Command line

The command to list classes is `lsclass`. The syntax of this command is:

```
lsclass [ -C |-D |-f ] [ -r ] [ -d Config_dir ] [ -S Superclass ] [ Class ]
```

With no arguments, `lsclass` simply lists all superclasses in the current configuration. This command is accessible to all users in the system.

The options for this command are:

`-C` To display the class attributes, shares, and limits in colon-separated records:

```
# lsclass -C devlt
#name:description:tier:inheritance:authuser:authgroup:adminuser:
admingroup:rset:CPUshares:CPUmin:CPUsoftmax:CPUhardmax:
memoryshares:memorymin:memorysoftmax:memoryhardmax:
DiskIOshares:DiskIOmin:DiskIOsoftmax:DiskIOhardmax
devlt::0:no:::bob:::20:0:100:100:-:10:100:100:-:0:100:100
```

`-D` To display the default values for the class attributes, shares, and limits in colon-separated records:

```
# lsclass -D devlt
#name:description:tier:inheritance:authuser:authgroup:adminuser:
admingroup:rset:CPUshares:CPUmin:CPUsoftmax:CPUhardmax:memoryshares:
memorymin:memorysoftmax:memoryhardmax:DiskIOshares:DiskIOmin:
DiskIOsoftmax:DizkIOhardmax
::0:no::::::-:0:100:100:-:0:100:100:-:0:100:100
```

`-f` To display the output in stanzas, with each stanza identified by a class name. Each Attribute=Value pair is listed on a separate line:

```
Class:
   attribute1=value
   attribute2=value
   attribute3=value
```

`-r` To recursively display the superclasses with all their subclasses. When specifying `-r`:

- If no class name is given, `lsclass` will show all the superclasses with all their subclasses.
- If the name of a superclass is given, `lsclass` displays the superclass with all its subclasses.
- If the name of a subclass is given, `-r` is ineffective (displays only the subclass).

`-d Config_dir` To use /etc/wlm/Config_dir as alternate directory for the definition files. If this option is not present, the current configuration files in the directory pointed to by /etc/wlm/current are used.

`-S Superclass` To restrict the scope of the command to the subclasses of the specified superclass. When `-S` is used, only subclasses are shown.

SMIT

In SMIT, the classes can be listed through the *List all classes* screen or the following fastpath:

```
# smitty wlmlsclass
```

When under the scope of the general configuration, the screen will show all superclasses configured as shown in Figure 31 on page 73.

```
                                  COMMAND STATUS

Command: OK            stdout: yes           stderr: no

Before command completion, additional instructions may appear below.

System
Default
db1
db2
devlt
VPs
acctg
Shared







F1=Help             F2=Refresh          F3=Cancel           F6=Command
F8=Image            F9=Shell            F10=Exit            /=Find
n=Find Next
```

Figure 31. smitty wlmlsclass

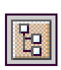
If the *Work on a set of subclasses* screen has been accessed to change into a superclass' context (see Section 3.3.3.1, "Working with sets of subclasses" on page 57, for further information on how to change the focus), the *List all classes* screen will print out the subclasses of the chosen superclass.

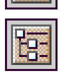
> **Note**
>
> Remember that the scope will be returned to the root of the currently-running configuration if the SMIT session is exited and restarted.

WSM

There are two views in WSM where the classes and their attributes for the chosen configuration can be visualized:

- In the *Configurations/Classes* screen, select the configuration option, *Show Configuration Details* (see also Figure 16 on page 55).
- In the *Configurations/Classes* screen, two icons can be seen at the top of the WSM window. They are Tree and Tree-Details:

 *Tree*

 *Tree-Details*

The first icon sets up a view that only shows the tree of configurations, superclasses, and subclasses. The second one creates a view in which some of the class attributes can be seen as shown in Figure 32.

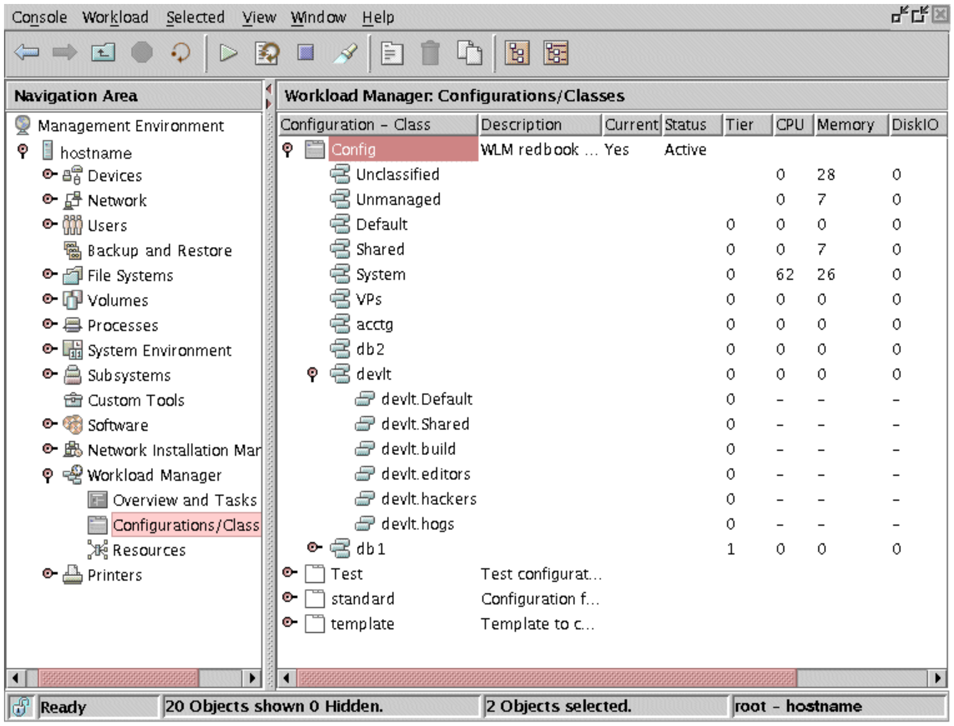


Figure 32. Tree-Details view in WSM

3.3.3.5 Removing a class - rmclass

To remove a class configured in our system, the three methods mentioned earlier can be used:

Command line

The command to remove classes is `rmclass`. The syntax of this command is:

```
rmclass [-d Config_dir] [-S Superclass] Name
```

The `rmclass` command removes the superclass or the subclass identified by the Name parameter from the class definition file, the class limits file, and the class shares file. The class must already exist. The predefined Default, System, Shared, Unmanaged, and Unclassified classes cannot be removed. In addition, when removing a superclass, *Super*, the directory, /etc/wlm/Config_dir/Super, and all the WLM property files it contains (if they exist) are removed. Removing a superclass will fail if any user created subclass still exists (subclass other than Default and Shared).

Only root can remove a superclass. Only authorized users whose user ID or group ID matches the user name or group name specified in the attributes, adminuser and admingroup, of a superclass can remove a subclass of this superclass.

The options for this command are:

`-d Config_dir` To use /etc/wlm/Config_dir as alternate directory for the properties files. If this flag is not used, the configuration files in the directory pointed to by /etc/wlm/current are used.

`-S Superclass` To specify the name of the superclass when removing a subclass. There are two ways of specifying the subclass *Sub* of superclass *Super*:

- Specify the full name of the subclass as *Super.Sub* and not use `-S`.
- Use the `-S` option to give the superclass name and use the short name for the subclass:

```
rmclass <options> -S Super Sub
```

SMIT

In SMIT, a class can be removed by accessing the *Remove a class* screen or using the following fastpath

```
# smitty wlmrmclass
```

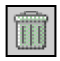
A superclass is removed by specifying its name, and a subclass is removed by specifying its full name.

If the *Work on a set of subclasses* screen has been accessed to change into a superclass' context (see Section 3.3.3.1 on page 57 for further information about changing the configuration's focus), the *Remove a class* screen will operate on the subclasses of the chosen superclass. While operating under a superclass' scope, the short name can be specified when removing a subclass of that superclass.

> **Note**
>
> Remember that the scope will be returned to the root of the currently-running configuration if the SMIT session is exited and restarted.

WSM

To remove a class in WSM, the system administrator can highlight the class to be deleted and press the Delete key, right-click on the class name, and chose the *Delete* option or click on the delete icon at the top of the WSM' window:


Delete

3.3.4 Working with rules

After configuring the needed classes, the process assignment criteria must be set up to have the applications classified according to the configuration design. This is done by creating the class assignment rules.

3.3.4.1 Adding a rule

To add a rule, we can directly edit the rules files; use SMIT or WSM.

Editing the rules files

As shown in Section 2.5.3, "Class assignment rules" on page 19, an assignment rule is a set of attributes with which the characteristics of a given process can be matched (or not). The rules file has the same format for both superclasses and subclasses, the only difference being the non-existence of a System class rule in the subclasses' rules files due to the non-existence of System subclasses.

The rules file for the example shown in Table 2 on page 21 would be:

```
* IBM_PROLOG_BEGIN_TAG
* This is an automatically generated prolog.
* bos43N src/bos/etc/wlm/rules 1.1
* Licensed Materials - Property of IBM
* (C) COPYRIGHT International Business Machines Corp. 1999
* All Rights Reserved
* US Government Users Restricted Rights - Use, duplication or
* disclosure restricted by GSA ADP Schedule Contract with IBM Corp.
* IBM_PROLOG_END_TAG
* class resvd user group application type tag
System - root - - - -
db1 - - - /usr/oracle/bin/db* - _db1
db2 - - - /usr/oracle/bin/db* - _db2
devlt - - dev - 32bit -
VPs - bob,!ted - - - -
acctg - - acct* - - -
```

```
Default - - - - - -
```

The *resvd* attribute (reserved for future use) must always exist and must always be set to hyphen (-).

Any hyphens (-) at the end of a rule can be omitted, as long as no subsequent attribute is set. For instance, the rule for the *acctg* superclass could be

```
acctg - - acct*
```

but the rule for the *db1* superclass could *not* be

```
db1 - - - /usr/oracle/bin/db* _db1
```

because _db1 would be interpreted by WLM as the *type* attribute, returning, thus, an invalid type attribute error.

For the type attribute position, one or more values could be placed, either ORed with commas (,), or ANDed with plus signs (+). For instance, the rule for the *devlt* class in the previous example could be:

```
devlt - - dev - 32bit,plock+fixed -
```

specifying that the processes classified under this class needed to be either 32 bit processes or have called `plock` and be fixed priority at the same time.

SMIT

In SMIT, a rule can be created by accessing the *Class assignment rules* and *Create a new rule* screens or by using the following fastpath:

```
# smitty crewlmrs
```

If the *Work on a set of subclasses* screen has been accessed to change into a superclass' context (see Section 3.3.3.1 on page 57 for more information about changing the configuration's focus), the *Create a new rule* screen will work under the scope of the chosen superclass. It will, therefore, create the rules for the superclass' subclasses. While operating under a superclass' scope, the short name can be specified when creating rules for a subclass of that superclass.

Note

Remember that the scope will be returned to the root of the currently-running configuration if the SMIT session is exited and restarted.

In Figure 33, we can see an example of the creation of a rule for the *hogs* subclass of the *devlt* superclass (from the example in Table 2 on page 21), after changing into *devlt* superclass' scope:

```
                              Create a new Rule

   Type or select values in entry fields.
   Press Enter AFTER making all desired changes.

                                                          [Entry Fields]
   * Order of the rule                                 [2]                #
   * Class name                                         hogs             +
   * User                                              [-]               +
   * Group                                             [-]               +
     Application                                       [-]
     Type                                              [32bit,plock+fixed]   +
     Tag                                               [-]







   F1=Help            F2=Refresh          F3=Cancel           F4=List
   F5=Reset           F6=Command          F7=Edit             F8=Image
   F9=Shell           F10=Exit            Enter=Do
```

Figure 33. Create a new Rule screen in SMIT

The *type* for the *hogs* subclass in Figure 33 could be configured as *32bit,plock+fixed* to specify that a process classified under this subclass had to be either 32 bit or have called `plock` and have fixed priority at the same time. If the F4 function key is pressed on the *type* attribute and more than one value chosen, they get comma-separated (or ORed). If the AND option is required, the plus sign must be entered *manually* in this attribute.

WSM

Working with rules in WSM (at general configuration or superclass levels) can be done in the *Configurations/Classes* screen by right clicking on the configuration to be changed and choosing the *Class Assignment Rules* option. The Class Assignment Rules screen is shown in Figure 34 on page 79.

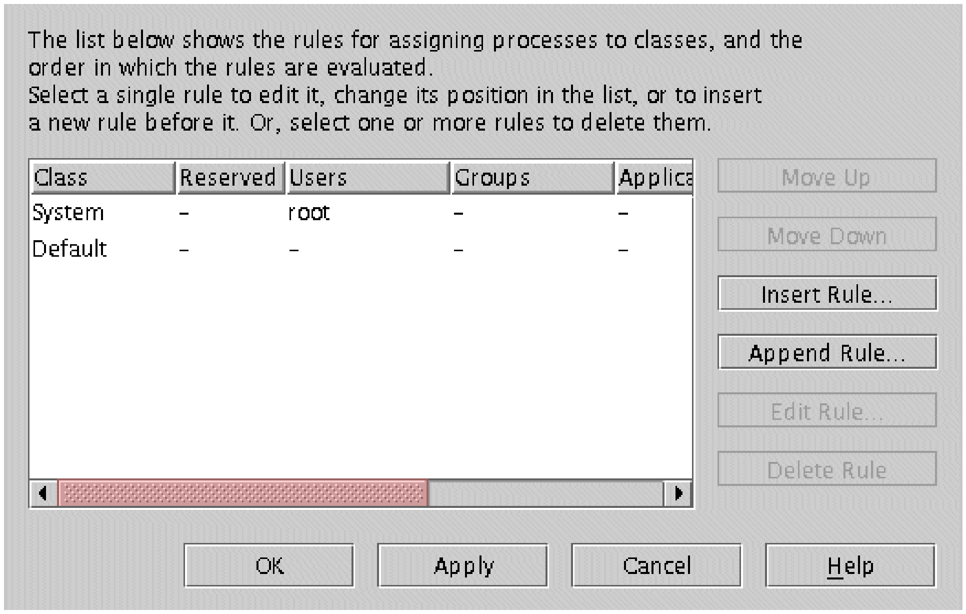


Figure 34. Class Assignment Rules screen in WSM

To add a rule, click on *Insert Rule*. The attributes of a rule can now be set (user, group, application, process type, and tag) as shown in Figure 35 on page 80.

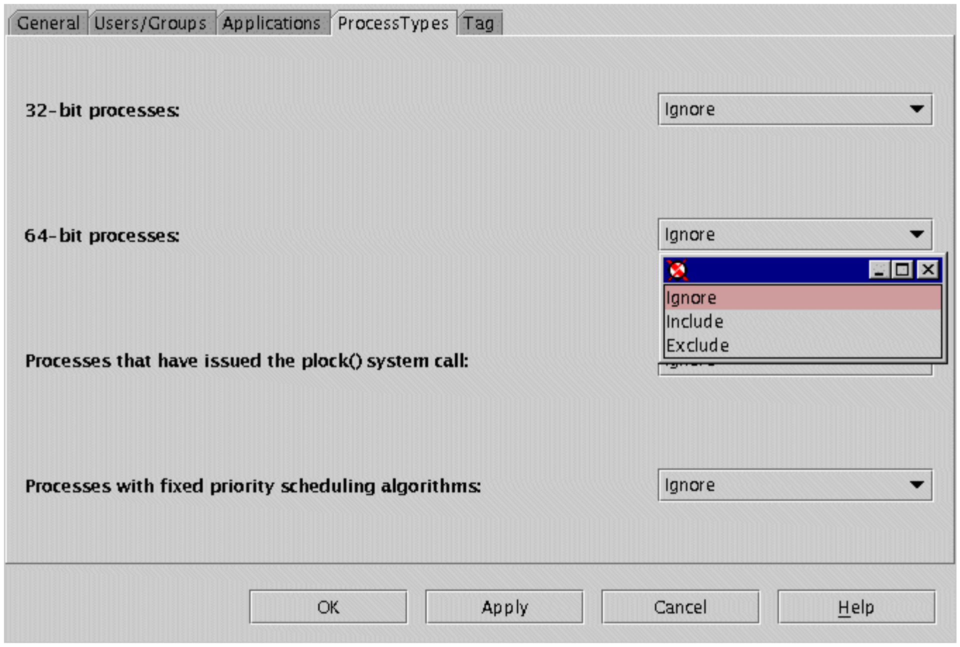


Figure 35. Adding a rule in WSM - setting process type attribute

After a rule has been created, it can be moved up or down the rules list by clicking on the options, *Move Up* or *Move Down*, in the *Class Assignment Rules* screen.

3.3.4.2 Changing a rule

A rule can be changed by directly editing the rules file (see Section 3.3.4.1, “Adding a rule” on page 76, for more information about editing the rules file) or by using SMIT or WSM.

SMIT

A rule can be changed in SMIT through the *Class assignment rules* screen and *Change/Show Characteristics of a Rule* or through the following fastpath:

```
# smitty chgwlmrs
```

Figure 36 on page 81 shows the *Select a Rule* screen.

```
lqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqk
x                              Select a Rule                                  x
x                                                                             x
x Move cursor to desired item and press Enter.                                x
x                                                                             x
x  #Order  Class    User     Group    Application             Type    Tag     x
x  1       System   root     -        -        -        -                     x
x  2       db1      -        -        /usr/oracle/bin/db*     -       _db1    x
x  3       db2      -        -        /usr/oracle/bin/db*     -       _db2    x
x  4       devlt    -        dev      -        32bit    -                     x
x  5       VPs      bob,sally         -        -        -     -               x
x  6       acctg    !ted     acct*    -        -        -                     x
x  7       Default  -        -        -        -        -                     x
x                                                                             x
x F1=Help                F2=Refresh              F3=Cancel                    x
x F8=Image               F10=Exit                Enter=Do                     x
x /=Find                 n=Find Next                                          x
mqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqj
```

Figure 36. Selecting a rule in SMIT

After selecting the rule to be changed, any of its attributes can then be edited, such as changing the group to *dev* in *db1* superclass' rule as shown in Figure 37 on page 81.

```
                     Change / Show Characteristics of a Rule

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                  [Entry Fields]
  Order of the rule                               2
  New Order of the rule                          [2]                  #
* Class name                                      db1                 +
* User                                           [-]                  +
* Group                                          [dev]                +
  Application                                    [/usr/oracle/bin/db*]
  Type                                           [-]                  +
  Tag                                            [_db1]






F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 37. Change/Show Characteristics of a Rule screen in SMIT

If the *Work on a set of subclasses* screen has been accessed to change into a superclass' context (see Section 3.3.3.1, “Working with sets of subclasses” on page 57, for more information about changing the configuration's focus), the *Change/Show Characteristics of a Rule* screen will operate on the rules of the subclasses of the chosen superclass.

Note

Remember that the scope will be returned to the root of the currently-running configuration if the SMIT session is exited and restarted.

If the F4 function key is pressed on the *type* attribute and more than one value chosen, they get comma-separated (or ORed). If the AND option is required, the plus sign must be *manually* entered in this attribute.

WSM

To change a rule in WSM, click *Edit Rule* in the *Class Assignment Rules* screen (see Figure 34 on page 79) at either the superclass or subclass level. A screen similar to the one in Figure 35 on page 80 will be shown allowing the system administrator to alter the rule's attributes.

3.3.4.3 Listing the rules

The rules currently configured can be visualized in the rules files. SMIT or WSM tools can also be used to list them.

SMIT

The rules in SMIT can be listed by accessing the *Class assignment rules* screen, followed by the *List all Rules* screen shown in Figure 38 on page 83.

```
                                 COMMAND STATUS

Command: OK            stdout: yes           stderr: no

Before command completion, additional instructions may appear below.

_#  Class     User      Group     Application         Type      Tag
001 System    root      -         -                   -         -
002 db1       -         -         /usr/oracle/bin/db* -         _db1
003 db2       -         -         /usr/oracle/bin/db* -         _db2
004 devlt     -         dev       -                   32bit     -
005 VPs       bob,sally -         -                   -         -
006 acctg     !ted      acct*     -                   -         -
007 Default   -         -         -                   -         -









F1=Help             F2=Refresh          F3=Cancel           F6=Command
F8=Image            F9=Shell            F10=Exit            /=Find
n=Find Next
```

Figure 38. List all Rules screen in SMIT

If the *Work on a set of subclasses* screen has been accessed to change into a superclass' context (see Section 3.3.3.1, "Working with sets of subclasses" on page 57, for more information about changing the configuration's focus), the *List all Rules* screen will print out the rules of the subclasses of the chosen superclass.

Note

Remember that the scope will be returned to the root of the currently-running configuration if the SMIT session is exited and restarted.

WSM

Listing the rules in WSM is done by simply accessing the *Class Assignment Rules* screen (see Figure 34 on page 79) either at the superclass or subclass level. The rules are immediately listed.

3.3.4.4 Removing a rule

A rule can be removed by either deleting its line from the rules file or by using SMIT or WSM tools.

SMIT

In SMIT, a rule can be deleted by accessing the *Class assignment rules* screen and choosing *Delete a Rule*. See Figure 36 on page 81 for details about selecting a rule.

WSM

In WSM, a rule can be deleted by accessing the *Class Assignment Rules* screen, highlighting the rule to be removed, and clicking *Delete Rule*.

3.3.5 Checking the configuration - wlmcheck

The configuration is set and running. Now is probably a good time to use the WLM checking command, `wlmcheck`. This command checks automatic assignment rules and/or determines the class in which a process with a specified set of attributes will be classified.

Command line

The syntax for the `wlmcheck` command is as follows:

```
wlmcheck [ -d config_dir ] [ -a <process attributes> ] [ -q ]
```

The following are the options for this command:

`-d config`	Uses the WLM property files in /etc/wlm/config instead of the values currently loaded into the kernel (active configuration).
`-a attributes`	Used to pass a set of values for the classification attributes of the process in order to determine which class the process will be put into. This is a way to check that the assignment rules are correct and classify processes as expected.
`-q`	Suppresses the output of the status of the latest activation/update of WLM (stands for quiet).

The `wlmcheck` command with no arguments returns the status of WLM and makes some coherency checks:

- Displays the current status of WLM (running/non running, active/passive, rsets bindings active/non active).
- Displays the status files that report the last loading errors, if any.
- Checks the coherency of the assignment rules files (syntax, existence of the classes, validity of user and group names, application path names, and so on).

If the `-d config_dir` option is not specified, the checks are performed on the configuration that is loaded into the kernel at this time. If WLM is not active, an error message is displayed. Specifying a configuration with `-d config_dir` allows you to perform the checks on configuration files, including the ones in /etc/wlm/current.

Used with the `-a` option, the `wlmcheck` command displays the class the process would be assigned to according to the set of assignment rules of the specified configuration.

The attributes are given as a string similar to the format used in the assignment rules file (single string with several space-separated fields) and should be enclosed in quotes. The fields are the same and appear in the same order as in the rules file: *reserved*, *user name*, *group name*, *application path name*, *process type*, *application tag* (see Section 3.1, “Property files” on page 32, for more information about the rules property file).

The difference is that, unlike in the assignment rules:

- The class field is omitted (it is actually an output of the `wlmcheck` command).
- Each field can have, at most, one value. Exclusions (!), comma-separated lists, and wild cards are not allowed.
- At least one field must be specified (have a value different from a hyphen (-)).

In addition, the first two fields are mandatory. The other fields, if not present, will default to a hyphen (-), which means that any value in the corresponding field of an assignment rule is a match. When one or more of the fields in the attribute string are either not present or specified as a hyphen (-), the string is likely to match more than one rule. In this case, the `wlmcheck` command will display all the classes corresponding to all the possible matches.

Example of valid attribute strings:

```
# wlmcheck -a "- root system /usr/bin/vi - -"

# wlmcheck -a "- - staff - 32bit"

# wlmcheck -a "- bob"
```

By default, the `wlmcheck` command outputs the contents of the status files for the last activation or update of WLM.

WSM

In WSM, `wlmcheck` can be invoked to check on the assignment rules coherency and to evaluate to which class a specific process would be assigned. This can be done in the *Configurations/Classes* screen by right clicking the configuration to be checked and choosing *Check Assignment* for the process classification evaluation and *Check Rules* for the coherency test. The Check Assignment screen, shown in Figure 39, appears.

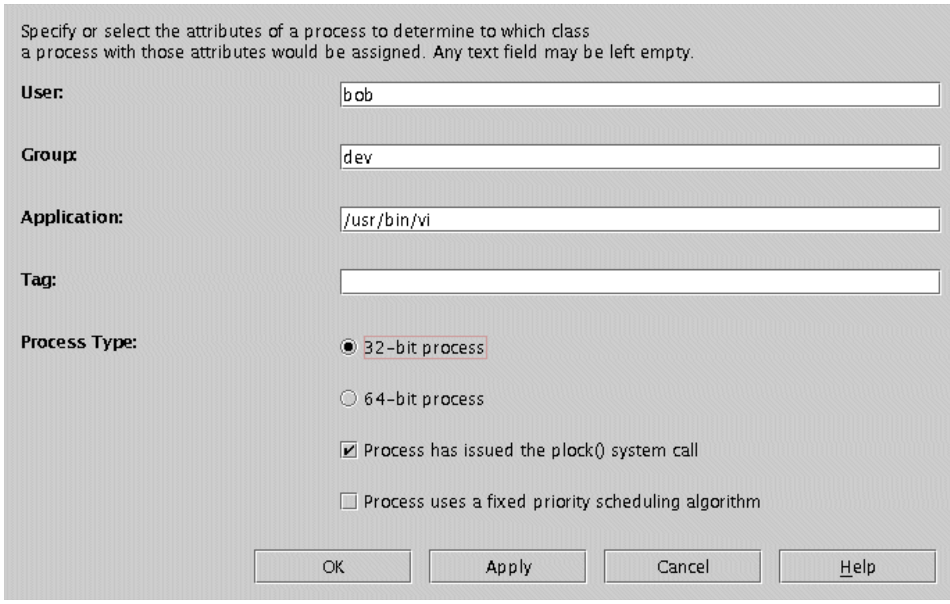


Figure 39. Check Assignment in WSM

3.3.6 Working with resource sets

WLM uses the concept of resource sets (or rsets) to restrict the processes in a given class to a subset of the system's physical resources. In AIX 5L, the physical resources managed are the memory and the processors. A valid resource set is composed of memory and, at least, one processor.

Figure 40 on page 87 shows the SMIT panel where a resource set can be specified for a specific class.

```
                         General characteristics of a class

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                        [Entry Fields]
  Class name                                           Redbook
  Description                                         [Redbook example]
  Tier                                                [0]                +#
  Resource Set                                         sys/cpu.00003      +
  Inheritance                                         [Yes]               +
  User authorized to assign its processes to this cl [user_s]            +
  ass
  Group authorized to assign its processes to this c [system]            +
  lass
  User authorized to administrate this class         [user_s]            +
  (Superclass only)
  Group authorized to administrate this class        [system]            +
  (Superclass only)


F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 40. Resource Set definition to a specific class

By default, the system creates one resource set for all physical memory, one for all CPU's, and one separate set for each individual CPU in the system. The `lsrset` command lists all resource sets defined. The following is a sample output for the `lsrset` command:

```
# lsrset -av
T  Name              Owner    Group    Mode     CPU  Memory  Resources
r  sys/sys0          root     system   r-----    4     511   sys/sys0
sys/node.00000 sys/mem.00000 sys/cpu.00003 sys/cpu.00002 sys/cpu.00001
sys/cpu.00000
r  sys/node.00000    root     system   r-----    4     511   sys/sys0
sys/node.00000 sys/mem.00000 sys/cpu.00003 sys/cpu.00002 sys/cpu.00001
sys/cpu.00000
r  sys/mem.00000     root     system   r-----    0     511   sys/mem.00000
r  sys/cpu.00003     root     system   r-----    1       0   sys/cpu.00003
r  sys/cpu.00002     root     system   r-----    1       0   sys/cpu.00002
r  sys/cpu.00001     root     system   r-----    1       0   sys/cpu.00001
r  sys/cpu.00000     root     system   r-----    1       0   sys/cpu.00000
```

3.3.6.1 Rset registry

As mentioned earlier, by default in AIX 5L, some resource sets are created for memory and CPU. It is possible to create different resource sets by grouping two or more resource sets and storing the definition in the rset registry.

The rset registry services enable system administrators to define and name resource sets so that they can then be used by other users or applications. In order to alleviate the risks of name collisions, the registry supports a two-level naming scheme. The name of a resource set is in the form, name_space/rset_name. Both the namespace and rset_name may each be 255 characters in size, are case-sensitive, and may contain only upper and lowercase letters, numbers, underscores, and periods (.). The namespace of sys is reserved by the operating system and used for rset definitions that represent the resources of the system.

The `SMIT rset` command has options to list, remove, show a specific resource set used by a process, and the management tools as shown in Figure 41.

```
                             Resource Set Management

Move cursor to desired item and press Enter.

  List All Resource Sets
  List All Resource Sets in a given namespace
  List All System RADs
  List Application-defined Resource Sets
  Remove Application-defined Resource Sets
  Show a Process Partition
  Manage Resource Set Database











F1=Help             F2=Refresh          F3=Cancel           F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 41. SMIT main panel for Resource Set Management

To create, delete, or change a resource set in the rset registry, you must select *Manage Resource Set Database* in the SMIT panel. In this panel, it is also possible to reload the rset registry definitions to make all changes available to the system. Figure 42 on page 89 shows the SMIT panel for rset registry management.

```
                       Manage Resource Set Database

Move cursor to desired item and press Enter.

  List All Resource Sets of the Database
  Add a Resource Set to the Database
  Remove a Resource Set from the Database
  Change / Show Characteristics of a Database Resource Set
  Reload Resource Set Database












F1=Help              F2=Refresh           F3=Cancel            F8=Image
F9=Shell             F10=Exit             Enter=Do
```

Figure 42. SMIT panel for rset registry management

To add a new resource set, you must specify a name space, a resource set name, and the list of resources. It is also possible to change permissions for the owner and group of this rset. In addition, the permissions for the owner, groups, and others can be specified. Figure 43 on page 90 shows the SMIT panel for this task.

```
                        Add a Resource Set to the Database

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                          [Entry Fields]
* Name Space                                           [Redbook]              +
* Resource Set Name                                    [CPU0and1]             +
* Owner                                                 root                  +
* Group                                                 system                +
* Owner Permissions                                     rw                    +
* Group Permissions                                     r-                    +
* Others Permissions                                    r-                    +
* Resources                                             sys/cpu.00001,sys/cpu.> +









F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 43. SMIT panel to add a new resource set

Whenever a new rset is created, deleted, or modified, a reload in the rset database is needed to make the changes effective.

3.4 WLM monitoring

To monitor the system's behavior under the influence of WLM, the `wlmstat` tool has been provided along with some changes in already-existing commands, such as `ps` and `svmon`. A higher interaction with Performance Toolbox was also supplied. Due to the vast extension of the monitoring theme, it is fully covered in Chapter 4, "WLM performance tools" on page 97.

3.5 Hints and tips

Practical use of WLM provided a collection of configuration and utilization hints and tips that help the system administrator take better advantage of the feature and avoid some identified problems. Some additional characteristics of WLM will also be pointed out in this section.

3.5.1 Things to do

The following points are some hints that can help you configure and use WLM to a considerable extent:

Before you start

Always study and anticipate the behaviors of your applications before beginning to use WLM. Know your applications' needs for disk, memory, and CPU use. Otherwise, you could end up giving unnecessary CPU cycles to a memory-bound application, instead of giving it the memory space it really needs.

A starting point

Keep it very simple at first, then build. A good starting point for a configuration of WLM would be to create a batch jobs class, an On-line Analytical Processing (OLAP) class, an On-line Transaction Processing (OLTP) class, a backup tasks class, and a Transaction Program class. Depending on the set of applications that are to be run on the system, the OLAP class could take DB2, UDB, or ORACLE; the OLTP class could contain SAP or Baan, and the Transaction Program class could hold MQSeries or Encina, for example. Classifying the processes per function gives the system administrator the ability to more easily decide where to change the configuration and progressively make it meet its original performance objective. This can be done by either gradually partitioning it into additional super or subclasses or by changing the rules or values of shares and limits. Additionally, it also helps to better determine where the source of a problem might reside. An unclear configuration gets too complex to manage as the number of classes or rules goes up.

Configuration steps

When configuring WLM on a server, perform the following steps:

1. Balance the load using only shares at first. Monitor WLM and the system for a reasonable period of time to assess application performance, and tune these values if necessary.
2. Set minimum limits for the applications that do not appear to be given their share of resources.
3. Prioritize workloads using tiers, if necessary, to promote a ranking among jobs. For greater impact, increase the separation of tiers. For example, the impact of a tier 1 and tier 7 separation will be greater than the impact of a tier 1 and tier 4 separation.
4. Set soft or hard maximum limits only if absolutely necessary to control poorly-behaved applications. Remember, a class at its memory maximum limit will cause paging activity even if there are plenty of free memory pages available.

Note

WLM configuration should be tested in a non-production environment to avoid possible disruption to users and applications.

Tiers

Tiers are used when a high-level of separation of processes' priorities is needed. This happens when there is a defined priority ranking among the applications. Configuration in tiers must be done bearing in mind that the processes assigned to higher numbered tiers should not expect to be able to compete for resources with the processes assigned to lower tiers. If process A from tier 0 has a high number of shares for resources and uses them all (running, for instance, a tight loop), process B from tier 1 might never get any CPU time during the execution of process A. But, this is exactly what is expected to happen sometimes; the system administrator should not allow a backup to stall a heavily-loaded e-business application during regular work hours, for instance. To make sure that the backup eventually happens, the system administrator can take advantage of the ability to have several WLM setups ready to run. He or she can configure `cron` to change WLM, at some chosen point in time, into a configuration where the backup process is assigned to tier 0, and, this way, it finally has its chance to run.

System and Default superclasses

For a given program, WLM chooses the first in the list of rules that matches the process' configuration, either by USERID, GROUPID, the name of the executable itself, the type, tag, or any possible combination of these attributes. Since every process is considered to belong to, at least, the *Default* superclass, and since system jobs should not be classified differently than they are in the *System* superclass, we should have the *System* class' rule placed as close to the top of the rules list as possible, and *Default* class' rule should be placed at the very bottom. The only circumstance in which the list of rules may and must have other classes before the *System* class' rule is when the root user is supposed to launch a program that we want placed in a specific, user-created class. There are no reasons why any rule should come after *Default*'s rule; it would never be used.

The *System* superclass should not be anywhere other than in tier 0. Placing it on a different tier would ruin the normal functioning of the system. We must not forget that, besides the user applications, kernel processes are being controlled by WLM as well, and if they do not get their share of resources and, therefore, are not allowed to do their work, nothing else will be able to run properly. This idea must also be kept in mind when configuring the values for shares and limits for the *System* superclass. These values should never be so low as to impair the system’s work or so high that they substantially subtract performance from the applications.

Shares versus hard and soft limits

It is recommended to use resource shares rather than limits to start with. WLM sees resource shares as goals to be achieved, and this allows greater system flexibility than imposed limits. If the resource shares set up by a system administrator are not optimal, the system should still be able to balance the load reasonably well. With hard limits set, WLM can do little to prevent applications from being starved of resources. For example, if the maximum memory limit is set smaller than the average working set of the application, this may incur significant performance degradation. In summary, it is better to wait to assign limits until after experience has been gained with the results from setting resource shares, and when setting resource limits, start by setting only the minimums. It is also suggested that memory minimums for *all* classes be used before imposing a memory maximum for any class. This is for performance reasons, basically. A class that reaches its maximum memory limit starts paging against itself, which causes the paging algorithm (LRU) to run even when there are plenty of memory pages available. This, by itself, causes some performance impact. The recommended minimum limit for other classes is to make sure that LRU will not steal pages from these classes below those limits, which would cause an even greater performance impact. This would happen if, by some chance, some last and most probable next accessed pages were stolen from a non-minimum limited class.

Rules

The more specific assignment rules should appear first in the *rules* file, and the more general rules should appear last.

High-availability clustering multiprocessing program (HACMP)

It is recommended to make the HACMP startup entry in WLM systems as close to the end of the /etc/inittab file as possible in order to make sure WLM is fully-initialized before the cluster manager starts. Otherwise, the deadman switch might trigger a false failover while something, such as WLM, initializes.

WLM on the SP systems

WLM cannot be used to provide distributed workload management over multiple nodes on the SP systems. Nevertheless, if some nodes are similar in applications structure and configurations, having WLM working in all of them is as easy as performing the following steps:

1. Configure WLM in one node.

2. Use the `tar` command to gather all text files which make up the configuration.
3. Use `dsh` to distribute them to every node applicable.
4. Use the `tar` command to unpack the files.
5. Start up WLM, specifying the configuration files directory.

3.5.2 Things to be aware of

The following points are descriptions of some difficulties found:

svmon

A problem with the `svmon` command is observed while submitting a heavy memory workload on an 64 bit machine with more than 2 GB memory running AIX 4.3.3 system at maintenance level 2 and perfagent.tools at the 2.2.33.15 level. `svmon` needs to allocate real memory to work, and being unable to do so, it halts the system. Though this is not a problem directly connected to WLM, it is bound to be observed in WLM environments; so, the use of the `svmon` tool is only recommended in WLM systems with the perfagent.tools fileset at the 2.2.33.16 level or later.

wlmstat

On WLM's first release, when using `tee` and `wlmstat` commands together to monitor performance on the screen and gather the information on a file at the same time, the output of `wlmstat` was not immediate. It only displayed information on the screen or wrote something on the file every 4 KB of data gathered. This situation is solved in AIX 5L.

vmtune

Unless done with extreme caution, changing some `vmtune` options, such as `minperm`, `maxperm`, `minfree`, and `maxfree` to anything other than default values might impair WLM and degrade system performance. Any potential tuning of these values should be done before using WLM.

Note

If a problem is experienced with WLM after changing any `vmtune` values, these settings should be moved back to default options.

Non-configured WLM startup

WLM is not started on AIX by default. Its startup must be issued manually or placed in /etc/inittab to be launched upon reboot. The system administrator must make sure, however, that this does not happen before WLM is fully-configured and ready to run. A non-configured WLM startup degrades system performance significantly.

Setuid inside applications
If an application runs a `setuid` while launched to change its *effective* UID, its classification stays related to the UID of the user that originally started it, because it occurs no reclassification. A dynamic reclassification only occurs in those cases when the change is made to the process' *real* UID.

The same situation is observed for groups and `setgid`.

> **Note**
>
> If any undesirable behavior occurs when WLM is running, it can be stopped using the `wlmcntrl -o` command. Stopping WLM will turn off all WLM management of resources, and the system behavior will quickly return to the normal state.

3.5.3 Additional characteristics

The following points depict some additional characteristics of WLM:

Overhead
Comparing both performances of AIX 4.3.2 (without WLM) and 4.3.3 (with WLM), WLM process does not represent any overhead on the system. The reason for this situation to be observed is based on the significant improvements in performance that AIX provides in the 4.3.3 release, with the creation of dedicated run queues per processor, for instance. These improvements, combined with the further enhancements of performance that a well-tuned WLM supplies, make the overhead of having an additional process to control the resources almost ineffective. Nevertheless, between an AIX V4.3.3 system and an AIX V4.3.3 system with WLM, some overhead might be noticed. This will increase based on the number and complexity of the rules configured in WLM.

Passive mode
When configuring WLM, know your users and applications. It is important to understand the user base and their computing needs. It is also important to have an understanding of the resources required by all applications in the system. This is where the WLM passive mode can help.

The passive mode provides a way to monitor the impact WLM brings to the system. By comparing system behavior between active and passive modes, the system administrator can easily redefine WLM configuration strategies.

Monitoring

Performance monitoring experiences a deep change with the introduction of WLM. The scheduler and WLM use fairly different time boundaries to work:

- WLM uses a 1 ms time boundary for CPU use accounting and 10 ms for dispatching and makes priority recalculations every second.
- The scheduler uses a 10 ms time boundary for CPU use accounting, 10 ms for dispatching, and it makes priority recalculations every second.

These differences create the substantial value discrepancies that can be observed when `wlmstat` and `vmstat` are run simultaneously in a WLM environment. As a result of WLM using 1 ms as a time boundary for CPU use accounting (against the 10 ms the scheduler uses), the `wlmstat` command gets to be much more accurate in its calculations than `vmstat`. Therefore, for reliable values, `wlmstat` is the suggested tool to use in WLM environments.

Dynamic update

Tiers, resource soft and hard limits, resource shares, rules, and every sort of WLM configuration can now be modified while WLM is running and take immediate effect without the need to stop and restart WLM that existed in its previous release.

Dump analysis

The `snap` command is used to collect system information and dump files for problem determination. In AIX 5L, this command has a `-w` option, which is used to gather WLM information and join it to the already-existing one (basically, assembles the contents of the /etc/wlm directory). This feature can be very useful when analyzing an unknown technical problem, that might (or might not) be WLM-related.

The substitute for the kernel-debugging `crash` command in AIX 5L, the `kdb` command, also incorporates options to analyze the behavior of WLM configuration at the kernel level when, for instance, a dump occurs.

Chapter 4. WLM performance tools

This chapter presents useful tools to monitor and analyze WLM activity. The real time performance tools, such as wlmstat, ps, topas, and svmon, are components of the AIX base operating system. System administrators who need a long-term analysis tool and a method to collect trend values should use wlmperf, xmtrend, and jazizo. They are delivered with the Performance Trend Toolbox Feature.

4.1 wlmstat

To monitor the statistical resouce utilization by each superclass and subclass and to display the status of WLM, use the `wlmstat` command. This command shows the contents of WLM data structures that are retrieved from the kernel.

The syntax is:

```
wlmstat [-l class | -t tier] [-S | -s] [-c | -m | -b] [-B device] [-q]
[-T] [-a] [-w][-v] [interval] [count]
```

Where:

`-l class`	Indicates the resource utilization for a specific class. If not specified, all classes are displayed.
`-t tier`	Displays statistics only for the given tier.
`-S`	Displays statistics for superclasses only.
`-s`	Displays statistics for subclasses only. If neither `-S` nor `-s` are specified, the statistics for both superclasses and subclasses are displayed. In this case, the statistics for each superclass are listed followed by the statistics for the subclasses belonging to that superclass.
`-c`	Shows only CPU statistics.
`-m`	Shows only physical memory statistics.
`-b`	Shows only disk I/O statistics.
`-B device`	Displays statistics for the given disk I/O device. Statistics for all the disks accessed by the class are displayed by passing an empty string (`-B ""`).
`-q`	Represses output of status files of last action (quiet).
`-T`	Returns the total numbers for resource utilization since each class was created (or WLM started). The units are:

- Number of CPU ticks per CPU (seconds) used by each class
- Number of memory pages multiplied by the number of seconds used by each class
- Number of 512 byte blocks sent/received by a class for all the disk devices accessed

`-a` Delivers absolute figures (relative to the total amount of the resource available to the whole system) for subclasses, with a 0.01 percent resolution. By default, the figures shown for subclasses are a percentage of the amount of the resource used by the superclass, with a one percent resolution. For instance, if a superclass has a CPU target of seven percent and the CPU percentage shown by `wlmstat` without `-a` for a subclass is five percent, `wlmstat` with `-a` will show the CPU percentage for the subclass as 0.35 percent.

`-w` Displays the memory *high water mark*, that is, the maximum number of pages that a class had in memory since the class was created (or WLM started).

`-v` Shows most of the attributes concerning the class. The output includes internal parameter values intended for AIX support persons. Table 3 shows a list of some attributes that may be of interest to users.

Table 3. wlmstat - selection of internal parameters

Column header	Description
CLASS	Class name
tr	Tier number from 0...9
i	Value of the inheritance attribute: 0 = no , 1 = yes
#pr	Number of processes in the class. If no process is assigned to a class, the following values may not be significant.
CPU	CPU utilization of the class in percent
MEM	Physical memory utilization of the class in percent
DKIO	Disk I/O bandwidth utilization for the class in percent
sha	Number of shares. If no ("-") shares are defined, then sha = -1
min	Resource minimum limit in percent
smx	Resource soft maximum limit in percent

Column header	Description
hmx	Resource hard maximum limit in percent
des	desired percentage target calculated by WLM using the numbers of the shares in percent
npg	number of memory pages owned by the class

`interval` Specifies an interval in seconds (default to 1).

`count` Specifies how many times wlmstat will print a report (default to 1).

The results of `wlmstat` in the normal (non verbose) case are tabulated with the following fields:

CLASS Class name

CPUtotal CPU time used by the class in percent

MEM Physical memory used by the class in percent

DKIO Disk I/O bandwidth used by the class in percent

Disk I/O

DKIO is the average of the disk bandwidth on all the disk devices accessed by the class. It is not very significant. For instance: A class uses 80 percent of the bandwidth of one disk and 5 percent of the bandwidth of two other disks. Then the value of DKIO for this class is 30 percent:

$$\frac{(80 \text{ percent (disk1)} + 5 \text{ percent (disk2)} + 5 \text{ percent (disk3)})}{3(\text{number of disks})} = 30 \text{ percent}$$

To achieve a detailed output of the utilization per disk, use the `-B` device option.

Examples:
To get a printout of current WLM activity, enter:

```
(0)itsosrv1:/# wlmstat
         CLASS CPU MEM DKIO
  Unclassified   0   0    0
     Unmanaged   0   0    0
       Default   0   0    0
        Shared   0   0    0
        System   0   6    0
          oltp  75  18    0
oltp.Default    68  17    0
 oltp.Shared     0   0    0
  oltp.spray     7   1    0
           dss  10  27    0
        backup  13  28    0
(0)itsosrv1:/#
```

To get a report for the superclass, *oltp*, enter:

```
(0)itsosrv1:/# wlmstat -l oltp
         CLASS CPU MEM DKIO
          oltp  74  17    0
oltp.Default    67  16    0
 oltp.Shared     0   0    0
  oltp.spray     7   2    0
(0)itsosrv1:/#
```

To get a report for the subclass, spray, of the superclass, *oltp*, updated every 10 seconds for one minute, enter:

```
(127)itsosrv1:/# wlmstat -l oltp.spray 10 6
       CLASS CPU MEM DKIO
oltp.spray     5   1    0
oltp.spray     5   2    0
oltp.spray     7   1    0
oltp.spray     6   2    0
oltp.spray     6   1    0
oltp.spray     5   1    0
(0)itsosrv1:/#
```

To get a detailed CPU report for all classes, enter the information shown in the next screen.

```
(0)itsosrv1:/# wlmstat -c -v
           CLASS tr i #pr CPU sha min smx hmx des  rap urap pri
    Unclassified  0 0   1   0  -1   0 100 100 100    0   97  10
       Unmanaged  0 0   0   0  -1   0 100 100   0    0   97  10
         Default  0 0   1   0  -1   0 100 100   0    0   97  97
Default.Default   0 0   1   0   1   0 100 100 100  100   48  48
 Default.Shared   0 0   0   0  -1   0 100 100   0    0   96  96
          Shared  0 0   0   0  -1   0 100 100   0    0   97  97
 Shared.Default   0 0   0   0   1   0 100 100 100  100   48  48
  Shared.Shared   0 0   0   0  -1   0 100 100   0    0   96  96
          System  0 0  43   0  10  10 100 100  10  100    0   0
 System.Default   0 0  43   0   1   0 100 100 100  100    0   0
  System.Shared   0 0   0   0  -1   0 100 100   0    0   48  48
            oltp  0 0 101  77  35   0 100 100  38 -100  194 194
   oltp.Default   0 0  -5  71  -1   0 100 100 100    0  144 144
    oltp.Shared   0 0   0   0  -1   0 100 100   0    0  144 144
     oltp.spray   0 0 107   6  30   0 100 100   6  -90  187 187
             dss  0 0   3  10  20   0 100 100  22  100    0   0
    dss.Default   0 0   2  10   1   0 100 100 100  100    0   0
     dss.Shared   0 0   0   0  -1   0 100 100   0    0   48  48
          backup  0 0   2  11  35   0 100 100  38  100    0   0
 backup.Default   0 0   3  11   1   0 100 100 100  100    0   0
  backup.Shared   0 0   0   0  -1   0 100 100   0    0   48  48
(0)itsosrv1:/#
```

4.2 ps

The `ps` command writes the current status of active processes and associated kernel threads to standard output.

Syntax (X/Open Standards):

```
ps [-A] [-N] [-a] [-d] [-e] [-f] [-k] [-l] [-F format] [-o Format]
[-c Clist] [-G Glist] [-g Glist][-m] [-n NameList] [-p Plist]
[-t Tlist] [-U Ulist] [-u Ulist]
```

In this book, we focus on the `ps` command to view the current status of processes in a single class or set of classes (either subclass or superclass).

Flags:

`-a` Writes information about all processes to standard output, except the session leaders and processes not associated with a terminal.

`-e` Writes information about all processes to standard output, except kernel processes.

`-c Clist` Only displays information about processes assigned to the workload management classes listed in the `Clist` variable.

The `Clist` variable is either a comma-separated list of class names or a list of class names enclosed in double quotation marks (`" "`) and separated from one another by a comma or by one or more spaces, or both.

`-o Format` Displays information in the format specified by the Format variable. Multiple field specifiers can be specified for the Format variable. The Format variable is either a comma-separated list of field specifiers or a list of field specifiers enclosed within a set of `" "` (double-quotation marks) and separated from one another by a comma, one or more spaces, or both.

Each field specifier has a default header. The default header can be overridden by appending an = (equal sign) followed by the user-defined text for the header. The fields are written in the order specified on the command line in column format. The field widths are specified by the system to be at least as wide as the default or user-defined header text. If the header text is null (for example, if `-o user=` is specified) the field width is at least as wide as the default header text. If all header fields are null, no header line is written.

The following field specifiers are recognized by the system and are relevant for use with WLM:

`pid` Indicates the decimal value of the process ID. The default header for this field is PID.

`user` Indicates the effective user ID of the process. The textual user ID is displayed. If the textual user ID cannot be obtained, a decimal representation is used. The default header for this field is USER.

`class` Indicates the workload management class assigned to the process. The default header for this field is CLASS.

`pcpu` Indicates the ratio of CPU time used to CPU time available, expressed as a percentage. The default header for this field is %CPU.

`tag` Indicates the Workload Manager application tag. The default header for this field is TAG. The tag is a character string up to 30 characters long and may be truncated when displayed by `ps`. For processes that do not set their tag, this field displays as a hyphen (-).

`thcount` Indicates the number of kernel threads owned by the process. The default header for this field is THCNT.

`vsz` Indicates, as a decimal integer, the size in kilobytes of the process in virtual memory. The default header for this field is VSZ.

`wchan` The event for which the process or kernel thread is waiting or sleeping. For a kernel thread, this field is blank if the kernel thread is running. For a process, the wait channel is defined as the wait channel of the sleeping kernel thread if only one kernel thread is sleeping; otherwise, a star is displayed. The default header for this field is WCHAN.

`args` Indicates the full command name being executed. All command-line arguments are included, though truncation may occur. The default header for this field is COMMAND.

To get a detailed report of all classes, enter:

```
ps -ae -o pid,user,class,pcpu,tag,thcount,vsz,wchan,args
```

Examples:

To get a simple `ps` output for the superclass, *backup*, and the subclass, *spray*, of the superclass, *oltp* (oltp.spray), enter the information in the following screen:

```
(0)itsosrv1:/# ps -c backup,oltp.spray
   PID    TTY  TIME CMD
 14086  pts/6  0:00 sh
 16490  pts/6  0:00 spray
 17234  pts/6  0:00 spray
 17698  pts/6  0:00 spray
 18928  pts/6  0:00 spray
 19868  pts/6  0:00 spray
 20878  pts/6  0:00 spray
 21108  pts/6  0:00 spray
 21718  pts/1  0:00 ksh
 24124  pts/6  0:00 spray
 25102  pts/6  0:00 spray
 25696  pts/6  0:00 spray
 26286  pts/6  0:00 spray
 26836  pts/6  0:00 spray
 27964  pts/1  0:01 backupserver
 28988  pts/6  0:00 spray
 31850  pts/6  0:00 spray
 32718  pts/6  0:00 spray
 33778  pts/1 110:09 backupserver
 36112  pts/6  0:00 spray
 36414  pts/6  0:00 spray
 38842  pts/6  0:00 spray
 40650      -  0:00
 41310  pts/6  0:00 spray
 41524  pts/6  0:00 spray
 42904  pts/6  0:00 spray
 43854  pts/6  0:00 spray
 45848  pts/6  0:00 spray
 46180  pts/6  0:00 sh
(0)itsosrv1:/#
```

4.3 topas

The `topas` command reports selected statistics about activity on the local system. It uses the curses library to display its output in a format suitable for viewing on an 80x24 character-based display or in a window of at least the same size in a graphical display.

The `topas` command requires the perfagent.tools fileset to be installed on the system.

Syntax:

```
topas [-d number_of_hot_disks] [-h show help information]
[-i monitoring_interval_in_seconds] [-n number_of_hot_network_interfaces ]
[-p number_of_hot_processes] [-w number_of_hot_WLM classes]
[-c number_of_hot_CPUs]
```

If the `topas` command is invoked without flags, it runs with its following default flags:

```
topas -d5 -i2 -n2 -p12 -w2 -c1
```

topas extracts statistics from the system with an interval specified by the monitoring_interval_in_seconds argument.

The following flags can be used when *starting* `topas`.

`-d`	Specifies the maximum number of disks shown. If this number exceeds the number of disks installed, the latter is used. If this argument is omitted, a default of five is assumed. If a value of zero is specified, no disk information is displayed.
`-h`	Displays help information.
`-i`	Sets the monitoring interval in seconds. The default is two seconds.
`-n`	Specifies the maximum number of network interfaces shown. If this number exceeds the number of network interfaces installed, the latter is used. If this argument is omitted, a default of two is assumed. If a value of zero is specified, no network information is displayed.
`-p`	Specifies the maximum number of processes shown. If this argument is omitted, a default of 12 is assumed. If a value of zero is specified, no process information is displayed. Retrieval of process information constitutes the majority of the topas overhead. If process information is not required, you should always use this option to specify that you don't want process information.
`-w`	Specifies the maximum number of WLM classes to display. If this number exceeds the number of WLM classes installed, the latter is used. If this argument is omitted, a default of two is assumed. If a value of zero is specified, no WLM class information is displayed.
`-c`	Specifies the maximum number of CPUs to display. If this number exceeds the number of CPUs available, the latter is used. If this argument is omitted, a default of one is assumed. If a value of zero is specified, no CPU information is displayed.

While `topas` is *running*, it accepts one-character subcommands. Each time the monitoring interval elapses, the program checks for one of the following subcommands and responds to the action requested.

`a`	Show all of the variable sections (network, disk, and process) if screen space allows.
`c`	Show CPU data. Pressing the c key the first time will list the CPUs. Pressing it again will show the totals; pressing it a third time will turn off this section, and pressing it again will list the CPUs, and so on.
`d`	Show disk information. If the requested number of disks and the requested number of network interfaces will fit on a 24-line display, both are shown. If there is space left on a 24-line display to list at least three processes, as many processes as will fit are also displayed. Pressing the d key the first time will list the disks. Pressing it again will show the totals; pressing it a third time will turn off this section, and pressing it again will list the disks, and so on.
`h`	Show the same help screen as displayed by the `-h` command line argument.
`n`	Show network interface information. If the requested number of disks and the requested number of network interfaces will fit on a 24-line display, both are shown. If there is space left on a 24-line display to list at least three processes, as many processes as will fit are also displayed. Pressing the n key the first time will list the network adapters. Pressing it again will show the totals; pressing it a third time will turn off this section, and pressing it again will list the disks, and so on.
`w`	Display WLM classes. Pressing the w key will toggle this section on and off.
`W`	Replace the default display with a WLM classes only display. This display gives more detailed information about WLM classes running on the system than the WLM section of the main display. When the W key is pressed again, it toggles back to the default main display.
`p`	Show process information. If the requested number of processes leaves enough space on a 24-line display to also display the requested number of network interfaces, those are shown. If there is also space to show the requested number of disks, those are shown as well.

`P` Replace the default display with a process only display. This display provides more detailed information about processes running on the system than the process section of the main display. When the P key is pressed again, it toggles back to the default main display.

`f` Move the cursor over the WLM class and press *Focus* to show the top processes in the group.

`q` Quit the program.

The output consists of two fixed parts and a variable section. The top two lines at the left of the display show the name of the system on which topas runs, the date and time of the last observation, and the monitoring interval.

The second fixed part fills the rightmost 25 positions of the display. It contains five subsections of statistics, as follows:

EVENTS/QUEUES

Displays the per-second frequency of selected system-global events and the average size of the thread run- and wait queues:

Cswitch — The number of context switches per second over the monitoring interval

Syscalls — The total number of system calls per second executed over the monitoring interval

Reads — The number of read system calls per second executed over the monitoring interval

Writes — The number of write system calls per second executed over the monitoring interval

Forks — The number of fork system calls per second executed over the monitoring interval

Execs — The number of exec system calls per second executed over the monitoring interval

Runqueue — The average number of threads that were ready to run but were waiting for a processor to become available

Waitqueue — The average number of threads that were waiting for paging to complete

FILE/TTY

Displays the per-second frequency of selected file and tty statistics.

Readch	The number of bytes read per second through the read system call over the monitoring interval
Writech	The number of bytes written per second through the write system call over the monitoring interval
Rawin	The number of raw bytes read per second from TTYs over the monitoring interval
Ttyout	The number of bytes written to TTYs per second over the monitoring interval
Igets	The number of calls per second to the inode lookup routines over the monitoring interval
Namei	The number of calls per second to the pathname lookup routines over the monitoring interval
Dirblk	The number of directory blocks scanned per second by the directory search routine over the monitoring interval

PAGING

Displays the per-second frequency of paging statistics.

Faults	Total number of page faults taken per second over the monitoring interval. This includes page faults that do not cause paging activity.
Steals	Physical memory 4K frames stolen per second by the virtual memory manager over the monitoring interval.
PgspIn	Number of 4K pages read from paging space per second over the monitoring interval.
PgspOut	Number of 4K pages written to paging space per second over the monitoring interval.
PageIn	Number of 4K pages read per second over the monitoring interval. This includes paging activity associated with reading from file systems. By subtracting PgspIn from this value, you get the number of 4K pages read from file systems per second over the monitoring interval.
PageOut	Number of 4K pages written per second over the monitoring interval. This includes paging activity associated with writing to file systems. By subtracting PgspOut from this value, you get the number of 4K pages written to file systems per second over the monitoring interval.

Sios — The number of I/O requests per second issued by the virtual memory manager over the monitoring interval.

MEMORY

Displays the real memory size and the distribution of memory in use.

Real,MB	The size of real memory in megabytes.
% Comp	The percentage of real memory currently allocated to computational page frames. Computational page frames are generally those that are backed by paging space.
% Noncomp	The percentage of real memory currently allocated to non-computational frames. Non-computational page frames are generally those that are backed by file space, either data files, executable files, or shared library files.
% Client	The percentage of real memory currently allocated to cache remotely mounted files.

PAGING SPACE

Displays size and utilization of paging space.

Size,MB	The sum of all paging spaces on the system, in megabytes
% Used	The percentage of total paging space currently in use
% Free	The percentage of total paging space currently free

NFS

Displays NFS status in calls/second

- Server V2 calls/sec
- Client V2 calls/sec
- Server V3 calls/sec
- Client V3 calls/sec

The variable part of the topas display can have up to five subsections. If more than one appears, they are always shown in the following order:

- CPU
- Network Interfaces
- Physical Disks
- WorkLoad Management Classes

- Processes

CPU utilization

By default, this display shows a bar chart with cumulative CPU usage. If more than one CPU is displayed, a list of CPUs are displayed followed by the cumulative totals across all CPUs on the system, not just what is displayed.

User	This shows the percent of CPU used by programs executing in user mode. (Default sorted by User%)
Kern	This shows the percent of CPU used by programs executing in kernel mode.
Wait	This shows the percent of time spent waiting for I/O.
Idle	This shows the percent of time the CPU(s) is idle.

Network Interfaces

Lists the selected number of network interfaces. The interfaces are ordered after the activity over the monitoring interval. The interface that transferred most bytes (sum of bytes read and written) over the interval is listed first. Sorting is only valid for up to 16 network adapters. For each network interface, the following fields are displayed:

Network	The name of the network interface.
KBPS	The total throughput in megabytes per second over the monitoring interval. This field is the sum of kilobytes received and kilobytes sent per second.
I-Pack	The number of data packets received per second over the monitoring interval.
O-Pack	The number of data packets sent per second over the monitoring interval.
KB-In	The number of kilobytes received per second over the monitoring interval.
KB-Out	The number of kilobytes sent per second over the monitoring interval.

Physical disks

Lists the selected number of physical disks. The disks are ordered after the activity over the monitoring interval. The interface that was most busy over the interval is listed first. Sorting is only valid for up to 128 disks. For each disk, the following fields are displayed:

Disk	The name of the physical disk.
Busy%	Indicates the percentage of time the physical disk was active (bandwidth utilization for the drive).
KBPS	The number of kilobytes read and written per second over the monitoring interval. This field is the sum of KB-Read and KB-Read.
TPS	The number of transfers per second that were issued to the physical disk. A transfer is an I/O request to the physical disk. Multiple logical requests can be combined into a single I/O request to the disk. A transfer is of indeterminate size.
KB-Read	The number of kilobytes read per second from the physical disk.
KB-Writ	The number of kilobytes written per second to the physical disk.

WLM Classes

Workload Management Classes displays the top n WLM Classes by default sorted by CPU%.

WLM-Class	The name of the class. The mode in which WLM is running (active) or (passive) is shown
CPU%	The average CPU utilization of the WLM class over the monitoring interval
Mem%	The average memory utilization of the WLM class over the monitoring interval
Disk-I/O%	The average percent of disk I/O of the WLM class over the monitoring interval

Processes

Lists the selected number of processes or as many as will fit on the display. The processes are ordered after their CPU usage over the monitoring interval. The process that consumed the most CPU over the interval is listed first. For each process, the following fields are displayed:

Name	The name of the executable program executing in the process. The name is stripped of any pathname and argument information and truncated to nine characters in length.

PID	The process ID of the process.
CPU%	The average CPU utilization of the process over the monitoring interval. The first time a process is shown, this value is the average CPU utilization over the lifetime of the process.
PgSp	The size of the paging space allocated to this process. This can be considered an expression of the footprint of the process but does not include the memory used to keep the executable program and any shared libraries on which it may depend.
Owner	The name of the user that owns the process (only when WLM section is off).
Class	The WLM class to which the process belongs (only when WLM section is on).

Examples

To run the program with default options, type:

```
topas
```

The result is shown in Figure 44 on page 113.

```
Topas Monitor for host:    mothra              EVENTS/QUEUES    FILE/TTY
Wed Sep  6 11:51:11 2000   Interval:  2        Cswitch      21  Readch        0
                                               Syscall      25  Writech      50
Kernel    0.0  |                            |  Reads         0  Rawin         0
User      0.2  |                            |  Writes        0  Ttyout        0
Wait      0.0  |                            |  Forks         0  Igets         0
Idle     99.7  |############################|  Execs         0  Namei         0
                                               Runqueue    0.0  Dirblk        0
Network  KBPS   I-Pack  O-Pack   KB-In  KB-Out Waitqueue   1.0
tr0       0.0      0.9     0.4     0.0     0.0
lo0       0.0      0.0     0.0     0.0     0.0 PAGING           MEMORY
                                               Faults        0  Real,MB     511
Disk    Busy%     KBPS     TPS KB-Read KB-Writ Steals        0  % Comp     15.0
hdisk0    0.0      0.0     0.0     0.0     0.0 PgspIn        0  % Noncomp   5.0
                                               PgspOut       0  % Client    0.0
WLM-Class (Active)     CPU%    Mem%  Disk-I/O% PageIn        0
Unmanaged                 0       7          0 PageOut       0  PAGING SPACE
Unclassified              0       8          0 Sios          0  Size,MB       0
                                                                % Used      0.9
Name          PID CPU% PgSp Class              NFS (calls/sec)  % Free     99.0
topas       11902  0.2  0.8 System             ServerV2      0
syncd        2706  0.0  0.1 System             ClientV2      0    Press:
gil          1806  0.0  0.0 System             ServerV3      0    "h" for help
init            1  0.0  0.8 System             ClientV3      0    "q" to quit
snmpd        5942  0.0  0.7 System
```

Figure 44. topas - example 1

To display five hot disks every five seconds and omit network interface and process information, type:

```
topas -i5 -d5 -n0 -p0
```

The result is shown in Figure 45 on page 114.

```
Topas Monitor for host:    itsosrv1           EVENTS/QUEUES    FILE/TTY
Thu Sep  7 12:29:38 2000   Interval:  5       Cswitch      24  Readch      422
                                              Syscall      29  Writech       9
Kernel    0.0   |                           | Reads         5  Rawin         0
User      0.0   |                           | Writes        0  Ttyout        0
Wait      0.0   |                           | Forks         0  Igets         0
Idle     99.9   |###########################| Execs         0  Namei         1
                                              Runqueue    0.0  Dirblk        0
Disk    Busy%     KBPS     TPS KB-Read KB-Writ Waitqueue   2.0
hdisk2    0.0      0.0     0.0     0.0     0.0
hdisk0    0.0      0.0     0.0     0.0     0.0 PAGING           MEMORY
hdisk3    0.0      0.0     0.0     0.0     0.0 Faults        0  Real,MB    1023
hdisk6    0.0      0.0     0.0     0.0     0.0 Steals        0  % Comp     10.0
hdisk1    0.0      0.0     0.0     0.0     0.0 PgspIn        0  % Noncomp   3.0
                                              PgspOut       0  % Client    0.0
WLM-Class (Active)     CPU%    Mem%  Disk-I/O% PageIn        0
Unclassified              0       0          0 PageOut       0  PAGING SPACE
Unmanaged                 0       0          0 Sios          0  Size,MB       0
                                                                % Used      0.6
                                              NFS (calls/sec)  % Free     99.3
                                              ServerV2       0
                                              ClientV2       0   Press:
                                              ServerV3       0   "h" for help
                                              ClientV3       0   "q" to quit
```

Figure 45. topas - example 2

To display the five most active processes and neither network nor disk information, type:

```
topas -p5 -n0 -d0
```

The result is shown in Figure 46 on page 115.

```
Topas Monitor for host:    mothra              EVENTS/QUEUES    FILE/TTY
Wed Sep  6 11:57:27 2000   Interval:  2        Cswitch      25  Readch       0
                                               Syscall     107  Writech   1925
Kernel    0.2  |                            |  Reads         0  Rawin        0
User      0.0  |                            |  Writes       30  Ttyout       0
Wait      0.0  |                            |  Forks         0  Igets        0
Idle     99.7  |############################|  Execs         0  Namei        8
                                               Runqueue    0.0  Dirblk       0
WLM-Class (Active)     CPU%    Mem%  Disk-I/O% Waitqueue   1.0
Unmanaged                 0       7         0
Unclassified              0       8         0  PAGING           MEMORY
                                               Faults        0  Real,MB    511
Name         PID CPU% PgSp Class               Steals        0  % Comp    15.0
topas      11904  0.3  0.8 System              PgspIn        0  % Noncomp  5.0
gil         1806  0.0  0.0 System              PgspOut       0  % Client   0.0
syncd       2706  0.0  0.1 System              PageIn        0
ksh        12144  0.0  0.2 System              PageOut       0  PAGING SPACE
telnetd    12448  0.0  0.5 System              Sios          0  Size,MB      0
                                                                % Used     0.9
                                               NFS (calls/sec)  % Free    99.0
                                               ServerV2       0
                                               ClientV2       0   Press:
                                               ServerV3       0   "h" for help
                                               ClientV3       0   "q" to quit
```

Figure 46. topas - example 3

To see detailed information about the defined WLM classes running on the system, use the subcommand, W, when topas is running as shown in Figure 47 on page 116.

```
Topas Monitor for host:    mothra      Interval:   2    Wed Sep  6 11:55:21 2000
WLM-Class (Active)              CPU%      Mem%     Disk-I/O%
System                            0         4           0
Shared                            0         2           0
Default                           0         0           0
Unmanaged                         0         7           0
Unclassified                      0         8           0


▯

==============================================================================
                             DATA  TEXT  PAGE               PGFAULTS
USER       PID  PPID PRI NI   RES   RES SPACE    TIME CPU%  I/O  OTH COMMAND
root     11902 12144 108 20   250    12   230    0:03  0.5    0    0 topas
root      1032     0  16 41     3  3775     3    0:00  0.0    0    0 lrud
root      1290     0  60 41     4  3775     4    0:00  0.0    0    0 xmgc
root      1548     0  36 41     4  3775     4    0:00  0.0    0    0 netm
root      1806     0  37 41    16  3775    16    0:02  0.0    0    0 gil
root      2064     0  16 41     4  3775     4    0:00  0.0    0    0 wlmsched
root      2706     1 108 20    42     1    37    0:01  0.0    0    0 syncd
root      3196  5680 108 20   210    11   202    0:00  0.0    0    0 portmap
root      3362     0 108 20     4  3775     4    0:00  0.0    0    0 lvmbb
root      3666     1 108 20   134    23   124    0:00  0.0    0    0 errdemon
root      3910  5680 108 20    96     8    87    0:00  0.0    0    0 syslogd
```

Figure 47. topas - example 4

4.4 svmon

This tool generates snapshots of a system's virtual memory. It has been enhanced with usability, scalability, and speed improvements on the largest enterprise server systems. In addition, the `svmon` tool was enhanced to generate reports on users, commands, and WLM classes to support WLM functions.

The `svmon` command requires the perfagent.tools fileset to be installed on the system.

The `svmon` command displays information about the current state of memory. The displayed information does not constitute a true snapshot of memory because the `svmon` command runs at the user level with interrupts enabled. The segment is the basic object used to report memory consumption. A segment is a set of pages; so, the statistics reported by `svmon` are expressed in terms of pages. A page is a 4K block of virtual memory while a frame is a 4K block of real memory. Unless otherwise noted, all statistics are in units of 4096-bytes of memory pages.

The memory consumption is reported using the inuse, free, pin, virtual and paging space counters. The inuse counter represents the number of used frames. The free counter represents the number of free frames from all memory pools. The pin counter represents the number of pinned frames, that is frames that cannot be swapped. The virtual counter represents the number of pages allocated in the system virtual space. The paging space counter represents the number of pages reserved or used on paging spaces.

A segment can be used by multiple processes. Each page from such a segment is accounted for in the inuse, pin, virtual, or pgspace fields for each process that uses the segment. Therefore, the total of the inuse, pin, virtual, and pgspace fields over all active processes may exceed the total number of pages in memory or on paging space.

VMM manages virtual page counters for statistical purpose only, which means they are not always up-to-date, and their values may be less than the corresponding inuse counters.

A segment belongs to one of the five following types: persistent, working, client, mapping, or real memory mapping. Persistent segments are used to manipulate files and directories. Working segments are used to implement the data areas of processes and shared memory segments. Client segments are used to implement some virtual file systems, such as the Network File System (NFS) and the CD-ROM file system. Mapping segments are used to implement the mapping of files in memory. Real memory mapping segments are used to access the I/O space from the virtual address space.

The `svmon` command can create nine types of reports:

- Global
- User
- Command
- Class
- Tier
- Process
- Segment
- Detailed segment

- Frame

This book focus on describing only the workload management reports, *class* and *tier*. These reports are available when the workload manager is running. Otherwise, the message, "WLM must be started", is displayed, and no statistics are reported. When the workload manager is running in passive mode, `svmon` will display the message, "WLM is running in passive mode", before displaying the statistics.

Note

WLM provides dynamic reclassification of processes and their segments. At each iteration, svmon uses a snapshot of the class configuration by using the wlm_get_info system call and accesses the related processes and segments. The segstat_tbl, process_tbl and wlm_tbl are freed at the end of each iteration. Consequently, svmon is able to see the changes. Also, if a class disappears, svmon reports a message without any error.

Problems may appear when a segment or process is loaded in the svmon private data base with a given class ID associated to a given classname and the class ID or the classname changes before the real analysis of the segment or process. Then svmon can report wrong statistics.

4.4.1 Workload manager class report

There are two types of classes: *superclasses* and *subclasses*. Superclass names are up to 16 characters long and cannot contain a period. Subclass names start with their superclass name followed by a period and subclass part, which can be up to 16 characters long and cannot contain a period. The total number of superclasses that can be defined is limited to 27. The total number of subclasses that can be defined for a superclass is 10.

Superclasses and subclasses will be treated identically. When a superclass is passed as an argument, `svmon` reports all the segments belonging to all the subclasses of the superclass without giving subclass statistics.

The class report is printed when `-W` is specified.

Syntax:

```
svmon -W [clnm1...clnmN] [-e] [-k] [-r] [-n | -s] [-w | -f | -c][-tCount]
[-u | -p | -g | -v] [-iInterval [NumIntervals]] [-l] [-d] [-z] [-m]
```

The following flags can be specified:

`-e`	Shows the statistics of the subclasses of the class and reports the segments statistics per subclass. In this case, the class parameter must be a superclass name.
`-k`	When `-k` is specified, `svmon` reports statistics using a process point of view. There will be no change to this option except when `-e` is specified. Then, the segments of each subclass will be split into three categories: System, exclusive, and shared.
`-r`	If the `-r` flag is specified, each segment is followed by the range(s), within the segment, where pages have been allocated.
`-n`	Indicates that only non-system segments are to be included in the statistics. By default, all segments are analyzed.
`-s`	Indicates that only system segments are to be included in the statistics. By default, all segments are analyzed.
`-w`	Indicates that only working segments are to be included in the statistics. By default, all segments are analyzed.
`-f`	Indicates that only persistent segments (files) are to be included in the statistics. By default, all segments are analyzed.
`-c`	Indicates that only client segments are to be included in the statistics. By default, all segments are analyzed.
`-tCount`	Displays memory usage statistics for the top Count object to be printed.
`-u`	Indicates that the objects to be printed are sorted in decreasing order by the total number of pages in real memory. It is the default sorting criteria if none of the following flags are present: `-p`, `-g`, or `-v`.
`-p`	Indicates that the objects to be printed are sorted in decreasing order by the total number of pages pinned.
`-g`	Indicates that the objects to be printed are sorted in decreasing order by the total number of pages reserved or used on paging space. This flag, in conjunction with the segment, report shifts the non-working segment at the end of the sorted list.
`-v`	Indicates that the objects to be printed are sorted in decreasing order by the total number of pages in virtual

space. This flag, in conjunction with the segment report, shifts the non-working segment at the end of the sorted list.

`-iInterval [NumInterval]`	Instructs the `svmon` command to print statistics out repeatedly. Statistics are collected and printed every Interval seconds. NumIntervals is the number of repetitions; if not specified, svmon runs until user interruption (Ctrl-C).
`-l`	Shows, for each displayed segment, the list of process identifiers that use the segment and, according to the type of report, the entity name (login, command, or class) to which the process belongs. For special segments, a label is displayed instead of the list of process identifiers. *System segment:* This label is displayed for segments that are flagged *system*. *Unused segment:* This label is displayed for segments that are not used by any existing processes. *Shared library text:* This label is displayed for segments that contain text of shared library and that may be used by most of the processes (libc.a). This is to prevent the display of a long list of processes.
`-d`	Displays for a given entity, the memory statistics of the processes belonging to the entity.
`-z`	Displays the maximum memory size dynamically allocated (malloc) by svmon during its execution.
`-m`	Displays information about source segment rather than a mapping segment when a segment is mapping a source segment.

The column headings in a class report are:

Class or Superclass	Indicates the class or superclass name.
Inuse	Indicates the total number of pages in real memory from segments belonging to the class
Pin	Indicates the total number of pages pinned from segments belonging to the class

Pgsp Indicates the total number of pages reserved or used on paging space by segments belonging to the class

Virtual Indicates the total number of pages allocated in the virtual space of the class

After these statistics are displayed, `svmon` displays information about the segments belonging to the class.

Examples:
To print out the memory usage statistics for the superclass, *backup*, enter the information shown in the following screen:

```
((0)itsosrv1:/# svmon -W backup

===============================================================================
Superclass                          Inuse     Pin      Pgsp  Virtual
backup                              52833      10         0    50329

    Vsid      Esid Type Description                 Inuse    Pin Pgsp Virtual
    6784         - work                             27989      0    0 28017
   1aa18         - work                             21887      0    0 21887
   14356         - pers /dev/lv_wlm1:17              1250      0    -     -
   173f5         - pers /dev/lv_wlm2:17              1250      0    -     -
    5347         - work                               103      2    0   101
    c34e         - work                                77      0    0    77
   1891a         - work                                77      0    0    77
   14636         - work                                46      0    0    37
    5327         - work                                28      0    0    20
   1d83f         - work                                16      0    0    18
   1e33c         - work                                16      0    0    13
   10772         - work                                15      0    0    13
    6a84         - work                                15      0    0    13
   15457         - work                                14      0    0    14
    38a1         - work                                 8      0    0     8
   126f0         - work                                 8      0    0     8
   11313         - pers /dev/hd1:26                     6      0    -     -
    e50c         - work                                 5      2    0     5
    b549         - work                                 5      2    0     5
    12e3         - work                                 3      2    0     3
   13351         - work                                 3      0    0     3
   14a16         - work                                 3      0    0     0
   12970         - work                                 3      0    0     5
    6904         - work                                 2      2    0     2
    a9c8         - work                                 1      0    0     3
    2320         - pers /dev/hd1:32                     1      0    -     -
   1d39f         - pers /dev/hd2:16870                  1      0    -     -
    834a         - pers /dev/hd1:23                     1      0    -     -
```

To print out the memory usage statistics for the subclass, *spray*, enter the information shown in the following screen.

```
(0)itsosrv1:/# svmon -W oltp.spray

===============================================================================
Class                                Inuse  Pin   Pgsp  Virtual
oltp.spray                             852   20      0      944

    Vsid     Esid Type Description                 Inuse   Pin Pgsp   Virtual
    d96f        - work                                77     2    0    77
    c6ae        - work                                76     2    0    76
    da0f        - work                                76     2    0    76
    98eb        - work                                75     2    0    75
    d5cf        - work                                75     2    0    75
   12350        - work                                75     2    0    75
   1da1f        - work                                75     2    0    75
    e9ac        - work                                34     0    0    22
   1f9bd        - work                                34     0    0    22
    4786        - work                                34     0    0    22
   147d6        - work                                33     0    0    22
    23c0        - work                                33     0    0    22
   13771        - work                                33     0    0    22
     5e2        - work                                33     0    0    22
    44c6        - work                                29     0    0    21
    862a        - work                                20     2    0    80
    e9cc        - work                                20     2    0    80
    d8af        - work                                20     2    0    80=
```

To print out the memory usage for the superclass, *oltp*, with its subclasses, enter the information shown in the following screen.

```
(0)itsosrv1:/# svmon -W oltp -e

===============================================================================
Superclass                           Inuse      Pin      Pgsp  Virtual
oltp                                 35941       26         0    35934

===============================================================================
Class                                Inuse      Pin      Pgsp  Virtual
oltp.Default                         35895       24         0    35899

    Vsid      Esid Type Description                 Inuse   Pin Pgsp Virtual
    a4c8         - work                             33198     0    0 33206
   17995         - work                              1493     0    0  1533
    33e1         - work                               194     0    0   195
     782         - work                               189     0    0   189
    92eb         - work                               103     2    0   101
   1d81f         - work                                88     0    0    88
   1e99c         - work                                84     0    0    84
    e6ec         - work                                74     0    0    74
   10712         - work                                57     0    0    48
    c2ee         - work                                53     0    0    53
    e2ec         - work                                28     0    0    20
    98ab         - work                                22     0    0    22
    3541         - work                                18     0    0    20
   126b0         - work                                17     0    0    17
   152f7         - work                                13     0    0    11
    c38e         - work                                 8     0    0     8
    72e5         - pers /dev/hd1:25                     6     0    -     -
    e58c         - work                                 4     2    0     4
   1971b         - work                                 3     0    0     0
    b8a9         - work                                 2     2    0     2
    b2e9         - pers /dev/hd1:19                     1     0    -     -
    f2ed         - pers /dev/hd1:28                     1     0    -     -
   1e4bc         - work                                 1     0    0     3

===============================================================================
Class                                Inuse      Pin      Pgsp  Virtual
oltp.spray                              46        2         0       35

    Vsid      Esid Type Description                  Inuse   Pin Pgsp Virtual
    848a         - work                                 76     2    0    76
   1d8bf         - work                                 58     2    0    58
   1d75f         - work                                 33     0    0    22
   1d85f         - work                                 29     0    0    21
   17535         - work                                 20     2    0    80
    d7ef         - work                                 20     2    0    80
   157b7         - work                                 16     0    0    11

===============================================================================
Class                                Inuse      Pin      Pgsp  Virtual
oltp.Shared                              0        0         0        0
```

To print out statistics using a process of view for each subclass of the superclass oltp, enter:

```
(0)itsosrv1:/# svmon -W oltp -e -k

===============================================================================
Superclass                             Inuse      Pin     Pgsp  Virtual
oltp                                   21432     3670     1584    23238

===============================================================================
Class                                  Inuse      Pin     Pgsp  Virtual
oltp.Default                           16340     1929      792    17146
...............................................................................
SYSTEM segments                        Inuse      Pin     Pgsp  Virtual
                                        4209     1759      792     3151

    Vsid     Esid Type Description              Inuse   Pin  Pgsp Virtual
       0        0 work kernel seg                3939  1735   792  2881
    62e4        - work                            270    24     0   270
...............................................................................
EXCLUSIVE segments                     Inuse      Pin     Pgsp  Virtual
                                       11108      170        0    10914

    Vsid     Esid Type Description                Inuse   Pin Pgsp Virtual
   135f1        3 work shmat/mmap                     9     0    0     9
     902        2 work process private                4     2    0     4
    eaec        f work shared library data            1     0    0     1
...............................................................................
SHARED segments                        Inuse      Pin     Pgsp  Virtual
                                        1010        0        0     3070

    Vsid     Esid Type Description                Inuse   Pin Pgsp Virtual
   16834        f work shared library data           29     0    0    21
   14094        - pers /dev/hd2:16981                 2     0    -     -
===============================================================================
Class                                  Inuse      Pin     Pgsp  Virtual
oltp.spray                              5092     1741      792     6092
...............................................................................
SYSTEM segments                        Inuse      Pin     Pgsp  Virtual
                                        3939     1735      792     2881

    Vsid     Esid Type Description                Inuse   Pin Pgsp Virtual
       0        0 work kernel seg                  3939  1735  792  2881
...............................................................................
EXCLUSIVE segments                     Inuse      Pin     Pgsp  Virtual
                                         167        4        0      156

    Vsid     Esid Type Description                Inuse   Pin Pgsp Virtual
    6724        2 work process private               58     2    0    58
    6904        f work shared library data           33     0    0    22
...............................................................................
SHARED segments                        Inuse      Pin     Pgsp  Virtual
                                         947        0        0     3027

    Vsid     Esid Type Description                Inuse   Pin Pgsp Virtual
    c02c        d work shared library text          869     0    0  3027
    e0ae        1 pers code,/dev/hd2:4205            57     0    -     -
===============================================================================
Class                                  Inuse      Pin     Pgsp  Virtual
oltp.Shared                                0        0        0        0
```

4.4.2 Workload manager tier report

The tier value for a superclass is the position of the class in the hierarchy of resource limitation desirability. The tier value for a subclass is the position of the subclass in the hierarchy of resource limitation desirability.

The tier report is printed when `-T` is specified.

Syntax:

```
svmon -T [tier1...tierN] [-a supclnm] [-x] [-e] [-r] [-u | -p | -g | -v]
[-n | -s] [-w | -f |-c] [-t Count] [-iInterval[NumIntervals]][-l] [-z] [-m]
```

The following flags can be specified:

`-a`	Applies a tier to a superclass.
`-x`	Displays information about the segments belonging to each class.
`-e`	Reports the statistics of the subclasses of each superclass belonging to the tier.
`-r`	If the `-r` flag is specified, each segment is followed by the range(s), within the segment, where pages have been allocated.
`-l`	If the `-l` flag is specified, each segment is followed by the list of process identifiers that are using it. Besides the process identifier, the tier number and class that the process belongs to are also displayed.

Note

`-e` is only allowed with `-T` and `-W`
`-x` is only allowed with `-T`
`-x` is only allowed with `-T`
`-r` or `-l` is only allowed with `-T` if `-x` is specified

The column headings in a tier report are:

Tier	Indicates the tier number.
Superclass	Optional column heading. Indicates the superclass name when tier applies to a superclass (when the `-a` flag is used).
Inuse	Indicates the total number of pages in real memory from segments belonging to the tier.

Pin — Indicates the total number of pages pinned from segments belonging to the tier.

Pgsp — Indicates the total number of pages reserved or used on paging space by segments belonging to the tier.

Virtual — Indicates the total number of pages allocated in the virtual space of the tier.

After these statistics are displayed, `svmon` displays information about the classes belonging to the tier.

Examples:
To print out the memory usage for all defined tiers, enter the information shown in the following screen:

```
(0)itsosrv1:/# svmon -T

===============================================================================
Tier                                       Inuse      Pin     Pgsp  Virtual
   0                                      234012    10687     1498   195497

===============================================================================
Superclass                                 Inuse      Pin     Pgsp  Virtual
backup                                     67746       10        0    65721
dss                                        64771        8        0    64799
oltp                                       42123      182        0    41726
Unclassified                               31181       26        0      126
System                                     26744    10459     1498    19158
Shared                                      1207        0        0     3760
Default                                      240        2        0      207
Unmanaged                                      0        0        0        0
```

To print out the memory usage for the tier 0, enter the information shown in the following screen.

```
(0)itsosrv1:/# svmon -T

===============================================================================
Tier                                 Inuse      Pin     Pgsp  Virtual
   0                                234012    10687     1498   195497

===============================================================================
Superclass                           Inuse      Pin     Pgsp  Virtual
backup                               67746       10        0    65721
dss                                  64771        8        0    64799
oltp                                 42123      182        0    41726
Unclassified                         31181       26        0      126
System                               26744    10459     1498    19158
Shared                                1207        0        0     3760
Default                                240        2        0      207
Unmanaged                                0        0        0        0
```

To print out the memory usage for all tier subclasses of the superclass oltp, enter the following:

```
(0)itsosrv1:/# svmon -T -a oltp

===============================================================================
Tier                                 Inuse      Pin     Pgsp  Virtual
   0 oltp                            35677       18        0    35651

===============================================================================
Class                                Inuse      Pin     Pgsp  Virtual
oltp.Default                         35677       18        0    35651
oltp.Shared                              0        0        0        0

===============================================================================
Tier                                 Inuse      Pin     Pgsp  Virtual
   1 oltp                              524       22        0      656

===============================================================================
Class                                Inuse      Pin     Pgsp  Virtual
oltp.spray                             524       22        0      656
```

To print out the memory usage for the tier 0, including the subclass statistics, enter the information shown in the following screen.

```
(0)itsosrv1:/# svmon -T 0 -e

===============================================================================
Tier                                  Inuse      Pin     Pgsp  Virtual
   0                                 228018    10511     1372   189497

===============================================================================
Superclass                            Inuse      Pin     Pgsp  Virtual
backup                                68169        8        0    65673
dss                                   65995        6        0    66025

===============================================================================
Superclass                            Inuse      Pin     Pgsp  Virtual
oltp                                  34587       20        0    34540

===============================================================================
Class                                 Inuse      Pin     Pgsp  Virtual
oltp.Default                          34587       20        0    34540
oltp.Shared                               0        0        0        0
oltp.spray                                0        0        0        0
Unclassified                          31181       26        0      116
System                                26639    10449     1372    19176
Shared                                 1207        0        0     3760
Default                                 240        2        0      207
Unmanaged                                 0        0        0        0
```

To print out the memory usage for the subclasses in tier 0 of the superclass, *oltp*, including the segment statistics and the list of process identifiers, enter the information shown in the following screen.

```
(0)itsosrv1:/# svmon -T 0 -a oltp -x -l

===============================================================================
Tier                                    Inuse      Pin     Pgsp  Virtual
   0 oltp                               36063       28        0    36010

===============================================================================
Class                                   Inuse      Pin     Pgsp  Virtual
oltp.Default                            36063       28        0    36010

    Vsid     Esid Type Description                  Inuse   Pin Pgsp Virtual
    44c6        f work shared library data             13     0    0     11
                  pid:23798    tier: 1 class:oltp.spray
    f4ad        - work                                 13     0    0     11
                  Unused segment
    e32c        f work shared library data             13     0    0     11
                  pid:36314    tier: 0 class:oltp.Default
     7e2        - work                                 13     0    0     11
                  Unused segment
     402        f work shared library data             13     0    0     11
                  pid:31514    tier: 0 class:oltp.Default
   1f4bd        - work                                 13     0    0     11
                  Unused segment
   13a31        f work shared library data             13     0    0     11
                  pid:29392    tier: 1 class:oltp.spray
   168f4        - work                                 12     0    0     12
                  Unused segment
   152f7        f work shared library data             12     0    0     10
                  pid:18794    tier: 0 class:oltp.Default
   1993b        2 work process private                 11     2    0     11
                  pid:33954    tier: 1 class:oltp.spray
    72e5        1 pers code,/dev/hd1:25                 6     0    -      -
                  pid:37556    tier: 0 class:oltp.Default
                  pid:31514    tier: 0 class:oltp.Default
                  pid:29392    tier: 1 class:oltp.spray
                  pid:23156    tier: 0 class:oltp.Default
                  pid:22092    tier: 1 class:oltp.spray
                  pid:18794    tier: 0 class:oltp.Default
                  pid:18496    tier: 1 class:oltp.spray
    c2ee        3 work shmat/mmap                       6     0    0      6
    D2ef        2 work process private                  5     2    0      5
                  pid:18794    tier: 0 class:oltp.Default
   15837        2 work process private                  4     2    0      4
                  pid:31514    tier: 0 class:oltp.Default
    ea8c        - work                                  4     0    0      4
                  Unused segment
   16754        - work                                  4     0    0      4
                  Unused segment
   178d5        2 work process private                  4     2    0      4
                  pid:29392    tier: 1 class:oltp.spray
    9aeb        2 work process private                  4     2    0      4
                  pid:37556    tier: 0 class:oltp.Default

===============================================================================
Class                                   Inuse      Pin     Pgsp  Virtual
oltp.Shared                                 0        0        0        0
```

4.5 Web-based System Manager (WSM)

Apart from being a graphical user interface to configure WLM, Web-based System Manager (WSM) provides some monitoring tools to analyze and manipulate resource usage on a per-resource and per-class basis and view the allocation of processes to classes. WSM filesets are shipped with the Base Operating System, and the tool is launched with the AIX command, `wsm`.

The resource-based monitoring screens are accessible under the *Resources* view. When WLM is started, this option displays a view of the managed resources in the current configuration, and their current resource usage as shown in Figure 48.

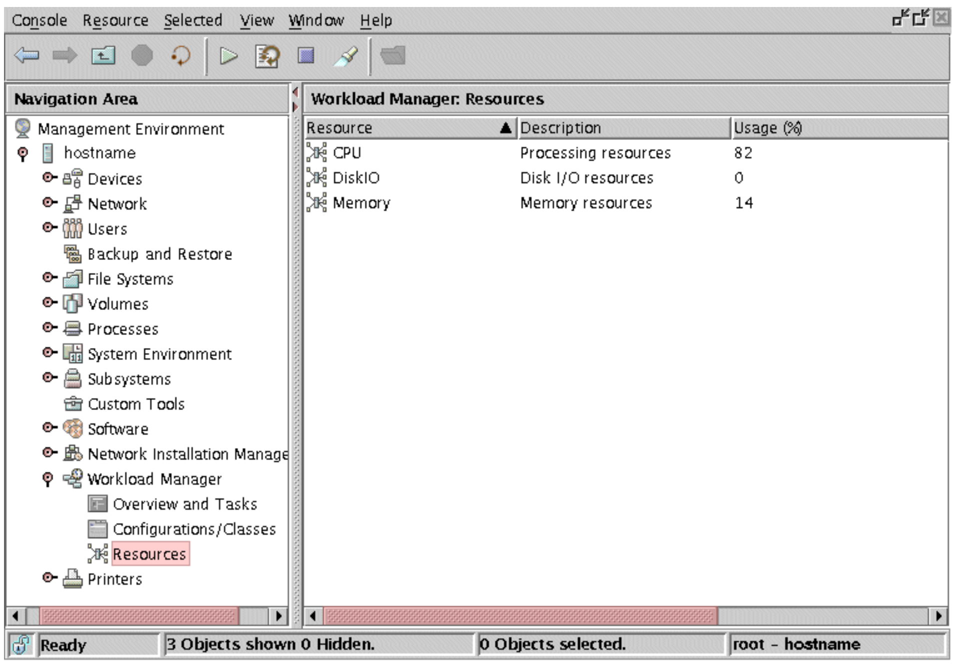
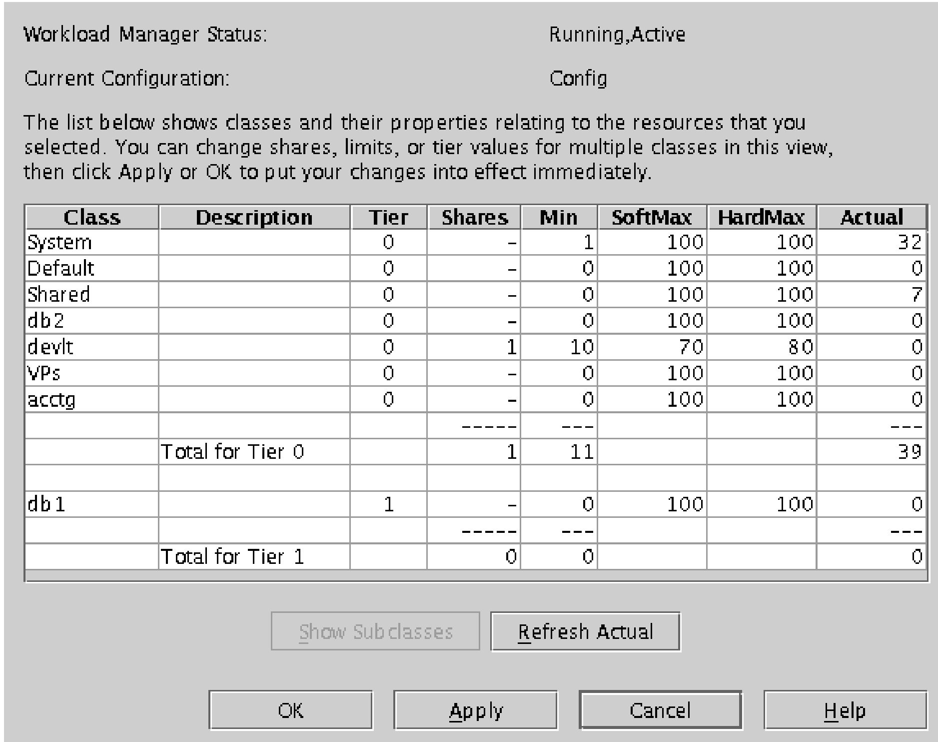


Figure 48. Resources screen in WSM

By double clicking any of the resources, its utilization on a per class basis is displayed. For instance, a sample output of memory usage by class could be the one shown in Figure 49 on page 131.



Workload Manager Status: Running,Active

Current Configuration: Config

The list below shows classes and their properties relating to the resources that you selected. You can change shares, limits, or tier values for multiple classes in this view, then click Apply or OK to put your changes into effect immediately.

Class	Description	Tier	Shares	Min	SoftMax	HardMax	Actual
System		0	-	1	100	100	32
Default		0	-	0	100	100	0
Shared		0	-	0	100	100	7
db2		0	-	0	100	100	0
devlt		0	1	10	70	80	0
VPs		0	-	0	100	100	0
acctg		0	-	0	100	100	0
			-----	---			---
	Total for Tier 0		1	11			39
db1		1	-	0	100	100	0
			-----	---			---
	Total for Tier 1		0	0			0

Figure 49. Memory usage by class

This screen also allows the system administrator to directly edit and modify the values in the different fields by clicking on the field whose value should be changed. After changing one or more of the values, the administrator clicks on *Apply*, waits a few minutes for the new settings to take effect, then clicks on *Refresh Actual* to see the updated actual usage. If the new usage numbers are not satisfactory, the administrator can repeat the process.

From this screen, the system administrator can also choose to monitor and manipulate resource utilization at the subclass level. For that purpose, the superclass whose subclasses are to be analyzed must be highlighted, and the *Show Subclasses* option must be chosen. The output is similar to that shown in Figure 49.

It is also possible in WSM to observe the processes classification on a per-class basis. In the *Configurations/Classes* view, by right-clicking the name of a class in a configuration tree, you get access to the classes options. One of them is *Show Processes*, which launches a view of the allocated processes to the specified class. An example of the output of this option for a class with the /usr/bin/vi process in it can be seen in Figure 50.

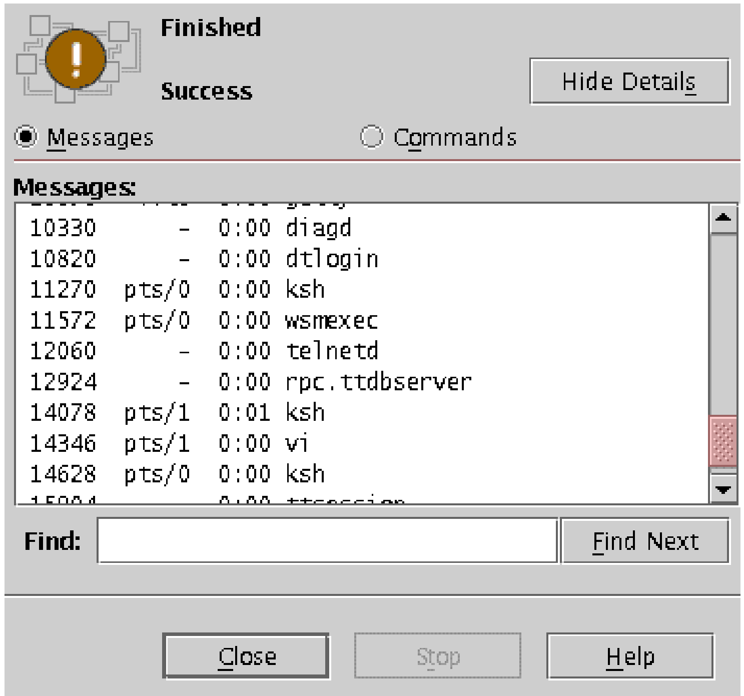


Figure 50. Show processes in WSM

4.6 Monitoring Workload Manager with PTX

Performance Toolbox (PTX) for AIX provides a high-level graphical user interface for monitoring a wide variety of system resources. It can be used to view and analyze AIX WLM information. These interfaces allow the user to monitor the behavior of a WLM configuration, analyze trends, and record activities.

A new parent context name, WLM, is added to the System Performance Measurement Interface (SPMI). In PTX, the SPMI provides access to hundreds of performance metrics. For each WLM class, it includes metrics and associated properties (min, soft max, hard max, target, and actual usage). Any metric available via the SPMI can be processed by the PTX agents, recorded, filtered, and viewed by local or remote PTX clients.

There are no design limitations on the SPMI for two reasons:

- WLM already collects most of the data needed to provide performance monitoring support.
- An API exists to retrieve data.

4.6.1 xmperf

xmperf is the primary Performance Toolbox Manager user interface.

This tool is used for monitoring any metric on local or remote systems. The interface is composed of a set of instruments, with each instrument containing one or more metrics. Instruments can be displayed in a variety of styles (including lines, bars, pie charts, and speedometers). Each set of metrics can be displayed at sampling periods measuring from under 1 second to a half-hour.

The xmperf tool can also record and play back metric values for long-term analysis.

Using xmperf has little impact on system performance because the SPMI utilizes existing system calls to access the WLM information.

Note

Superclass configurations are defined as percentages of total system resources. Subclass attributes, such as shares, min, and max, are defined as percentages of the parent superclass allocations. However, PTX reports all class resource usage as a percentage of the total system resource.

The standard xmperf menus allow users to select the metrics to be displayed. Figure 51 on page 134, Figure 52 on page 135, and Figure 53 on page 136 show the hierarchy of WLM-related metrics.

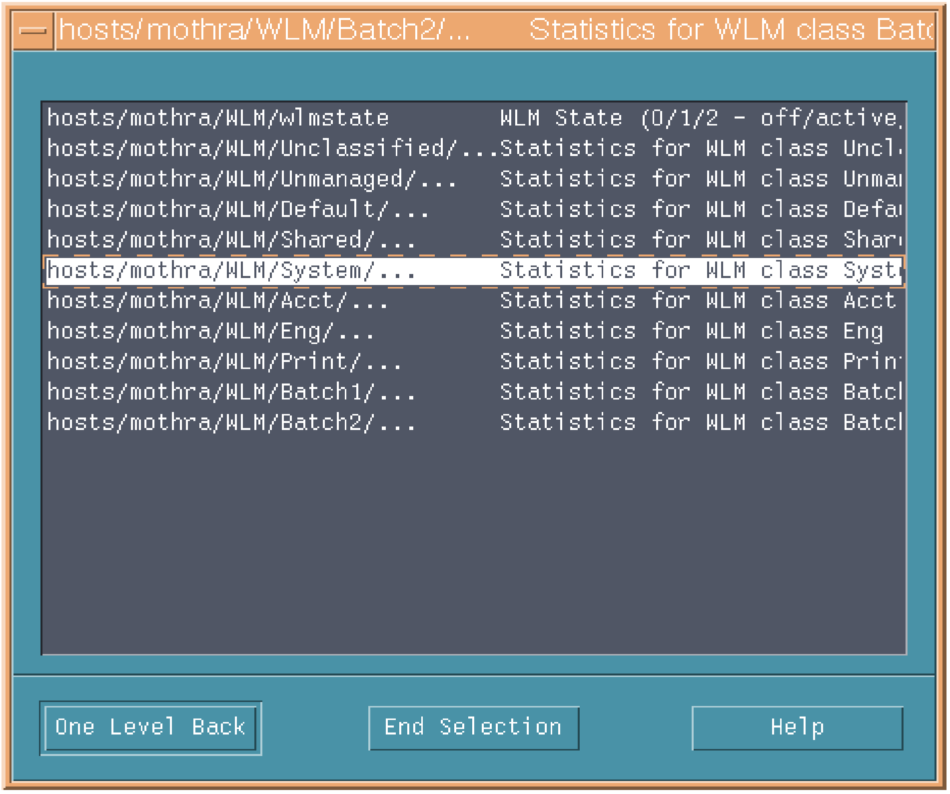


Figure 51. xmperf selection list for available classes

Selecting *Statistics for WLM class System*, takes you to a selection of the resources that are available to the selected class, System, as shown in Figure 52 on page 135.

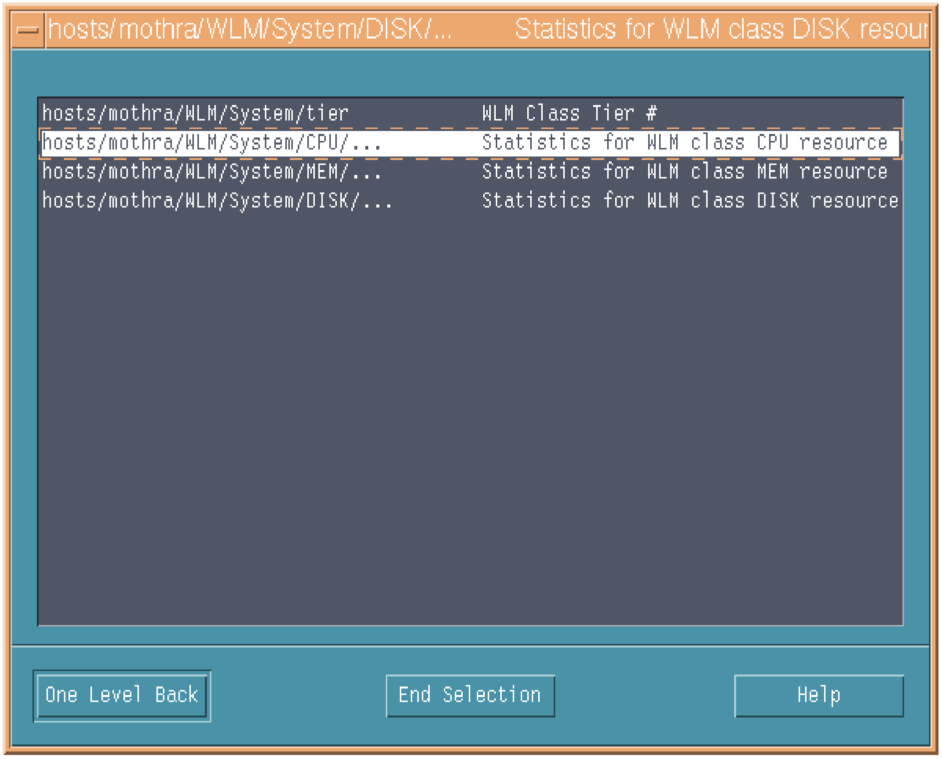


Figure 52. xmperf selection list for the previously selected classes resources

Selecting *Statistics for WLM class CPU resource* takes you to a panel where you can select the resource attributes for the resource CPU for the class, System, as shown in Figure 53 on page 136.

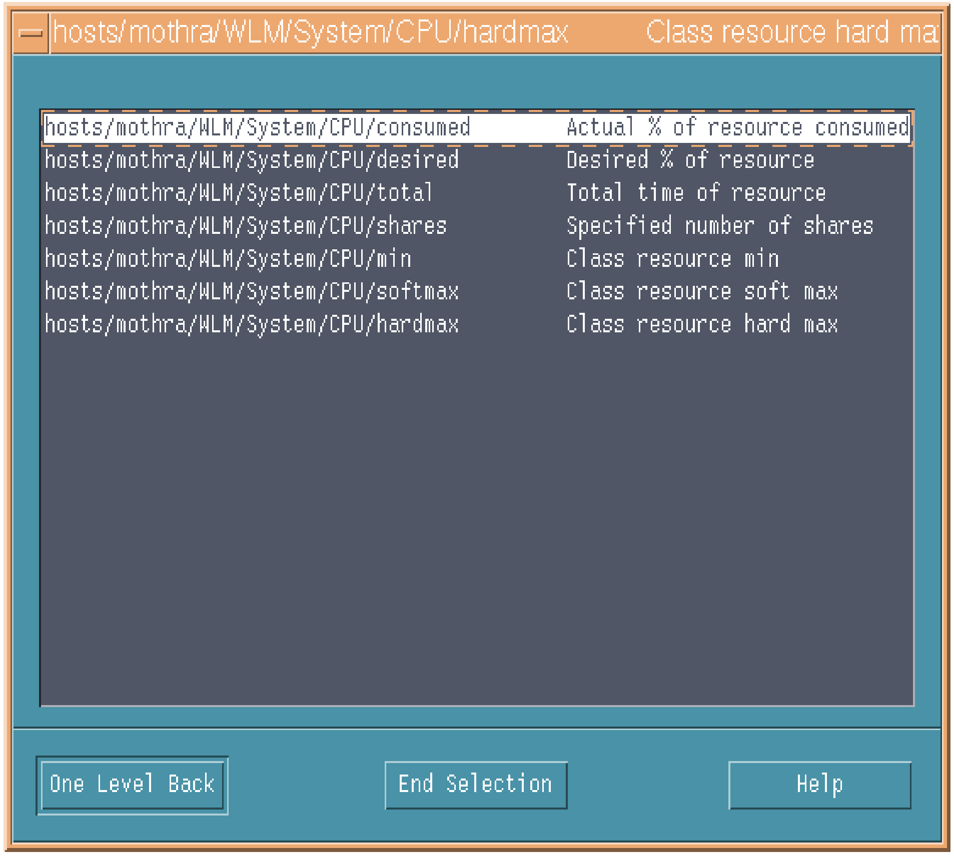


Figure 53. xmperf selection list for the classes resource attributes

These xmperf selections built PTX monitoring consoles.

The following are some examples of typical PTX monitoring consoles. This PTX console, shown in Figure 54 on page 137, displays two instrument windows.

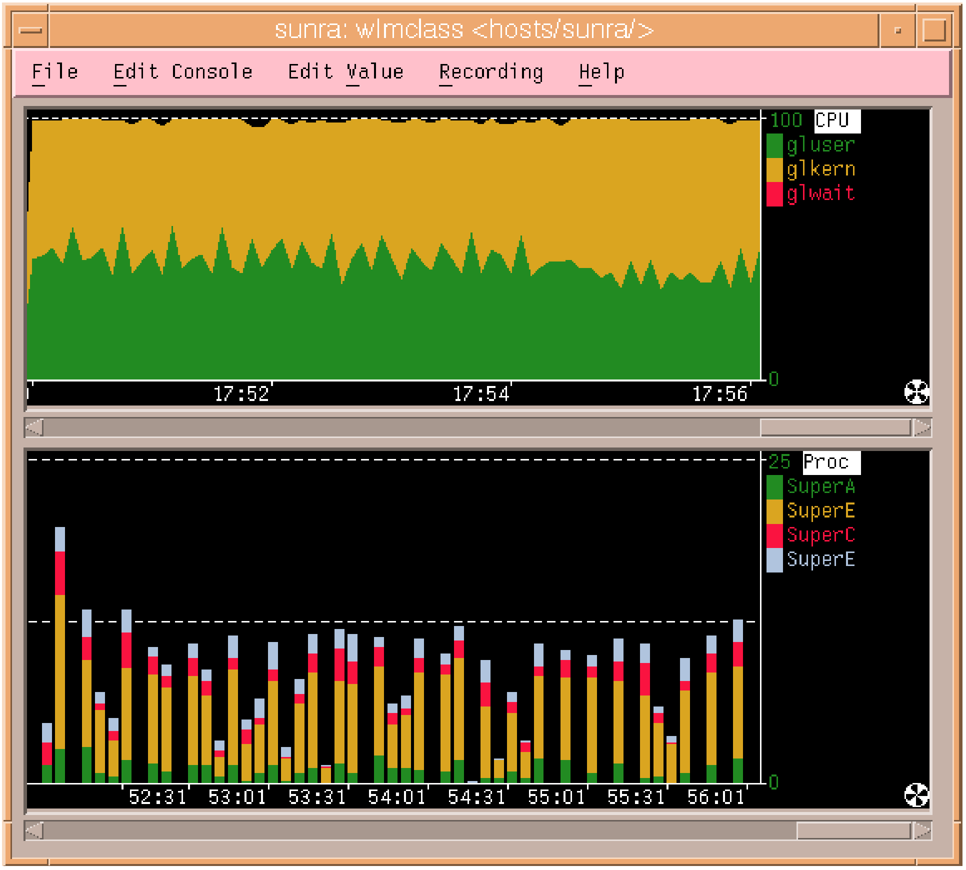


Figure 54. PTX console displaying CPU and class CPU metrics

The top instrument displays the CPU user, kernel, and wait metric values in a stacked area format. Stacked metrics are added together and displayed in separate colors. Here, user and kernel mode are each using about 50 percent of the system.

The lower instrument displays the load of four WLM superclasses on system CPU resource. The classes are stacked on top of each other in bar format. This format shows their relative sizes to each other. For display purposes, the upper scale is adjusted to 25 percent.

Both instruments are recording the data. In the PTX console, displayed in Figure 55 on page 138, the colors are used to associate the real time bars with the associated metric.

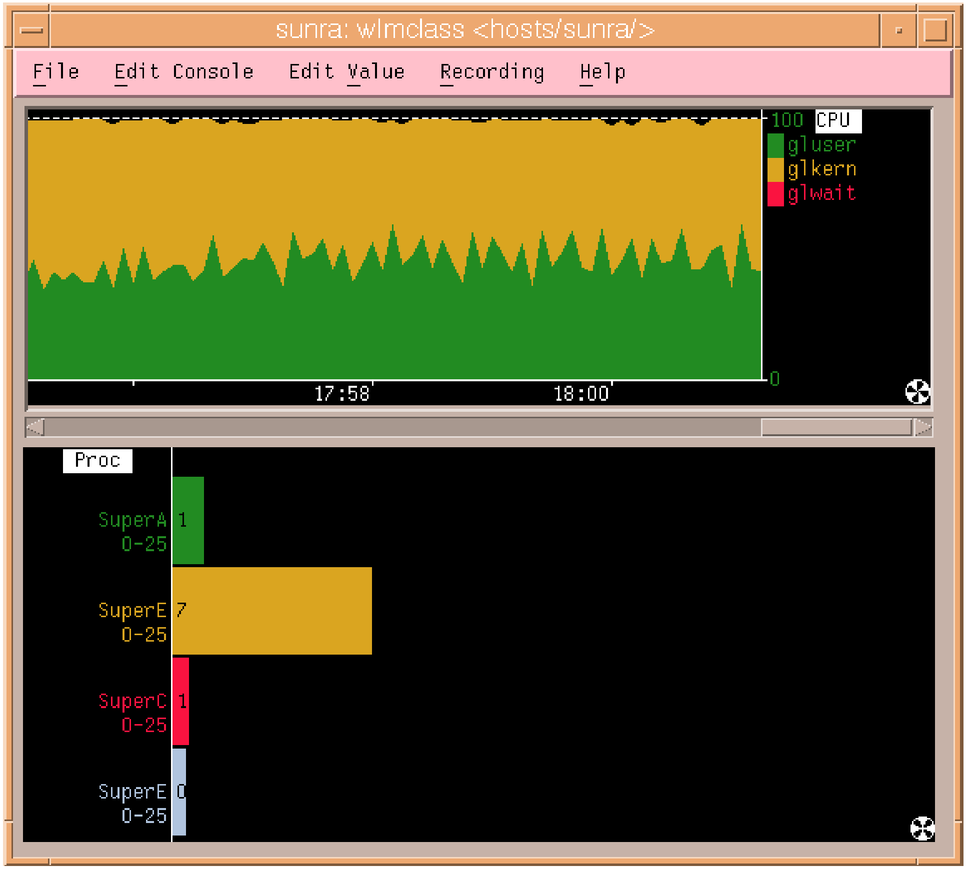


Figure 55. PTX console displaying WLM class metrics in bar format

Here again, the upper scale for the lower instrument is adjusted to 25 percent. The lower instrument of the PTX console, shown in Figure 56 on page 139, shows the WLM class metrics in a pie format.

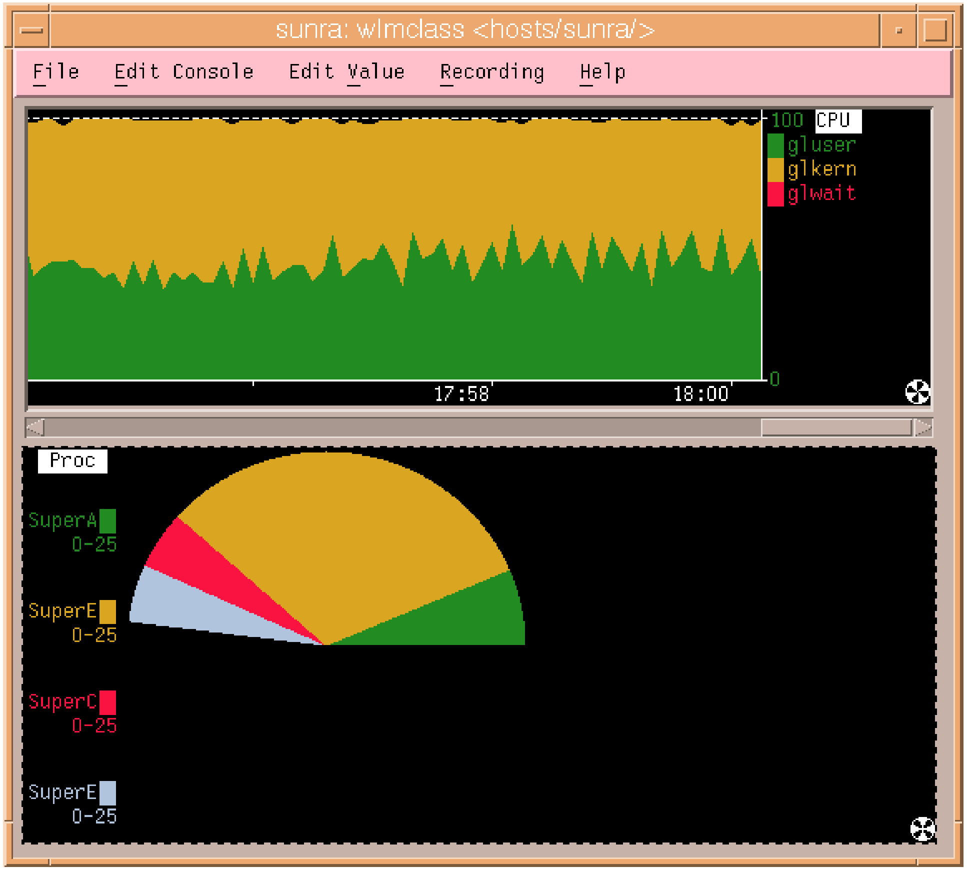


Figure 56. PTX console displaying WLM class metrics in pie format

4.6.2 xmservd

The PTX Performance Aide consists of a set of agents and utilities for collecting, filtering, recording, and reporting performance metrics. The Performance Aide is required for the PTX Manager to view metrics remotely over the network.

The Performance Aides primary agent is known as xmservd. This agent can also record metrics specified in a configuration file. The configuration file specifies the Metric name, start time, stop time, days to record, recording frequency, and other items. Refer to the *AIX Performance Toolbox User's Guide V1 and V2.1*, SC23-2625, for more details on using the Performance Aide to monitor a system. The HTML version of this guide ships with the base AIX media, along with other standard documentation.

Performance Aide recordings can be post-processed by the PTX Azizo and ptxtab tools. The ptxtab tool allows users to convert the recording into a comma- or tab-delimited spreadsheet format that can be imported into third-party spreadsheet applications.

For more information please refer to:

AIX Performance Toolbox User's Guide V1 and V2.1, SC23-2625

4.6.3 Performance Toolbox (PTX) Outlook

The following updates to PTX are planned for the first half of 2001:

- Customer interfaces to WLM for analyzing long-term performance: This update will include interfaces for quick-look, detailed, and tabular formats. Analysis fidelity will be measured in minutes and hours and time periods from different parts of the day, week, or month can be compared to one another.
- wlmmon
  wlmmon: The tool will be shipped in the base AIX operating system as a stand-alone java application. It can be started from Web-based System Manager but will not use the Web-based System Manager framework. Analysis fidelity will be measured in minutes and hours and time periods can be analyzed within 6-24 hours of current time.
- Customer graphical user interface for monitoring real-time WLM activity. Views will be based on the busiest WLM classes, resources, and processes. This capability will be equivalent to a graphical version of the topas tool, and will include recording and playback features.

Chapter 5. Manual assignment

The automatic assignment, used by WLM throughout its whole execution, is based on five attributes to work. These attributes are the process' characteristics used as classification criteria: User name, group name, application pathname, process type, and application tag. Refer to Section 2.5.1, "Automatic assignment" on page 17, for more information on how automatic assignment works. With these attributes as classification criteria, it is practically impossible for WLM to automatically classify two instances of the same application differently. Unless the application itself uses WLM's API routine, wlm_set_tag, to tag all its occurrences differently, all these attributes will, most of the time, be equal throughout all instances of a process. For example, different Oracle database instances in a system are normally launched by the same user (therefore, having the same group), have the same executable, and, of course, are of the same type. If application tagging is not being used, WLM cannot place the database instances in different classes, but, depending on the importance to the business that these instances might have, the system administrator might want to assign the resources throughout these processes differently. That is when manual assignment joins the party.

Manual assignment is a feature introduced in AIX 5L. It allows system administrators and applications to, at any time, override the traditional WLM automatic assignment (processes' automatic classification based on class assignment rules) and force a process to be classified in a specific class. The following sections focus on the description of manual assignment and on some sample scripts that can be used to manually assign different instances of some database products.

5.1 Description

The manual assignment can be made or canceled separately at the superclass level, the subclass level, or both. In order to manually assign processes to a class or cancel an existing manual assignment, a user must have the right level of privilege (that is, they must be the root user or adminuser/admingroup for the superclass or authuser/authgroup for the superclass or subclass). A process can be manually assigned to a superclass only, a subclass only, or to a superclass and a subclass of the superclass. In the latter case, the dual assignment can be done simultaneously (with a single command or API call) or at different times, possibly by different users.

A manual assignment will remain in effect (and a process will remain in its manually-assigned class) until:

- The process terminates.
- WLM is stopped. When WLM is restarted, the manual assignments in effect when WLM was stopped are lost.
- The class the process has been assigned to is deleted.
- A new manual assignment overrides a prior one.
- The manual assignment for the process is canceled.

In order to assign a process to a class or cancel a prior manual assignment, the user must have authority both on the process and on the target class. These constraints translate into the following:

- The root user can assign any process to any class.
- A user with administration privileges on the subclasses of a given superclass (that is, the user or group name matches the attributes, adminuser or admingroup, of the superclass) can manually reassign any process from one of the subclasses of this superclass to another subclass of the superclass.
- An user can manually assign his/her own processes (same real or effective user ID) to a superclass and/or a subclass for which he or she has manual assignment privileges (that is, the user or group name matches the attributes, authuser or authgroup, of the superclass or subclass).

This defines three levels of privilege among the persons who can manually assign processes to classes, root, of course, being the highest. In order for a user to modify or cancel a manual assignment, he or she must be at the same level of privilege as the person who issued the last manual assignment or higher.

5.1.1 First assignment

In this section, the first time assignment is described with a few examples:

The system administrator manually assigns process *P1* from the superclass, *superA*, to the superclass, *superB*. The automatic assignment rules for the subclasses of the superclass, *superB*, will be used by WLM to determine which subclass of the *superB* superclass the process is ultimately assigned to. *P1* will end up, for instance, in the subclass, *superB.subA*, and is flagged as having a *superclass only* assignment.

A user with the right privileges assigns a process, *P2*, from its current class, *superA.subA*, to a new subclass of the same superclass, *superA.subB*. *P2* is assigned to its new subclass and flagged as having a *subclass only* assignment.

The WLM administrator of the subclasses of the superclass *superB*, can decide to manually reassign the process, *P1*, to another subclass of *superB*, for instance, *subC*. *P1* will be reclassified into *superB.subC* and will be now flagged as having *both superclass* and *subclass* level assignment.

5.1.2 Reassignment and cancellation

In this section, the reassignment and assignment cancellation are explained with a few examples:

Suppose that the system administrator thinks that *P2* should really be in a superclass with more resource, and decides to manually assign *P2* above to the superclass, *superC*. Previously, *P2* was manually assigned to the subclass, *subB*, of the superclass, *superA*, with a *subclass only* assignment. Since *P2* is assigned to a different superclass, the previous manual assignment becomes meaningless and is canceled. *P2* now has a *superclass only* manual assignment to the superclass, *superC*, and is assigned to a subclass of *superC* using the automatic assignment rules.

Now, the system administrator decides to terminate the manual assignment from *P1* to the superclass, *superB*, set up earlier. *P1*'s *superclass level* manual assignment is canceled, and *P1* is assigned a superclass using the top level automatic assignment rules:

- If the rules have not changed, *P1* will be assigned to the superclass, *superA* (its original class), and its *subclass level* manual assignment to *superB.subC* above becomes meaningless and is canceled.
- If for some reason the top level rules assign *P1* in superclass *superB*, then the subclass level assignment to *superB.subC* is still valid and remains in effect. *P1* now has a *subclass only* manual assignment.

The reassignment/cancellation of a manual assignment at the subclass level is simpler and just affects the subclass level assignment.

5.1.3 Interaction with inheritance

When a process is manually assigned to a superclass and/or subclass with the inheritance attribute set to *yes*, if the process is a process group leader, WLM will attempt to reclassify all the processes in the process group.

So, the class inheritance attribute has two interpretations, depending on if we are dealing with automatic or manual assignment. See Figure 57.

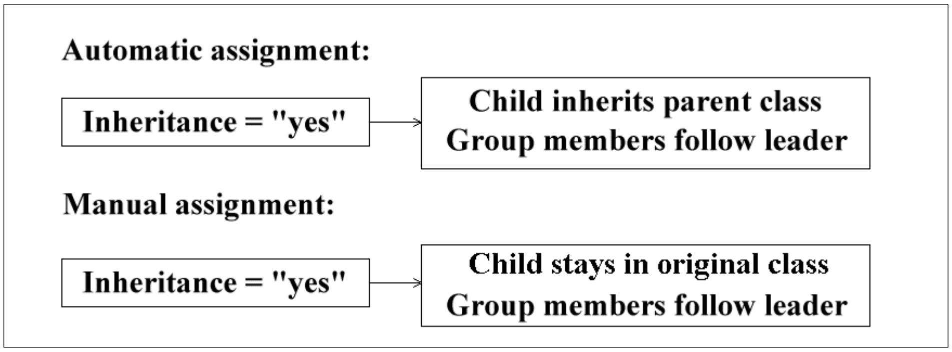


Figure 57. Inheritance in automatic and manual assignments

Let us describe how all this works together with a few examples:

Refer to Figure 58 on page 145 for an illustration of the first example:

1. Process *A*, classified into *class1*, which has inheritance set to *yes*, launches the child processes, *A1* and *A2*.
2. *A1* and *A2* get classified into *class1* as well.
3. The system administrator manually assigns process *A* into *class2*, which also has inheritance set to *yes*. *A1* and *A2* stay in *class1*.
4. Process *A* launches a new child process, *A3*, which gets classified in *class2*.
5. The manual assignment of process *A* is cancelled. *A* goes back to *class1*, and *A3* stays in *class2*.

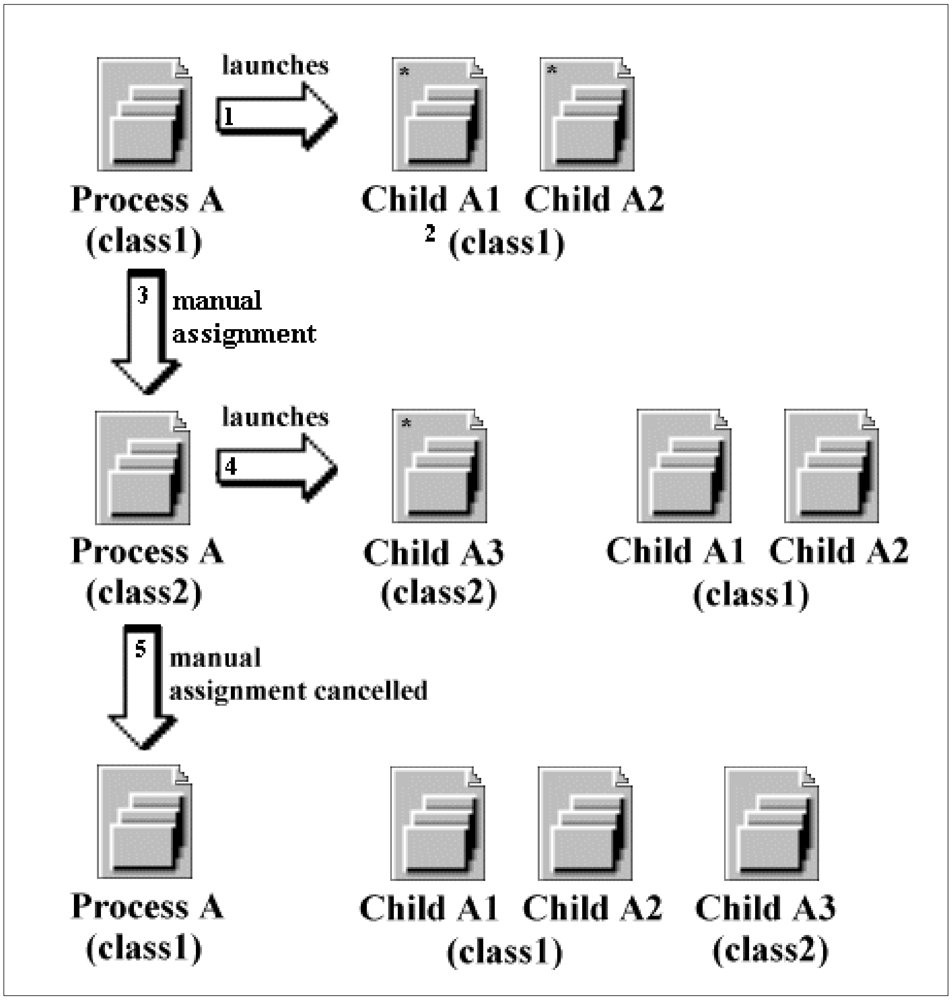


Figure 58. First example of manual assignment and inheritance interaction

Refer to Figure 59 on page 146 for an illustration of the second example:

1. Process *B* is the leader of a process group (*PGID1*) of which processes *C* and *D* are members. Processes *B*, *C*, and *D* are automatically classified in *class1*.
2. The system administrator manually assigns process *B* to *class2*, which, as we know, has inheritance set to *yes*.
3. Processes *C* and *D* follow the process group leader *B* into *class2*.

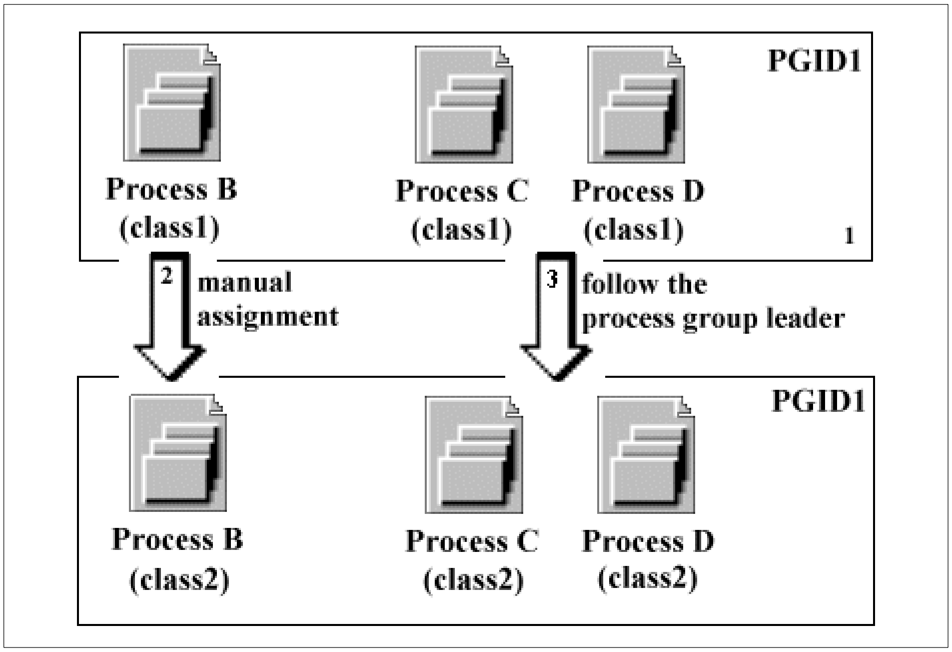


Figure 59. Second example of manual assignment and inheritance interaction

There are cases where some of the processes in the process group will not be reclassified to the new class of the group leader. For instance, if some of the processes themselves have been manually assigned to their current class, they will remain in their class.

5.2 Manual assignment methods

A process or a group of processes can be manually assigned to a superclass and/or subclass using the WLM administration interfaces Web-based System Manager (WSM) and SMIT, the command, `wlmassign`, or an application using the WLM API function, `wlm_assign`.

Command line - wlmassign

The command used in WLM to perform manual assignments and unassignments is `wlmassign`. The syntax of the command is:

```
wlmassign [ -s | -S ]  [ -u | class ] [ pid_list ] [ -gpgid_list ]
```

The options to this command are:

`-u`	Cancel any manual assignment in effect for the processes in the *pid_list* or the *pgid_list*. If none of the `-s` or `-S` flags are used, this cancels the manual assignments for both the superclass and the subclass level.
`-S`	To specify a superclass-only level assignment or unassignment when used with a subclass name of the form, *supername.subclass*.
`-s`	To specify a subclass-only level assignment or unassignment, when used with a subclass name of the form, *supername.subname*.
`-g pgid_list`	To indicate that the following is a list of pgids (and not pids, which would be what the command would interpret by default).

The `wlmassign` command is used to:

- Assign a set of processes specified by a list of process identifiers (pids) and/or process group identifiers (pgids) to a specified superclass or subclass, thus, overriding the automatic class assignment or a prior manual assignment
- Cancel a previous manual assignment for the processes specified in pid_list and/or pgid_list allowing the processes to be subjected to the automatic assignment rules again.

The `wlmassign` command allows you to specify processes using a list of pids, a list of pgids, or both. The format of these lists is pid[,pid[,pid[...]]] or pgid[,pgid[,pgid[...]]], that is, comma (,) separated lists of pids and pgids.

The name of a valid superclass or subclass must be specified to manually assign the target processes to a class. The assignment can be done or canceled at the superclass level, the subclass level, or both. The processes can be assigned to the superclass only by specifying the `-S` option or the subclass only by specifying the `-s` option. For a manual assignment, if the class name is the name of a superclass, the processes in the list will be assigned to the superclass. The subclass will then be determined using the assignment rules for the subclasses of the superclass. If the class name is a subclass name, *supername.subname*, the processes will, by default, be assigned to both the superclass and the subclass. The following are examples from Table 2 on page 21:

1. To assign a process with pid 9846 to superclass *VPs*, enter:

```
# wlmassign -S VPs 9846
```

or:

```
# wlmassign VPs 9846
```

This is a superclass-only assignment. The assignment rules for superclass *VPs* select a subclass for the process (for instance, *Default*)

2. To assign at the subclass level, the process with pid 9846 from *VPs.Default* to *VPs.editors*, enter:

```
# wlmassign -s VPs.editors 9846
```

or:

```
# wlmassign VPs.editors 9846
```

This would become a superclass and subclass assignment.

3. To cancel the subclass level assignment of a process with pid 9846 (the process still has the superclass level assignment staying, thus, in superclass VPs and being submitted to the superclass assignment rules), enter:

```
# wlmassign -u -s 9846
```

4. Finally, to cancel the superclass level assignment of a process with pid 9846 (making it be submitted to the general configuration assignment rules):

```
# wlmassign -u -S 9846
```

SMIT

A process can be manually assigned in SMIT by accessing the *Assign/Unassign processes to a class/subclass* screen or using the following fastpath

```
# smitty wlmassign
```

For instance, to manually-assign a process with pid 9846 to superclass *VPs*, (from the example in Table 2 on page 21) and subclass *editors*, see Figure 60 on page 149.

```
                    Assign/Unassign processes to a class/subclass

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                          [Entry Fields]
  Assign/Unassign to/from Superclass/Subclass/Both       Assign Superclass        +
  Class name (for assignment)                           [VPs.editors]             +
  List of PIDs                                          [9846]                    +
  List of PGIDs                                         []                        +









F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 60. Manual assignment in SMIT

To manually unassign the same process from the subclass *editors* of *VPs* superclass, the administrator can assign it to another class or cancel its subclass level assignment as shown in Figure 61.

```
                    Assign/Unassign processes to a class/subclass

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                          [Entry Fields]
  Assign/Unassign                                        unassign subclass        +
  Class name                                            []                        +
  List of PIDs                                          [9846]                    +
  List of PGIDs                                         []                        +









F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 61. Subclass level unassignment in SMIT

Finally, to unassign the same process from the superclass *VPs* altogether, the system administrator can assign it to another class or cancel its superclass level assignment, as shown in Figure 62.

```
                 Assign/Unassign processes to a class/subclass

Type or select values in entry fields.
Press Enter AFTER making all desired changes.

                                                        [Entry Fields]
  Assign/Unassign                                      unassign class         +
  Class name                                          [VPs ]                  +
  List of PIDs                                        [9846]                  +
  List of PGIDs                                       []                      +










F1=Help             F2=Refresh          F3=Cancel           F4=List
F5=Reset            F6=Command          F7=Edit             F8=Image
F9=Shell            F10=Exit            Enter=Do
```

Figure 62. Superclass level manual unassignment in SMIT

The PGID's could have been used as well to perform the assignments and unassignments.

WSM

In WSM, manual assignment and unassignment is done by right clicking the configuration name to work with in the *Configurations/Classes* screen and by choosing the *Add* or *Remove Processes* option as shown in Figure 63 on page 151.

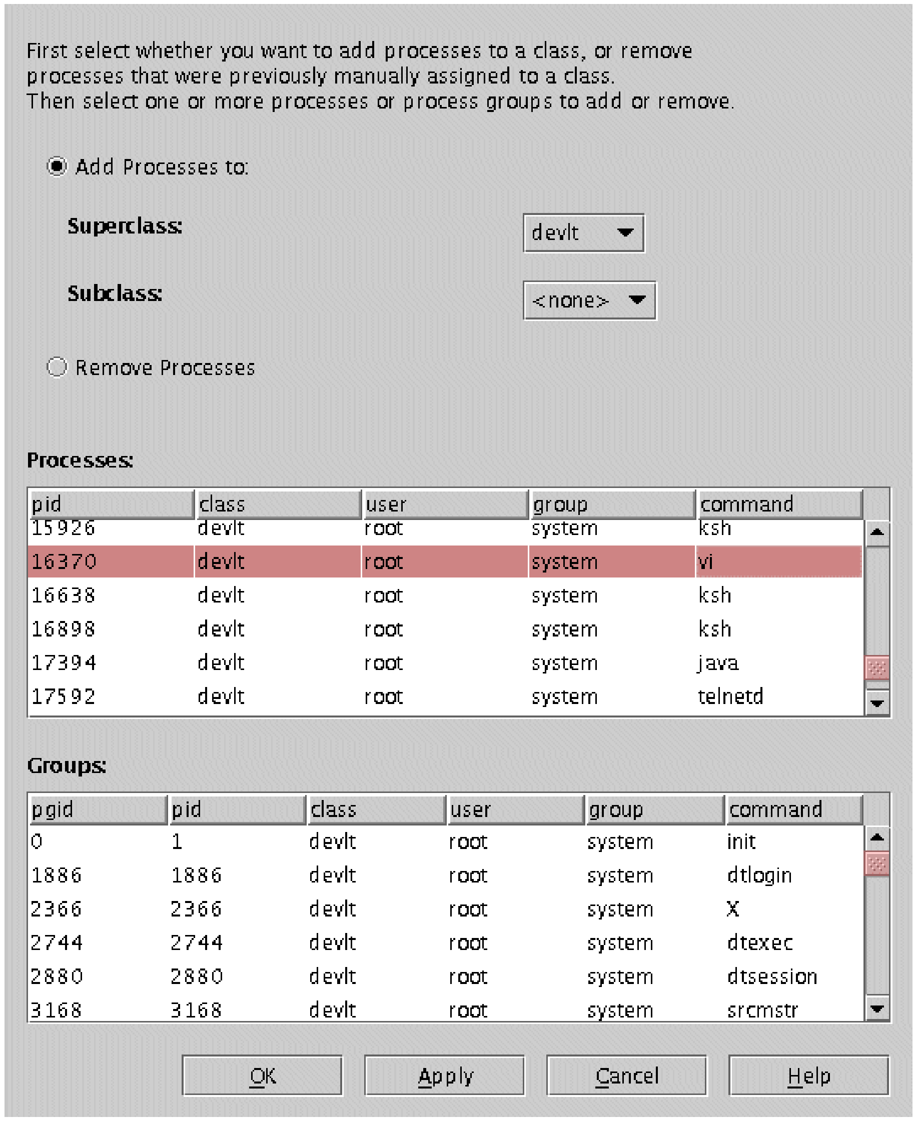


Figure 63. Manual Assignment in WSM

Applications - wlm_assign

An application can perform its own manual assignments and unassignments, using, for that purpose, one of the WLM API routines: `wlm_assign`. For more information about manual assignment in the API, see also Chapter 6, “WLM Application Programming Interface (API)” on page 157, and Appendix A.6, "WLM management" on page 236.

5.3 Examples

The examples described in this section focus mainly on well-known database applications that are the most commonly-known programs running more than one instance at the same time in the same system. Nevertheless, the scripts supplied are general enough (or easily modifiable) to meet any application whose behavior is similar to the examples.

5.3.1 Oracle example

Some databases, such as Oracle, for instance, change their processes to show the instances name in them. With this facility, we can differentiate Oracle's several instances by the name their processes assume on the process table. For example, if we have an Oracle instance, named *wlmdb*, and another, named *acct*, running on the same machine, the output of `ps -ef | grep ora` for their processes would be something like the following:

```
# ps -ef | grep ora
oracle 35614     1   0 23:20:49      -  0:00 ora_dbwr_wlmdb
oracle 35872     1   0 23:20:49      -  0:00 ora_reco_wlmdb
oracle 36130     1   0 23:20:49      -  0:00 ora_pmon_wlmdb
oracle 36388     1   0 23:20:49      -  0:00 ora_smon_wlmdb
oracle 36654     1   0 23:20:49      -  0:00 ora_lgwr_wlmdb
oracle 63186     1   0 23:20:50      -  0:00 ora_d000_wlmdb
oracle 94736     1   0 23:20:49      -  0:00 ora_s000_wlmdb
oracle 35614     1   0 23:20:49      -  0:00 ora_dbwr_acct
oracle 35872     1   0 23:20:49      -  0:00 ora_reco_acct
oracle 36130     1   0 23:20:49      -  0:00 ora_pmon_acct
oracle 36388     1   0 23:20:49      -  0:00 ora_smon_acct
oracle 36654     1   0 23:20:49      -  0:00 ora_lgwr_acct
oracle 63186     1   0 23:20:50      -  0:00 ora_d000_acct
oracle 94736     1   0 23:20:49      -  0:00 ora_s000_acct
root 64040 85492   7 23:56:12 pts/21  0:00 grep ora
```

From this knowledge, it is possible to create a Korn shell script that would be set to run at every boot of the system to classify these instances differently, using manual assignment. This script should only be run when it is absolutely certain that all the instances's processes are up and running. A position close to the end of /etc/inittab is recommended.

Note

Keep in mind that all manual assignments are cancelled if WLM or the applications are stopped. If, for any reason, the system administrator needs to stop and restart WLM or any of the manually-assigned applications, the manual assignments need to be remade by rerunning the script.

A sample script for this situation is provided in Appendix C.1, "Oracle example script" on page 259. Its functionality is described here.

Configuration file

The script uses a configuration file, which, for the sake of the example, is /etc/wlm/ma.conf. The format of this configuration file is one line per required manual assignment. These lines have the following format:

<Instance name> <Class> <Inheritance>

where:

- *Instance name* is the Oracle (or other application in a similar situation) instance name.
- *Class* is the name of the classes to manually assign the processes to. This name is *supername* for the superclasses and *supername.subname* for the subclasses.
- *Inheritance* is a flag that is set to *yes* if the processes belonging to a process group (whose leader is a process being manually assigned) should be manually assigned as well. If the group members should stay in the original class, this flag must be set to *no*.

Data structure

The script uses as data structure an array of three positions, named MANUAL, where:

- Position 0 takes the instance name.
- Position 1 takes the class name.
- Position 2 takes the inheritance flag value.

Function

The script has one single function, named `getpids()`, which receives, as a parameter, the instance name whose processes are to be manually assigned. The function gets the processes' IDs related to that instance (the ones that have the instance's name as part of their *own* name in the process table) and returns them in the format of a comma (,) separated list.

Script process

For each line read from the configuration file, the script does the following:

- Sets the MANUAL array with the values read from the configuration file (instance name, class name, and inheritance flag) and works with this data structure.

- Saves the inheritance attribute value of the target class and sets it to its new value.
- Invokes `getpids()` to get a comma (,) separated list of the PIDs to be manually assigned, that is, the ones related to the instance in question.
- Manually assigns the list of processes to the target class.
- Reverts the inheritance attribute value of the target class to the saved one.

5.3.2 DB2 UDB example

Some databases, such as DB2 UDB, hold the name of the instance in one of their processes' environmental variables. For DB2 UDB, for instance, the variable is called DB2INSTANCE. This way, we can differentiate the processes running under each instance by checking their environment DB2INSTANCE variable. For example, if 31538 is the PID for a `db2resyn` process, its environmental variables could be seen through the following command:

```
# ps eww 31538
   PID    TTY STAT  TIME COMMAND
 31538      - A     0:04 db2resyn DB2COMM=TCPIP DB2INSTANCE=db2
HOME=/usr/db2 LANG=en_US PWD=/usr/db2 TZ=CST6CDT USER=db2
PATH=/usr/db2/sqllib/bin:/usr/db2/sqllib/adm:/bin:
LIBPATH=/usr/db2/sqllib/lib:/usr/db2/sqllib/function:
```

From this knowledge, it is possible to create a Korn shell script that would be set to run at every boot of the system to classify these instances differently, using manual assignment. This script should only be run when it is absolutely certain that all the instance's processes are up and running. A position close to the end of /etc/inittab is recommended.

Note

Keep in mind that all manual assignments are cancelled if WLM or the applications are stopped. If, by any chance, the system administrator needs to stop and restart WLM or any of the manually assigned applications, the manual assignments need to be re-made by re-running the script.

A sample script for this situation is provided in Appendix C.2, "DB2 UDB example script" on page 260. Its functionality is described here:

Configuration file

The script uses a configuration file, which, for the sake of the example, is /etc/wlm/ma.conf. The format of this configuration file is one line per required manual assignment. These lines have the following format:

<Instance name> <Class> <Inheritance>

where:

- *Instance name* is the DB2 UDB (or other application in a similar situation) instance name.
- *Class* is the name of the classes to manually assign the processes to. This name is *supername* for the superclasses and *supername.subname* for the subclasses.
- *Inheritance* is a flag that is set to *yes* if the processes belonging to a process group (whose leader is a process being manually assigned) should be manually assigned as well. If the group members should stay in the original class, this flag must be set to *no*.

Data structure

The script uses, as a data structure, an array of three positions, named MANUAL, where:

- Position 0 takes the instance name.
- Position 1 takes the class name.
- Position 2 takes the inheritance flag value.

The variable APP is a string that characterizes the application in the process table. In the DB2 UDB example, it is set to *db2*.

The variable, VARIABLE, holds the name of the environmental variable that is to be used. In the DB2 UDB example, it is set to *DB2INSTANCE*.

Function

The script has one single function, named `getpids()`, which receives as parameter, the instance name whose processes are to be manually-assigned. The function gets the processes' IDs related to that instance (the ones that have the name of that instance associated with the environmental variable pointed to by VARIABLE) and returns them in the format of a comma (,) separated list.

Script process

For each line read from the configuration file, the script does the following:

- Sets a MANUAL array with the values read from the configuration file (instance name, class name, and inheritance flag) and works with this data structure
- Saves the inheritance attribute value of the target class and sets it to its new value
- Invokes `getpids()` to get a comma (,) separated list of the PIDs to be manually assigned, that is, the ones related to the instance in question
- Manually assigns the list of processes to the target class
- Reverts the inheritance attribute value of the target class to the saved one

5.4 Conclusion

Wrapping up the subject of manual assignment, it must be regarded as a very useful increment to WLM's automatic functionality. In WLM's first release, all the instances of a database were classified in the same manner, disregarding the importance each one of them could have to the business. Manual assignment comes forth to bring additional classification options (providing more flexibility of control over some important applications) essential to successful server consolidation.

Chapter 6. WLM Application Programming Interface (API)

The AIX Workload Manager Application Programming Interface (API) is comprised of a set of routines in the /usr/lib/libwlm.a library. These routines provide applications with the capability to perform all the tasks a WLM administrator can carry out using the WLM commands, that is, create, change, and remove classes, manually assign processes to specific classes and get WLM statistics. In addition, a routine, `wlm_set_tag`, allows an application to set up a process tag and specify whether this tag should be inherited by child processes at `fork` and/or `exec` times. The library provides support for multi-threaded 32 or 64 bit applications. Refer to Appendix A.1, "The Include file - sys/wlm.h" on page 217, for a technical description of the sys/wlm.h header file.

The API routines have the additional ability (over WLM commands' regular functionality) to make changes only to the currently-running configuration (in-core) data in the kernel, not saving them into the property files (thus, not making them available after restarting WLM). These changes can only be seen while existing in the directory that holds the image of the running configuration, */etc/wlm/.running*.

The application programmer must be aware that there are some initialization routines in the API that must be run before any others. Refer to Appendix A.3, "Initialization routines" on page 227, for the technical description of the initialization routines.

6.1 Application tag

The application tag interface, `wlm_set_tag`, is a technique provided to the applications that want to have some level of control over how their various instances are classified, such as databases, for example. The *tag* is a string of characters that is used as one of the classification criteria for the automatic classification of processes (using the rules file). This, basically, provides a process with an additional classification condition to add to the already defined ones, such as user, group, application pathname, and process type. Refer to Appendix A.4, "Application tag" on page 229 for a technical description of the `wlm_set_tag` routine.

6.1.1 Description

When an application process sets its tag, it is immediately reclassified using the superclass and subclass rules in effect for the currently-active WLM configuration. WLM goes through the assignment rules looking for a match using all the process attributes, including the new tag. In order to be effective, this tag must appear in one or more of the assignment rules. This means that the format and the use of the various tags each application might create must be clearly-specified in the application's administration documentation. This way, WLM administrators get to know all the choices of values a specific application tag might take and can use them in their assignment rules to distinguish between different instances of the same application.

Different system administrators might have different requirements depending on what set of application process characteristics they want to use to classify them. It is recommended that the application provide a set of configuration or runtime attributes that could be used to build the tag. This would provide the application administrator with the ability to specify the format of this tag to the application. The attributes that can be used for the tag and the syntax to be used to specify the format of the WLM tag are application dependent and are the responsibility of the application provider.

6.1.2 An application tag situation

Let us suppose that an instance of a database server is able to determine which database is working on *db_name* and through which TCP port, *port_num*, a given user is connected. Some WLM administrators may want to create different classes for processes accessing different databases and give each class different resource entitlements. Others might want to separate the processes serving remote requests from different origins and use the port number as a classification attribute. Others might want both and create one superclass for each database and subclasses per port numbers in each superclass. A way of accommodating these different needs would be to specify the content and format of the tag. We can imagine, for the sake of the example, that this could be passed to the application in a configuration file or runtime parameter, such as:

WLM_TAG=<$db_name> or WLM_TAG=<$port_num>

or

WLM_TAG=<$db_name>_<$port_num>

When setting its tag, an application can specify whether or not it will be inherited by its children so that all the processes spawned by a specific instance of an application can be classified in the same class. Setting the tag inheritance is probably how the application tag will be used most of the time.

Taking the example of a database, here is how application tags can be used:

Consider Table 2 on page 21, where the provider of a database server application could have specified that the tag would be the database name. Then, two instances of the server working on two different databases would set up two different tags, for instance, *_db1* and *_db2*. A system administrator could create two different classes, *db1* and *db2* and classify the two database servers (and all their children if tag inheritance is used) in these classes using the tags. It would then be possible to give each class a different resource entitlement according to specific business goals.

The corresponding assignment rules could look like:

```
* class   resvd   user  group    application          type  tag
*
db1       -       -     -        /usr/oracle/bin/db*  -     _db1
db2       -       -     -        /usr/oracle/bin/db*  -     _db2
```

6.1.3 Example of an application tag program

A simple program to launch an application with a specified tag in provided in Appendix D, "Sample program for application tag" on page 263. Let us say the program is called `settag`, and its syntax is:

```
# settag tag_name program_name
```

where:

`tag_name` is the string we want to tag the application with.

`program_name` is the application to be tagged.

Basically, the program procedure is:

- Run `wlm_initialize`, which is required before using any other API routine (refer to Appendix A.3, "Initialization routines" on page 227, for a technical description of the initialization routines).
- Run `wlm_set_tag`, to set the application tag. The *flags* argument of this routine is set in such a way that child processes of `settag` inherit the tag at `exec` and `fork` times.
- Launch the application, which inherits the tag from its parent, `settag`.

With this program, a system administrator can launch any application explicitly tagged and let WLM automatically classify it using, for that purpose, the rules that should have been previously created to handle the application tags.

As a usage example of this program, let us consider a Korn shell script, *test*, that simply issues a `sleep` command. The following rule was created to classify this process in the class, *myclass*, when issued with the *_mytag* tag:

```
myclass  -   root  -   test  - _mytag
```

The next screen exhibits the test performed and the output obtained:

- First, the `settag` program was run to launch and tag the *test* process with *_mytag*.
- The `ps` command was used to check the classification and tagging process.
- Second, the `settag` program was run again to launch and tag the *test* process with *_notag*.
- The `ps` command was used to check the classification and tagging process.

Note that, in the first `settag` run, the process, *test*, and the child process, *sleep*, were classified correctly in the *myclass* superclass. The second time `settag` was run, both processes were classified in the System class because there is no rule for tag *_notag*, and root was being used in the tests. This demonstrates how an application can provide differentiation between its various instances using application tagging:

```
# settag _mytag test &
# ps -ae -o class,pid,ppid,tag,args |grep tag |grep -v grep |grep -v ps
myclass.Default    2270  7324   _mytag   sleep 100
myclass.Default    7324  12192  _mytag   sh -- test
# settag _notag test &
# ps -ae -o class,pid,ppid,tag,args |grep tag |grep -v grep |grep -v ps
myclass.Default   2270  7324   _mytag   sleep 100
myclass.Default   7324  12192  _mytag   sh -- test
System            9214  17192  _notag   sleep 100
System            17192 12192  _notag   sh -- test
```

6.2 Class management

The WLM API provides applications with the ability to:

- Query the names and characteristics of the existing classes of a given WLM configuration (`wlm_read_classes`)
- Create a new class for a given WLM configuration and define the values of the various attributes of the class (tier, inheritance, adminuser,

admingroup, rset, authuser, and authgroup) and the shares and limits for the resources managed by WLM, such as CPU, physical memory, and disk I/O (`wlm_create_class`)

- Change the characteristics of an existing class of a given WLM configuration, including the class attributes and resource shares and limits (`wlm_change_class`)
- Delete an existing class of a given configuration (`wlm_delete_class`).

The changes will be applied only to the property files of the specified WLM configuration. Optionally, by specifying an empty string as the configuration name, it is possible to apply the change only to the currently-running classes resulting in an immediate update of the state of the active configuration.

The API calls require the same level of privilege from the caller that would be required for the command line, SMIT or WSM interfaces:

- Any user can read the class names and characteristics.
- Only root can create/modify/delete superclasses.
- Only root or designated superclass administrators (superclass attributes, adminuser and admingroup) can create/modify/delete subclasses of a given superclass.

In cases where WLM administration is done both through the command line and administration tools by WLM administrators and by applications through the API, some caution must be applied. Both interfaces share the same name space for the superclass/subclass names and the total number of superclasses and subclasses. In addition, when the API directly modifies the currently-running (in-core) WLM data (create new classes, for instance), the WLM administrators are not aware of this until they see classes they did not create appear on the output of commands, such as `wlmstat`. In order to avoid conflicts that would confuse the applications using this API, the classes created through the API that are not defined in the WLM property files are not automatically removed from the in-core data if the system administrator updates WLM. They remain in effect until explicitly removed through the wlm_delete_class routine or through an invocation of the `rmclass` command (invoked directly or through SMIT or WSM by the system administrator).

Refer to Appendix A.5, "Class management" on page 230, for technical descriptions of the class management routines.

6.3 WLM management

The WLM API also provides applications with the ability to:

- Query/change the mode of operation of WLM using the `wlm_set` function.
  - Query the current status of WLM.
  - Stop WLM.
  - Switch from active to passive mode and vice-versa.
  - Turn the rset binding on and off.
- Start/update WLM, using the current (or an alternate) configuration, with `wlm_load` routine.
- Assign a process or a group of processes to a class using the `wlm_assign` routine.

Here again, the API requires the same levels of privilege as the corresponding command line interfaces, `wlmcntrl` and `wlmassign`:

- Any user can query the state of WLM.
- Only root can change the mode of operation of WLM.
- Only root can update/refresh a whole configuration.
- Only root or an authorized superclass administrator (adminuser/admingroup) can update WLM for the subclasses of a given superclass.
- Only root, an authorized user (specified by authuser/authgroup) or an authorized superclass administrator (adminuser/admingroup) can assign processes to a superclass and/or subclass.

Refer to Appendix A.6, "WLM management" on page 236, for technical descriptions of WLM management routines.

6.4 WLM statistics

The WLM API routines `wlm_get_info` and `wlm_get_bio_stat` provide applications with access to the WLM statistics displayed by the `wlmstat` command.

Refer to Appendix A.7, "WLM statistics" on page 241 for technical descriptions of WLM statistics routines.

6.5 WLM classification

The API, routine `wlm_check`, allows to check the class definitions and the assignment rules for a given WLM configuration.

The API routine `wlm_classify` allows an application to find out which class a process with a specified set of attributes would be classified to.

Refer to Appendix A.8, "WLM classification" on page 246 for technical descriptions of WLM classification routines.

6.6 Binary compatibility

In order to provide binary compatibility, in the future, if there are any changes in the data structures, each API call receives a version number as one of the parameters. This will allow the library to determine which version of the data structures the application has been built with and read and/or write the correct data.

6.7 Integration with Tivoli products

By itself, WLM does not allow a system administrator to monitor the performance of an application. It can only work with system resources' usage and monitor if that usage is above or below the defined targets. However, an integration of the WLM API with Tivoli Application Performance Management (TAPM) can bring the best of the two worlds together: Monitoring an application's availability and response time and its behavior at the system level (resource usage).

6.7.1 TAPM overview

TAPM focuses on two different approaches to measure applications availability and response time: Application instrumentation and transaction simulation. Both methods consist of using the TAPM Application Response Measurement (ARM) API routines.

6.7.1.1 Application instrumentation

The application instrumentation approach focuses on changing the application code to include ARM API function calls. This method has the advantage of giving the application control over what is monitored and when but has the obvious drawback of the unavailability of the application's source code to many customers.

An example of application instrumentation would be to measure the end-user's response time, which could be defined as the time between the user submitting the transaction and the screen refreshing with the result. In order to measure the end-user's response time, ARM API calls that start and stop the TAPM agent timer have to be placed in the application code around the user transaction. In other words, an `arm_start` call must be made when the user clicks on the submit button, and an `arm_stop` call must be made when the screen refreshes.

The time the server component of the transaction takes could be measured in the same way.

6.7.1.2 Transaction simulation

In the second approach, meant for when the application's source code is not available, typical end-user transactions are collected in a script for simulation purposes. This script is edited to include the ARM API function calls, just like the application instrumentation approach. The script is then set to run periodically from a dedicated client, simulating the chosen transactions. The measurements it provides are good approximations of real end-user experience.

6.7.2 TAPM and WLM

In both approaches described in the previous section, the WLM API can work together with the ARM API to gather statistics of both system resources usage and response times on an AIX application environment. This can help to determine if an application performance bottleneck resides in the application itself or in a less appropriate configuration of resource targets for the application class. The WLM API calls to gather these statistics are `wlm_get_info` and `wlm_get_bio_stat`. Refer to Appendix A.1, "The Include file - sys/wlm.h" on page 217, for a description of the routines' data structures and to Appendix A.7, "WLM statistics" on page 241, for a technical description of the routines.

6.7.3 Monitoring an application in a WLM and Tivoli environment

In this section, the steps of the process of monitoring an application and using WLM and Tivoli products together are described.

The first step is to determine what to monitor and when:

- Which transactions within the application are to be studied?
- Which approach is to be used?
- At what time of day should the monitoring process run?

- What sort of system resource statistics are to be collected?

After the planning is done, the chosen method is applied. Applications are instrumented or scripts are written using the WLM and ARM API calls to collect the chosen statistics and performance measurements.

At this time, the instrumented applications or scripts need to be registered within the Tivoli environment and added to TAPM profiles before distributing them to any specific endpoints. The subsequent profile distribution will make the scripts or instrumented applications generate data. This data is stored in an external database, and, with the use of Tivoli Decision Support (TDS), reports can be generated from it.

The Distributed Monitoring agent provided with TAPM also enables you to detect and act upon any exceptions that might occur. These events can be forwarded to the Tivoli Enterprise Console (TEC). Examples of events needing immediate action would be a critical application getting resources way below its target (thus, presenting really low performance) or another process starving all other applications of a particular resource.

This process is briefly represented in Figure 64:

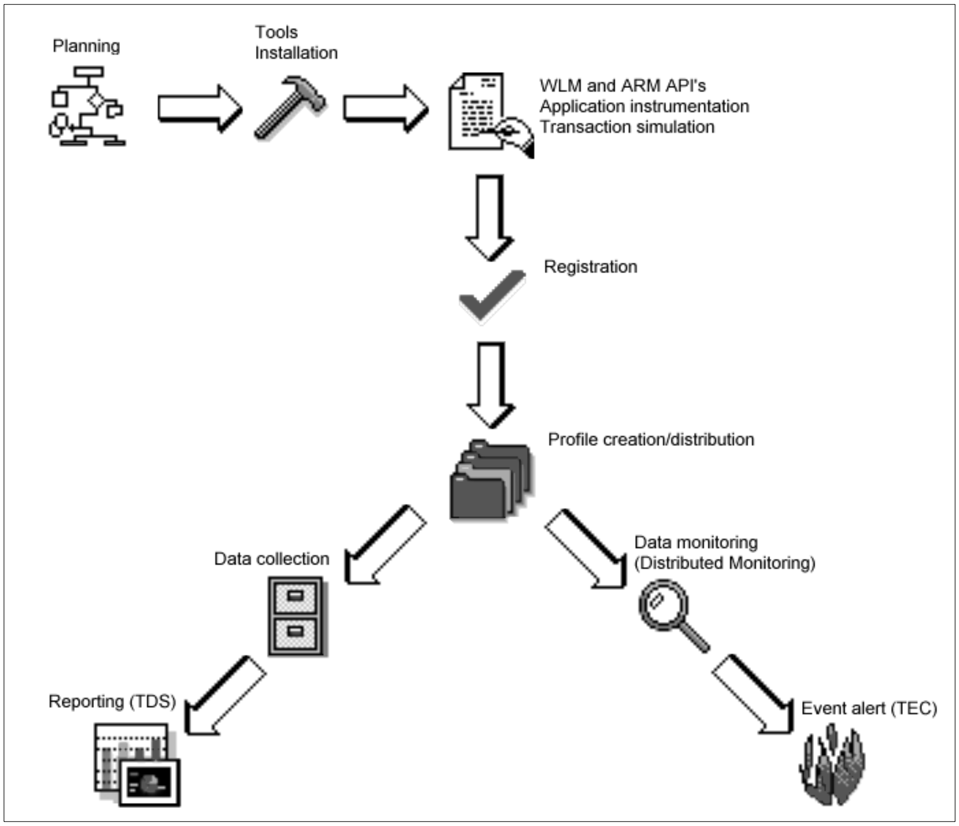


Figure 64. WLM and Tivoli interaction

6.8 Summary

The WLM API provides the applications with the ability to:

- Perform regular WLM and class administration tasks
- Tag processes to extend the range of classification criteria
- Gather resource usage statistics

With Tivoli product interaction, WLM's monitoring functionality can be extended to an application performance oriented one.

Chapter 7. Sizing recommendations for Workload Manager

The introduction of Workload Manager has greatly enhanced not only the functionality of AIX, but also helps to more efficiently use the capacity of RS/6000 servers. WLM provides the means to use otherwise wasted “overcapacity” without impairing the performance requirements of the primary workload(s). However, only after proper sizing and control of the nature and behavior of the workload mix will you achieve the expected improvement in overall system usage.

This chapter will suggest some recommendations for system capacity sizing when using AIX WLM. It does not deal with the sizing theories for individual applications.

7.1 Typical UNIX system capacity sizing

Few production UNIX systems have an average utilization of more than 70 percent (often more than 80 percent is considered resource constrained). Moreover, it is not surprising to find that the average utilization of most UNIX systems is below 40 percent. This is chiefly due to the following reasons:

- System sizing should be based on the highest expected peak load, not on the average workload.
- Generally, we want to have a generous amount of buffering capacity, often more than 20 percent, in addition to the top peak load.
- The duration of peak load time is, usually, not long.
- In most cases, a UNIX server is dedicated to only one application service, thus, producing a single pattern of peak loads.

The typical UNIX system resource utilization, therefore, is similar to that shown in Figure 65 on page 168. Actually, a substantial percentage of the total system resource is wasted in most UNIX systems, just in preparation for some peak loads that do not last long.

These peak loads cannot simply be ignored. When there is an unexpected peak of heavy workload whose resource consumption exceeds the system capacity, we often experience a duration of system hang-up until the load is over. This is one of the system administrator’s nightmares. So, even if system resource utilization is quite low, a system large enough to survive such peak workloads without a hang-up has to be prepared.

7.2 Considerations about server consolidation

The key to right-sizing a UNIX system is to eliminate that wasted capacity. It would not be practical to try to change the behavior of the application itself. Nor would it be acceptable to force the service users not to produce those peak loads.

One of the more reasonable solutions to this problem is to combine multiple application services with different system resource utilization patterns into a single server. By doing that, multiple patterns of peak loads can be combined to produce a greater average system usage.

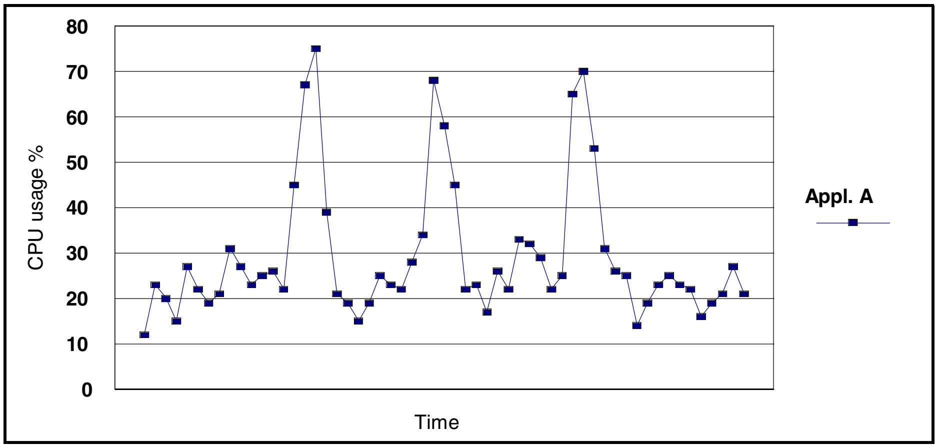


Figure 65. A typical CPU usage of a UNIX system running a single application service

Integrating multiple applications that run on separate, single systems into one system of larger capacity is part of a server consolidation solution. Running multiple applications on one server of larger capacity has many pros and cons.

The pros are:

- Only one instance of OS is required, thus, saving the resources needed for multiple OS instances, such as memory and disk space.
- More flexible utilization of system resources.
- The total cost of ownership is decreased (that is, less maintenance cost and less manpower).
- Even though there is more complexity in the system being administered, there are fewer systems to be maintained (for operating system updates, for instance).

- Simpler architecture than that of distributed server systems.

The cons are:

- Running more than one application service in one system can lead to resource contention among the applications, thus, degrading the performance of critical services or workloads.
- It is not always possible to limit the resource usage of some applications that are not mission-critical or tend to take up all the available system resources.
- If the system fails due to OS or other application errors, all other services are lost.
- If one application crashes or goes out of control, the other applications may be brought down due to it.

Many of these problems against server consolidation can be overcome with the modern UNIX technologies. The availability problems can be addressed by UNIX clustering technologies, such as HACMP for AIX. The resource contention problems can be solved by using a workload management solution.

The main reason for performance degradation when running multiple applications in a single system is the resource contention between applications. AIX WLM can effectively isolate applications by controlling the resource allocation algorithm of the UNIX scheduler, virtual memory manager (VMM), and the bandwidth of disk devices so that applications of more importance can be configured to receive preferential allocation of resources compared to less important ones.

To learn what functionality Workload Manager provides for integrating multiple applications on single systems, refer to Chapter 2, “AIX Workload Manager functionality” on page 7.

7.3 System capacity sizing for Workload Management

Workload Management can be very useful in terms of system capacity usage in two ways:

- WLM can help, by integrating multiple applications on a single server, to utilize the unused portion of system resource that would be wasted just in preparation for the peak loads if the applications ran on separate individual systems.

- WLM automates the process of (re-)scheduling system resources allocated to lower priority workloads back to high priority (critical) workloads whenever these enter their *peak load* period. This reallocation process can be so extreme that low priority jobs seem to be stopped. Therefore, the system should be sized sufficiently to handle the combined peak loads of critical workloads. Although some buffering (that is, extra resources) may still be desired to meet increasing resource requirements by critical applications, the amount of consolidated buffer space can be less than the combined buffers of individual systems.

7.3.1 System capacity sizing steps for server consolidation

One method of estimating the required system capacity for server consolidation is explained here. It should be noticed that this is just one of many methods of system sizing and that the method explained here may not be applicable to all cases. Basically, this method is based on the highest peak load of the monitored application. It is assumed that each existing application is running on its dedicated system.

7.3.1.1 Step 1 - Monitor resource usage

First, monitor for a sufficiently long period to get a distribution of workload load levels. The maximum load is an important statistic. A second important statistic is the average load exclusive of peak loads (for instance, 0-5 percent or 20 percent versus 80 percent peak load). Each of these levels has to be described according to their period and distribution over the day, week, and/or month.

Wherever possible, identify patterns related to the business cycle (Monday, Friday, weekend, end of month, end of quarter, end of business year). For example, in the banking business, there can be some days in a month on which the systems are used much more than on others.

The existing systems may be underutilized or overutilized. If the system is overutilized, that is, if the application requires more resource than is available in the current system, you cannot obtain the exact value of the highest peak load for that application. In that case, a test system with a larger capacity may be used, or the theoretical peak load has to be extrapolated using the monitored data.

As a result, a resource usage data table, such as the one in Appendix E, "Sample for CPU resource usage calculation" on page 265, can be obtained.

It is recommended that you draw a graph, such as the one shown in Figure 66 on page 174, for each application using the resource usage data.

7.3.1.2 Step 2 - Estimate the requirements for each application

The calculations to be done for such an estimation are:

- Minimum required capacity (AR)
- Resource Utilization Percentage (RUP)
- Average resource utilization percentage (ARUP)

Minimum required capacity (AR)

For a consolidated system, first build a table without regard to buffering.

The system sizing buffer is an estimate of the additional resources needed to handle:

1. Concurrent critical applications *growth*
2. Concurrent (though lower priority) resources for other workloads during critical application *peak* load requirements.

The minimum required capacity for each application is calculated by adding the estimated buffer to the highest peak load observed.

The *minimum required system capacity*, which is further on in this example used as the *total available system resource*, is calculated with the following formula

$$AR = \frac{HPx(100 + BF)}{100}$$

AR = Minimum Required System Capacity, in the following used as the Total Available System Resource.

HP = The highest peak load.

BF = The buffering factor as a percentage of the total capacity need.

Assume that this application is run on the system of this estimated capacity.

Resource Utilization Percentage (RUP)

Then, the *Resource Utilization Percentage (RUP)* of the application on this system of the estimated capacity can be calculated using the resource usage graph displayed in Section 7.3.1.1, “Step 1 - Monitor resource usage” on page 170, as follows:

$$RUP = \frac{(URxLTU)}{(ARxTUxLTU)}x100$$

UR = Actually used resource during the period (colored area under the usage curve of the example graph). UR can be calculated by adding the values of the resource usage measured at each measuring point.

AR = Total Available System Resource calculated earlier as the Minimum Required System Capacity (total area of the example graph).

TU = Number of time units during the monitoring period.

LTU = Length of Time Unit. If the monitoring interval is, for instance, set to seven seconds, the Length of Time Unit (LTU) is 7.

Average resource utilization percentage (ARUP)

The overall average of the resource utilization percentage of the multiple systems is calculated as follows:

$$ARUP = \frac{SUR}{(SARxTU)}x100$$

SUR = Sum of actually-used resources per system during the measuring period accommodating all the applications on one system.
This value is obtained by adding up the values of each system's Total Actually Used Resource (UR) and is the sum of the colored areas under the usage curves of the graphs in the example.

SAR = Sum of total available resources of all the systems or the sum of the total required system capacity for accommodating all the applications on one system.
This value is obtained by adding up the values of each system's Minimum Required System Capacity (AR) and is the sum of total areas of the graph boxes in the example.

TU = The number of time units during the monitoring period

7.3.1.3 Estimate the capacity for integrated applications

In this step, the minimum required capacity of a single system required for integrated applications is estimated.

Taking the sum of individual resource usage values of all the applications at one of the measurement points gives the expected resource usage value of the applications integrated into one system at the same measurement point. Repeating this at all measurement points produces a table of the expected resource usage data when the applications are integrated into one system, such as the one that is obtained for each separate application by actual monitoring in Section 7.3.1.1, "Step 1 - Monitor resource usage" on page 170.

An expected resource usage graph, such as the one shown in Figure 70 on page 178, can be obtained from this.

The minimum required capacity and the resource utilization percentage for integrated applications are calculated as described in Section 7.3.1.1, “Step 1 - Monitor resource usage” on page 170.

7.3.2 Examples

The following examples give a good illustration of the capacity usage benefit using the WLM solution.

The resource usage data table used in these examples is available in Appendix E, "Sample for CPU resource usage calculation" on page 265. The time unit used in the table is 10 minutes, and the number of this time unit monitored here is 50. Thus, the total monitoring duration is 500 minutes. It should be noticed that the minimum monitoring period has to be at least 24 hours in actual cases. The length of 500 minutes is used here just for simplicity of the example.

The examples here are about the CPU resource only. Considerations for memory and disk I/O bandwidth are discussed in Section 7.3.3, “Considerations for memory and disk I/O bandwidth” on page 181.

7.3.2.1 Base line - Applications running on separate systems

For example, assume that there are four different applications that have the CPU usage patterns shown in the following four figures.

Application A, shown in Figure 66 on page 174, exhibits short, pronounced peak loads.

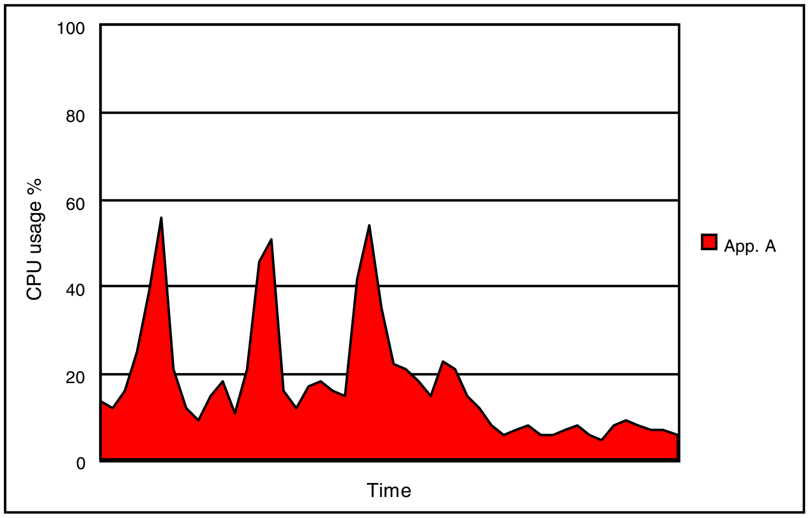


Figure 66. CPU usage pattern of Application A

Application B, shown in Figure 67, shows workload increasing and decreasing gradually over time.

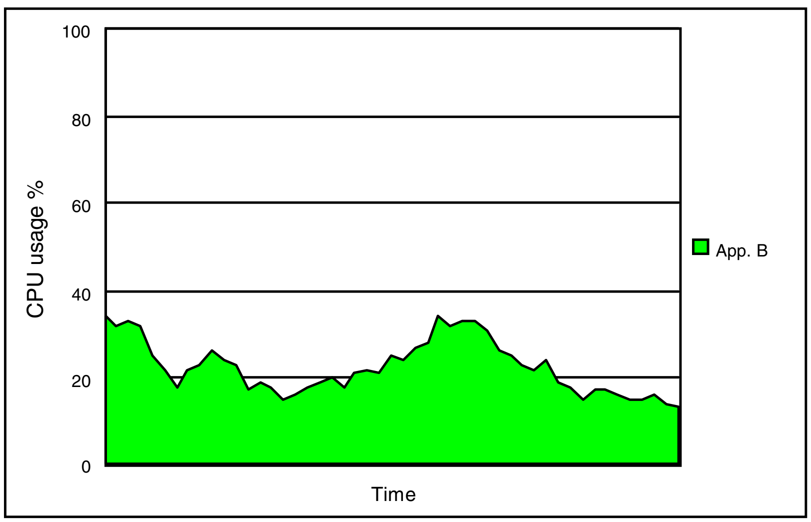


Figure 67. CPU usage pattern of Application B

Application C, shown in Figure 68 on page 175, can be a good example of a nightly batch job.

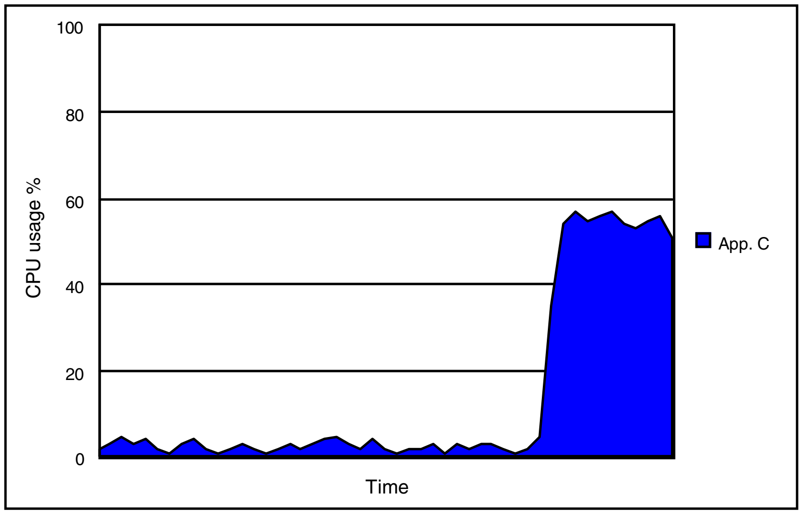


Figure 68. CPU usage pattern of Application C

Application D, shown in Figure 69, has a comparatively flat, constant resource usage pattern.

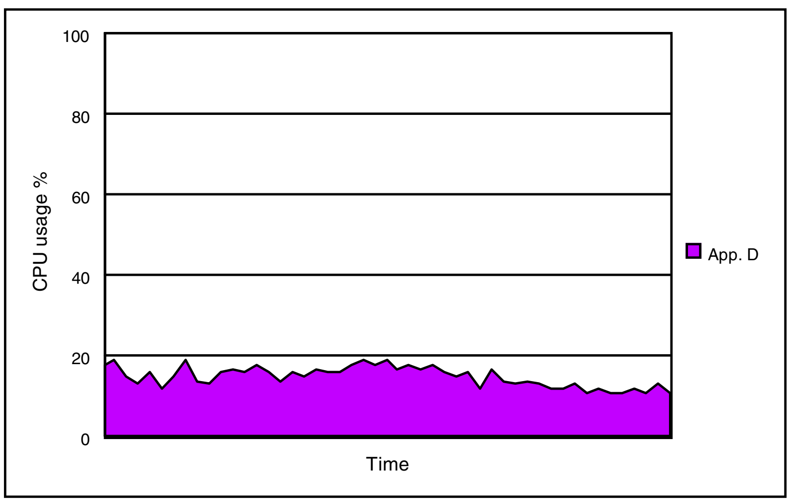


Figure 69. CPU usage pattern of Application D

Assume the capacity of the system on which these individual applications are running is10,000 tpm (transactions per minute). Because the system capacity is 10,000 tpm, each percentage value in the graphs is easily converted, by multiplying by 100, to the actual tpm value that was consumed by each application at the moment of measurement.

The highest peak loads of the applications are as follows:

- Application A: 5,600
- Application B: 3,400
- Application C: 5,700
- Application D: 1,900

The minimum required system capacity for each of the applications, based on the highest peak loads with a moderate buffering factor of 20 percent would be:

- Application A: 5600 X 1.2 = 6,700 tpm
- Application B: 3400 X 1.2 = 4,100 tpm
- Application C: 5700 X 1.2 = 6,800 tpm
- Application D: 1900 X 1.2 = 2,300 tpm

The values below one hundred are rounded here.

If these four applications are run on four individual servers dedicated to each application, the total CPU power needed for these four applications will add up to 19,900 tpm.

Total CPU power = the sum of CPU power of individual systems

= 6,700 + 4,100 + 6,800 + 2,300 = 19,900

The overall CPU utilization percentages of each application that runs on its dedicated individual system that has the respective minimum required system capacity calculated above are calculated as follows:

Resource utilization percentage = (UR / (AR X TU)) X 100

(See Section 7.3.1.2, “Step 2 - Estimate the requirements for each application” on page 171, for detailed information about this calculation.)

- Application A: (86800/(6700X50)) X 100 = 26 percent
- Application B: (111600/(4100X50)) X 100 = 54 percent
- Application C: (73600/(6800X50)) X 100 = 22 percent
- Application D: (74500/(2300X50)) X 100 = 65 percent

You can notice that the less variance the CPU resource utilization pattern shows along with time, the higher overall resource utilization percentage we get.

The average resource utilization percentages of the four systems are calculated as follows:

The average resource utilization percentage = (SUR / (SAR X TU)) X 100

(See Section 7.3.1.2, “Step 2 - Estimate the requirements for each application” on page 171, for detailed information about this calculation.)

The average resource utilization percentages of the four systems
= ((86800+111600+73600+74500) / ((6700+4100+6800+2300)X50)) = 35 percent

7.3.2.2 Approach 1 - All applications are mission-critical

Now, consider using WLM to integrate the four applications on a single server. It is assumed that WLM can address all the obstacles against the application integration on a single system. Then, the usage pattern shown in Figure 70 on page 178 is obtained.

In this case, the minimum required system capacity for the integrated applications based on the highest peak load, with the same buffering factor of 20 percent as before, is estimated as follows:

- The highest peak load in Figure 70 on page 178 is 9700.
- The minimum required capacity = 9700 X 1.2 = 11,600 tpm

The overall CPU usage percentage on the server of this capacity during the given time span would be:

Resource utilization percentage = (UR / (AR X TU)) X 100

(See Section 7.3.1.2, “Step 2 - Estimate the requirements for each application” on page 171, for detailed information about this calculation.)

Resource utilization percentage

= (86800+111600+73600+74500)/(11600X50) X 100 = 60 percent

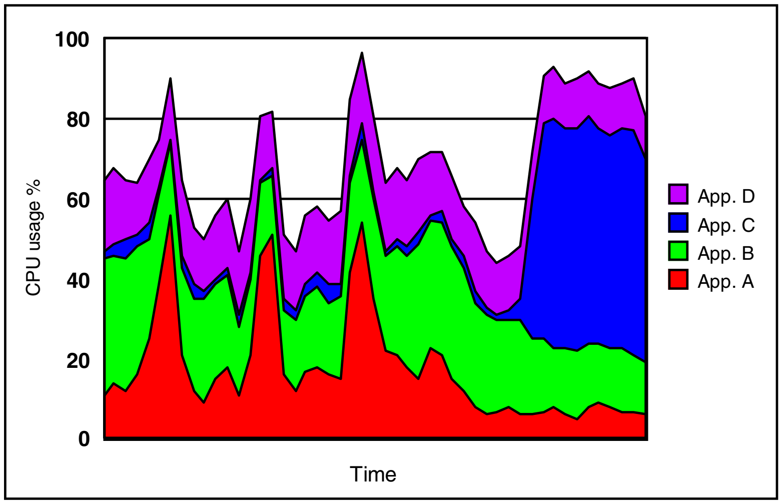


Figure 70. CPU usage pattern of applications integrated on a single server

7.3.2.3 Approach 2 - Only some of the applications are important

The capacity usage benefit of WLM becomes manifest when some of the integrated applications are not mission-critical. If WLM is not used, the system does not offer any practical method to give the higher priority to the more important applications. As a consequence, if the system resource is running short, all applications will contend for the resource, thus, hurting the performance of all applications. To guarantee the performance of some mission-critical applications, the required system capacity has to be estimated based on the top peak load, usually with some percentage of buffer capacity in case of unexpected heavy workloads, even if their duration is short.

The required system capacity can be reduced using WLM, if the performance of some of the integrated applications is not important. WLM can effectively control the resource allocation to each application, with its shares, limits, and tiers, to guarantee the performance of mission-critical applications. Of course, this makes sense only if the performance degradation of the other applications is acceptable to the business.

For example, in Figure 70, assume that Application B and Application D do not require prompt response or output and that only the response time of Application A and the processing time of Application C are important. Then, the required capacity is estimated (with a generous buffering factor of 40 percent) as follows:

The required capacity

= (the top peak of (Application A + Application C)) X 1.4

= 6,500 X 1.4 = 9,100 tpm

Because there are several points at which the total required CPU resource exceeds this value, without WLM, all the applications will be slowed down. However, by using WLM and placing Application A and Application C in a higher tier than the others, we can isolate the important applications from the others. At those points where resource is running short, only Application B and Application D are slowed down, which is acceptable to the overall business operation.

In this case, the overall resource utilization percentage is calculated as follows:

Resource utilization percentage = (UR / (AR X TU)) X 100

(See Section 7.3.1.2, “Step 2 - Estimate the requirements for each application” on page 171, for detailed information about this calculation.)

Resource utilization percentage

= ((86800+111600+73600+74500)/(9100X50)) X 100 = 76 percent

7.3.2.4 Comparison of the cases

You can clearly see the capacity usage benefit of server consolidation using WLM, as shown in Table 4 on page 180.

If you use four individual systems for your applications, you have to pay for four systems with the total capacity of 19,900 tpm, and you will be using only 35 percent of the total available resource. However, if you decide to integrate the applications into one system using WLM, you will need a system of 11,600 tpm, and the overall utilization will be up to 60 percent. Granted that only the performance of Application A and Application C is important, you can cut the estimate down to 9,100 tpm, even with a generous buffering factor of 40 percent. The overall utilization will be as high as 76 percent.

Table 4. Comparison of individual application systems and one integrated system

	Required capacity (tpm)	**Overall utilization (percent)**	**Remarks**
Application A	6,700	26	Pronounced, short peaks in resource usage pattern
Application B	4,100	54	Moderate peaks
Application C	6,800	22	Nightly batch
Application D	2,300	65	The most even resource usage pattern
Sum of A,B,C, and D	19,900	35	Total, and average of the four systems
Integrated applications	11,600	60	
Applications B and D are considered non-critical	9,100	76	There are some points where Applications B and D are slowed down

There are several points that you have to consider before estimating the required system capacity when using AIX WLM.

1. AIX WLM can help improve the overall resource utilization percentage, thus, reducing the required system capacity.
2. AIX WLM can be helpful in improving system capacity usage especially when the resource usage patterns of the applications are quite different from one another.
3. It is recommended that you integrate mission-critical applications with non-critical ones on one system to get the maximum benefit from using WLM.
4. If the overall resource utilization percentages of the individual application servers are already good, for example, more than 70 percent, and if you want to guarantee the performance of all the applications to be integrated into one system, there would be only a little gained in system capacity by using AIX WLM.

Thus, it is very important to have a well-designed plan on the grouping and deployment of different applications to get the expected improvement. For example, in Figure 70 on page 178, it would be a better idea to integrate Application A and Application C, which have different peak time and behavior on one system than to integrate Application B with Application D, both of which have rather constant, even resource utilization patterns. Often, it is more important to make a right selection of applications to be integrated, than to make good property files for WLM configurations.

7.3.3 Considerations for memory and disk I/O bandwidth

Basically, the same methodology can be used to estimate the capacity of memory and disk I/O bandwidth resources as that used to estimate CPU resource. However, special care should be taken when estimating the required capacity of memory since this is, by nature, not a renewable resource, as opposed to CPU, meaning that AIX might first have to take actions in order to provide the application with memory (for instance, freeing up memory pages by paging out the pages that another application is using).

The performance of mission-critical classes can be protected from memory swapping to or from paging spaces by setting generous minimum limits for them and/or placing those classes in a higher tier than the others. The system-defined classes, such as *Shared* and *System*, should be given enough minimum limits to ensure overall constant performance. However, the overall system performance might be degraded when some processes in one class begin to swap to or from paging spaces. It is recommended that you use a more conservative estimation for memory capacity sizing than for CPU capacity sizing.

It certainly helps to guarantee the performance of mission-critical applications by entitling more disk I/O bandwidth to them than to non-critical ones. However, in most situations, it is difficult to trace which process is using which disk for which logical volume. Thus, it is not easy to estimate the capacity usage benefit by using WLM.

7.4 Conclusion

AIX WLM can reduce the required minimum system capacity for applications by enhancing the overall system resource utilization. However, there is no committed capacity gain from using AIX WLM. Only by selecting the right set of applications to be integrated on a single system and by correct planning of the WLM configuration can you benefit from WLM in terms of system capacity usage. It is recommended that you set up the consolidation plan after monitoring the resource utilization pattern of each application.

Chapter 8. Practical experience

This chapter reflects some practical experiences with AIX WLM. The ISV case studies were carried out in the first six months of 2000. Therefore, new features of AIX WLM could not be tested. Readers should be aware of this fact and be motivated to make their own experiences after studying the results of this chapter.

Section 8.2, “Customer experience - WLM and a compute server for research” on page 210, reflects some experiences with WLM in a production environment at the Forschungszentrum Jülich GmbH (Research Center Jülich), in Germany, from the perspective of a system administrator.

8.1 ISV case studies

The case studies have been set up in the PeopleSoft ISV Lab in Austin, Texas USA, and in the IBM SAP International Competence Center (ISICC) in Walldorf, Germany.

The goal of the case studies was to see the effect of various WLM configurations on the different scenarios described in the following sections.

Be aware that the case studies did not focus on tuning the results to optimal performance.

8.1.1 PeopleSoft

The idea of this case study was to run four concurrent PeopleSoft benchmark kits in different combinations and different WLM configurations:

- PeopleSoft General Ledger (GL)
- PeopleSoft Payroll (PAYROLL)
- PeopleSoft Financial (FI)
- PeopleSoft Human Resources (HR)

GL and PAYROLL are batch benchmarks.

FI and HR are OLTP benchmarks.

The primary concern was to demonstrate that one class, such as batch, with high CPU requirements, does not dominate response time for interactive/OLTP workloads.

Because 32bit Oracle was run, it was decided to create four independent databases with four Oracle listener processes to improve performance. By doing this, the total System Global Area (SGA) size for all four benchmarks was about 10 GB, whereas, with a single database, the limit is about 2.5 GB.

8.1.1.1 Case study description

The OLTP benchmarks were run in a logical three tier configuration. With this setup, the number of users in the load was reduced. This means that the database server and application server were installed on the same host.

In the OLTP benchmarks, average retrieve and update response times were measured for an individual client with 1250 FI and 6000 HR concurrent users.

Mercury Interactive's LoadRunner was used to simulate concurrent users. For the FI benchmark, it submitted a business transaction at an average rate of five transactions per second. For the HR benchmark, it submitted a business transaction at an average rate of 13 transactions per second.

SQA Robot was used to automatically submit transactions and record the benchmark measurements on the client PCs. Measurements were recorded when the user load was attained and the environment reached the steady state.

Batch processes are background processes requiring no operator intervention or interactivity. Results of these processes are automatically logged in the database. The runtimes are posted to the Process Request database table. Both batch benchmark processes were initiated at the client workstations. For these benchmarks, all jobs were started from MicroFocus COBOL 4.1 script files executed on the RS/6000 S80 server (see Table 5 on page 187).

In PeopleSoft General Ledger (GL), the batch performance of 40 Journal Edit processes were measured. The eight Journal Post processes were not measured.

The Journal Edit process validates journal entries including items, such as ChartField values, control totals, and debit/credit balancing.

The Journal Post process summarizes detail line activity and either inserts a new row or updates an existing row in the ledger. There is one ledger row for each unique combination of ChartField values, accounting period, and fiscal year. In this benchmark, the Post step updated only existing ledger rows. This is typical for companies that perform the edit and post functions on a frequent basis. The database model represented an extra large organization that processes 3,000,000 journal transactions per run.

The PeopleSoft Payroll benchmark commits 32 jobs. Each of the jobs has three phases: Creation, Calculation, and Confirmation.

The Paysheet Creation process generates payroll data worksheets for employees consisting of standard payroll information for each employee for the given pay cycle. This process ran separately from the other two tasks and was not measured.

The Payroll Calculation process looks at Paysheets and calculates checks for those employees. Payroll Calculation can be run any number of times throughout the pay period. The first run does most of the processing while each successive run updates only the calculated totals of changed items. This interactive design minimizes the time required to calculate a payroll as well as the processing resources required. In this benchmark, Payroll Calculation was run only once as though it was the end of a pay period.

The Payroll Confirmation takes the information generated by Payroll Calculation and updates the employees' balances with the calculated amounts. The system assigns check numbers at this time and creates direct deposit records. Confirm can only be run once and, therefore, must be run at the end of the pay period. Only the last two phases were measured. The database model represented a large organization with 72,000 employees.

8.1.1.2 Case study method

First, each of the benchmarks was run individually on a six-way and 24-way RS/6000 S80 to establish the baseline. In this step, WLM was inactive.

Note

The results of the six-way baseline are not listed for all the tests described in this chapter.

Then, six WLM control files were set up to get a baseline running WLM in passive mode (see Section 8.1.1.3, "WLM configuration" on page 188). Running WLM in passive mode allows you to observe class resource allocations without actually incurring any WLM adjustment. The observed results were used as guidelines for setting up shares and limits in the WLM control files.

After getting a baseline running WLM in passive mode, the benchmarks were started consolidated with WLM in active mode. The goal of these runs was to make the two OLTP benchmarks work better in the consolidated server and not really care about the two batch benchmarks.

Both OLTP benchmarks ran with the GL batch and also with the PAYROLL batch (see Section 8.1.1.4, “One batch - Two OLTP benchmarks: PAYROLL-FI-HR” on page 194, and Section 8.1.1.5, “One batch - Two OLTP benchmarks: GL-FI-HR” on page 195).

Both batch benchmarks ran with two different WLM configuration files with no OLTP benchmark (see Section 8.1.1.6, “Two batch benchmarks: GL-PAYROLL” on page 196).

Finally, all four benchmarks ran with four different WLM configurations (see Section 8.1.1.7, “Two batch - Two OLTP benchmarks: PAYROLL-GL-FI-HR” on page 196). Figure 71 shows the HR OLTP benchmark environment.

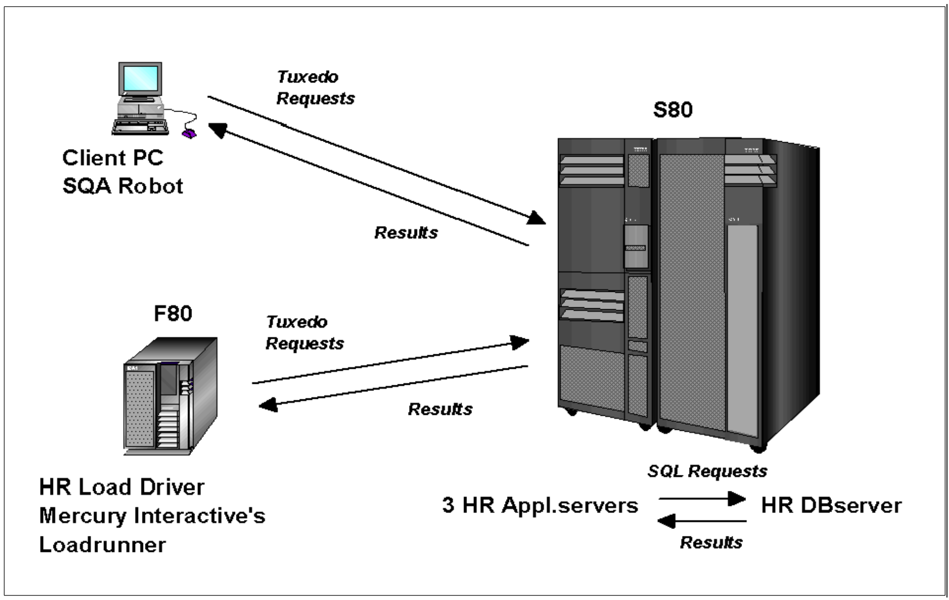


Figure 71. HR OLTP benchmark

The HR OLTP Mercury scripts were started on an RS/6000 F80 (see Table 5 on page 187). Three application server domains, each with 2000 users, ran on the RS/6000 S80 (see Table 5 on page 187). Figure 72 shows the FI OLTP benchmark environment.

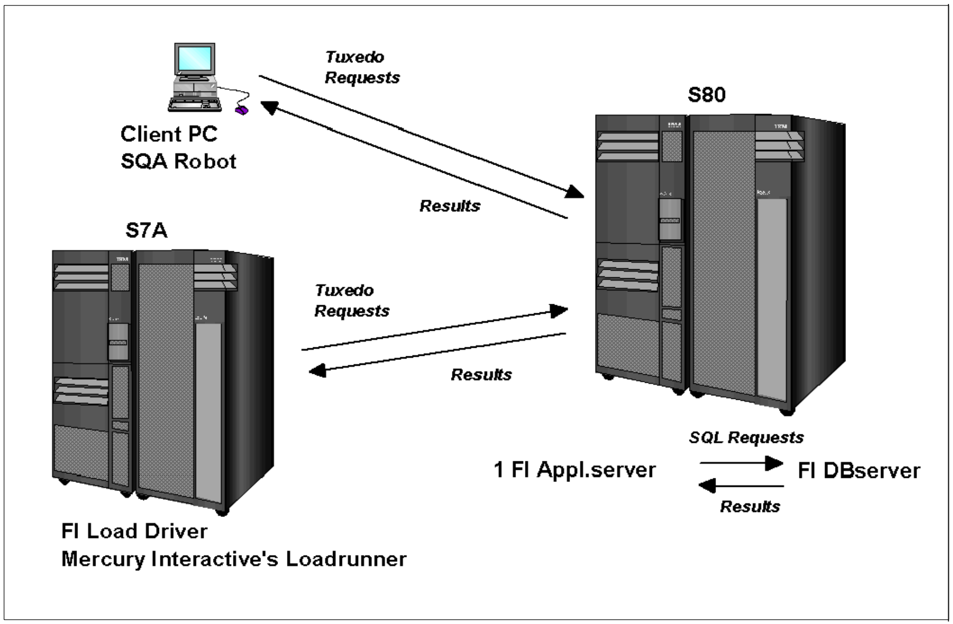


Figure 72. FI OLTP benchmark

The FI OLTP Mercury scripts were started on an RS/6000 S7A (see Table 5 on page 187). One application server domain with 1250 users ran on the RS/6000 S80 (see Table 5 on page 187).

Table 5 gives a list of the hardware configuration used for this case study.

Table 5. PeopleSoft case study HW configuration

Function	Model	CPU	Memory
DB and AP Server (logical 3-tier)	RS/6000 S80	24 Way	32 GB
HR Load Driver	RS/6000 F80	6 Way	16 GB
FI Load Driver	RS/6000 S7A	12 Way	16 GB
2 x Display Server	RS/6000 B50	1 Way	1 GB

Additionally, four PC clients were used as shown in Table 6.

Table 6. PeopleSoft case study PC HW configuration

Function	Clock speed	CPU	Memory
FS Client	400 MHz	1 Way	64 MB

Function	Clock speed	CPU	Memory
HR Client	166 MHz	1 Way	64 MB
PAY Client	180 MHz	1 Way	112 MB
GL Client	180 MHz	1 Way	80 MB

The following is a list of the software used for this case study:

- AIX 4.3.3 Maintenance level 2
- PeopleSoft Financials 7.52
- PeopleSoft Payroll 7.50
- PeopleSoft General Ledger 7.50
- PeopleSoft HRMS 7
- PeopleTools 7.55
- Oracle 8.0.5.1
- BEA TUXEDO 6.4 and 6.5
- Micro Focus COBOL 4.1
- SQR 4.3.2
- Mercury Interactive's LoadRunner 5.02
- Microsoft Windows NT 4.0
- SQA Suite Robot 6.1.0.42
- PAY Client: PT 7.58
- GL Client: PT 7.54.1
- FI Client: PT 7.55
- HR Client: PT 7.54.1

8.1.1.3 WLM configuration

Several WLM configurations were tested with various share and limit combinations.

Eight classes were active. Four classes were supplied by WLM (Unclassified, Shared, System, and Default). Four classes were configured by the benchmark team (pay, gl, fs, and hr).

For the two pseudo-classes (Unclassified and Shared) no classification rules, resource limits, or resource shares can be specified. These classes are outside WLM control and, therefore, fall under default AIX resource allocation control.

A unique user ID was created for each of the four databases. Each user belongs to the DBA group.

The WLM configuration is described in the following tables.

The WLM configuration, p_conf_1 (see Table 7), contains:

- Classes fs, hr, System, and Default: tier=0
- Classes pay and gl: tier=1
- All classes: CPU min=0 percent, max=100 percent, and share=1
- All classes: Memory min=0 percent, max=100 percent, and share=1

Table 7. p_conf_1

Tier	Class	User	CPU	Memory
1	pay	pay750	min=0 max=100 share=1	min=0 max=100 share=1
1	gl	gl75	min=0 max=100 share=1	min=0 max=100 share=1
0	fs	fs75	min=0 max=100 share=1	min=0 max=100 share=1
0	hr	hr75	min=0 max=100 share=1	min=0 max=100 share=1
0	System	root	min=0 max=100 share=1	min=0 max=100 share=1
0	Default	-	min=0 max=100 share=1	min=0 max=100 share=1

WLM configuration, p_conf_2 (see Table 8 on page 190), contains:

- Classes System and Default: tier=0
- Classes pay, gl, fs, and hr: tier=1
- Classes pay and gl: CPU min=0 percent, max=25 percent, and share=25

- Classes pay and gl: Memory min=0 percent, max=100 percent, and share=1
- Classes hr and fs: CPU min=0 percent, max=100 percent, and share=25
- Classes hr and fs: Memory min=0 percent, max=100 percent, and share=1
- Class System: CPU min=0 percent, max=100 percent, and share=1
- Class System: Memory min=1 percent, max=100 percent, and share=1
- Class Default: CPU min=0 percent, max=100 percent, and share=1
- Class Default: Memory min=0 percent, max=100 percent, and share=1

Table 8. p_conf_2

Tier	Class	User	CPU	Memory
1	pay	pay750	min = 0 max = 25 share = 25	min = 0 max = 100 share = 1
1	gl	gl75	min = 0 max = 25 share = 25	min = 0 max = 100 share = 1
1	fs	fs75	min = 0 max = 100 share = 25	min = 0 max = 100 share = 1
1	hr	hr75	min = 0 max = 100 share = 25	min = 0 max = 100 share = 1
0	System	root	min = 0 max = 100 share = 1	min = 1 max = 100 share = 1
0	Default	-	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1

WLM configuration p_conf_3 (see Table 9 on page 191) contains:

- Classes System and Default: tier=0
- Classes fs and hr: tier=1
- Classes pay and gl: tier=7
- All classes: CPU min=0 percent, max=100 percent, and share=1

- All classes: Memory min=0 percent, max=100 percent, and share=1

Table 9. p_conf_3

Tier	Class	User	CPU	Memory
7	pay	pay750	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1
7	gl	gl75	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1
1	fs	fs75	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1
1	hr	hr75	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1
0	System	root	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1
0	Default	-	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1

WLM configuration, p_conf_4 (see Table 10 on page 191), contains:

- Classes System and Default: tier=0
- Classes pay and gl: tier=1
- Classes pay and gl: CPU min=0 percent, max=100 percent, and share=50
- Classes pay and gl: Memory min=0 percent, max=100 percent, and share=1
- Classes System and Default: CPU min=0 percent, max=100 percent, and share=1
- Classes System and Default: Memory min=0 percent, max=100 percent, and share=1

Table 10. p_conf_4

Tier	Class	User	CPU	Memory
1	pay	pay750	min = 0 max = 100 share = 50	min = 0 max = 100 share = 1

Tier	Class	User	CPU	Memory
1	gl	gl75	min = 0 max = 100 share = 50	min = 0 max = 100 share = 1
0	System	root	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1
0	Default	-	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1

WLM configuration p_conf_5 (see Table 11 on page 192) contains:

- Classes System and Default: tier=0
- Classes pay and gl: tier=1
- Class pay: CPU min=0 percent, max=100 percent, and share=32
- Class gl: CPU min=0 percent, max=100 percent, and share=40
- Classes System and Default: CPU min=0 percent, max=100 percent, and share=1
- All classes: Memory min=0 percent, max=100 percent, and share=1

Table 11. p_conf_5

Tier	Class	User	CPU	Memory
1	pay	pay750	min = 0 max = 100 share = 32	min = 0 max = 100 share = 1
1	gl	gl75	min = 0 max = 100 share = 40	min = 0 max = 100 share = 1
0	System	root	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1
0	Default	-	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1

WLM configuration p_conf_6 (see Table 12) contains:

- Classes System and Default: tier=0
- Classes pay, gl, fs, and hr: tier=1

- Classes pay and gl: CPU min=0 percent, max=100 percent, and share=10
- Classes pay and gl: Memory min=0 percent, max=100 percent, and share=1
- Classes fs and hr: CPU min=0 percent, max=100 percent, and share=40
- Classes fs and hr: Memory min=0 percent, max=100 percent, and share=1
- Class System: CPU min=0 percent, max=100 percent, and share=1
- Class System: Memory min=1 percent, max=100 percent, and share=1
- Class Default: CPU min=0 percent, max=100 percent, and share=1
- Class Default: Memory min=0 percent, max=100 percent, and share=1

Table 12. p_conf_6

Tier	Class	User	CPU	Memory
1	pay	pay750	min = 0 max = 100 share = 10	min = 0 max = 100 share = 1
1	gl	gl75	min = 0 max = 100 share = 10	min = 0 max = 100 share = 1
1	fs	fs75	min = 0 max = 100 share = 40	min = 0 max = 100 share = 1
1	hr	hr75	min = 0 max = 100 share = 40	min = 0 max = 100 share = 1
0	System	root	min = 0 max = 100 share = 1	min = 1 max = 100 share = 1
0	Default	-	min = 0 max = 100 share = 1	min = 0 max = 100 share = 1

8.1.1.4 One batch - Two OLTP benchmarks: PAYROLL-FI-HR

Table 13 presents the process results of the two OLTP and one batch benchmark.

Table 13. PAYROLL-FI-HR

Application	Measured data	24-way baseline	WLM passive	WLM active with p_conf_3
PAYROLL (batch)	Calc+Cnfrm/Hr	407,932	227,488	241,530
	Percent CPU	74	41	42
FI (OLTP)	Average Ret	0.530	0.593	0.586
	Average Updte	0.755	1.002	0.868
	Overall Avrge	0.579	0.682	0.647
	Percent CPU	31	27	26
	TPM	257	262	264
HR (OLTP)	Average Ret	0.870	1.254	0.949
	Average Updte	0.672	0.779	0.736
	Overall Avrge	0.791	0.917	0.864
	Percent CPU	26	26	24
	TPM	922	911	897

For the batch benchmark, it shows the number of employees processed per hour for the Calculation and Confirmation phases and the CPU utilization in percent.

For the OLTP benchmarks, it displays the average retrieval time in seconds, the average update time in seconds, the overall average time in seconds, the CPU utilization in percent, and the number of transactions per minute (TPM).

Observations:

- The performance of FI and HR OLTP benchmarks improves when activating WLM.
- The performance of PAYROLL batch benchmark also improves when activating WLM.

8.1.1.5 One batch - Two OLTP benchmarks: GL-FI-HR

Table 14 presents the process results of the two OLTP and one batch benchmark.

Table 14. GL-FI-HR

Application	Measured data	24-way baseline	WLM passive	WLM active with p_conf_3
GL (batch)	Edit	13,088,434	7,680,491	8,125,457
	Percent CPU	82	48	50
FI (OLTP)	Average Ret	0.530	0.703	0.618
	Average Updte	0.755	1.285	0.994
	Overall Avrge	0.579	0.829	0.700
	Percent CPU	31	25	24
	TPM	257	261	261
HR (OLTP)	Average Ret	0.870	1.085	0.972
	Average Updte	0.672	0.867	0.740
	Overall Avrge	0.791	0.998	0.879
	Percent CPU	26	25	24
	TPM	922	911	909

For the batch benchmark, it shows the number of journal lines processed per hour in the Edit phase and the CPU utilization in percent.

For the OLTP benchmarks, it displays the average retrieval time in seconds, average update time in seconds, overall average time in seconds, CPU utilization in percent, and the transactions per minute (TPM).

Observations:

- The performance of FI and HR OLTP benchmarks improves when activating WLM.
- The performance of GL batch benchmark also improves when activating WLM.

8.1.1.6 Two batch benchmarks: GL-PAYROLL

Table 15 presents the process results of the two batch benchmarks with different WLM configurations.

Table 15. GL-PAYROLL

Application	Measured data	24-way baseline	WLM passive	WLM active with p_conf_4	WLM active with p_conf_5
GL (batch)	Edit	13,088,434	9,237,306	9,285,051	9,021,199
	Percent CPU	82	58	58	58
PAYROLL (batch)	Calc+Cnfrm/Hr	407,932	237,938	263,833	245,399
	Percent CPU	74	39	42	39

For the GL benchmark, it presents the number of journal lines processed per hour in the Edit phase and the CPU utilization in percent.

For the PAYROLL benchmark, it presents the number of employees processed per hour for the Calculation and Confirmation phases and the CPU utilization in percent.

Observations:

The performance of GL batch benchmark with 40-32 shares (p_conf_5) has a worse result than the passive or equal shares (p_conf_4) run.

8.1.1.7 Two batch - Two OLTP benchmarks: PAYROLL-GL-FI-HR

Table 16 shows the two batch and two OLTP process results with different WLM configurations.

Table 16. PAYROLL-GL-FI-HR

Application	Measured data	24-way baseline	WLM passive	WLM active with p_conf_3	WLM active with p_conf_6
PAYROLL (batch)	Calc+Cnfrm/Hr	407,932	155,072	145,425	148,423
	Percent CPU	74	24	22	23
GL (batch)	Edit	13,088,434	5,244,846	5,027,567	5,285,877
	Percent CPU	82	29	30	30

Application	Measured data	24-way baseline	WLM passive	WLM active with p_conf_3	WLM active with p_conf_6
FI (OLTP)	Average Ret	0.530	0.821	0.625	(not measured)
	Average Updte	0.755	1.933	1.075	(not measured)
	Overall Avrge	0.579	1.062	0.723	0.738
	Percent CPU	31	24	24	24
	TPM	257	261	262	262
HR (OLTP)	Average Ret	0.870	1.249	1.080	(not measured)
	Average Updte	0.672	1.013	0.821	(not measured)
	Overall Avrge	0.791	1.154	0.976	0.973
	Percent CPU	26	23	23	23
	TPM	922	901	905	904

For the GL benchmark, it shows the number of journal lines processed per hour in the Edit phase and the CPU utilization in percent.

For the PAYROLL benchmark, it displays the number of employees processed per hour for the Calculation and Confirmation phases and the CPU utilization in percent.

For the OLTP benchmarks, it displays the average retrieval time in seconds, the average update time in seconds, the overall average time in seconds, the CPU utilization in percent, and the transactions per minute (TPM).

Observations:

- FI OLTP benchmark performance is best with p_conf_3.
- HR OLTP benchmark performance is best with p_conf_6.
- GL batch benchmark performance is best with p_conf_6.
- Payroll batch benchmark performance is best when running WLM in passive mode.

The following tables display the best results in the top row and the worst results in the bottom row.

p_conf_3
Default and System classes were in tier 0; HR and FI classes were in tier 1 to

provide better fulfillment of their resource requirements, and payroll and GL classes were in tier 7 (see Table 9 on page 191). Table 17 contains an overview of the results for p_conf_3.

Table 17. Overview of the results for p_conf_3

Payroll	**GL**	**HR**	**FI**
24-way baseline 407,932 emp/hr	24-way baseline 13,088,434 lines/hr	24-way baseline 0.791 sec	24-way baseline 0.579 sec
6-way baseline 158,486 emp/hr	WLM passive 5,244,846 lines/hr	WLM active 0.976 sec	WLM active 0.723 sec
WLM passive 155,072 emp/hr	WLM active 5,027,567 lines/hr	6-way baseline 0.990 sec	6-way baseline 0.756 sec
WLM active 145,425 emp/hr	6-way baseline 3,794,586 lines/hr	WLM passive 1.154 sec	WLM passive 1.062 sec

p_conf_6

Default and System classes were in tier 0; all four benchmark classes were in tier 1, and the shares were adjusted in the shares file (see Table 12 on page 193). Table 18 contains an overview of the results for p_conf_6.

Table 18. Overview of the results for p_conf_6

Payroll (batch)	**GL (batch)**	**HR (OLTP)**	**FI (OLTP)**
24-way baseline 407,932 emp/hr	24-way baseline 13,088,434 lines/hr	24-way baseline 0.791 sec	24-way baseline 0.579 sec
6-way baseline 158,486 emp/hr	WLM active 5,285,877 lines/hr	WLM active 0.973 sec	WLM active 0.738 sec
WLM passive 155,072 emp/hr	WLM passive 5,244,846 lines/hr	6-way baseline 0.990 sec	6-way baseline 0.756 sec
WLM active 148,423 emp/hr	6-way baseline 3,794,586 lines/hr	WLM passive 1.154 sec	WLM passive 1.062 sec

8.1.1.8 Summary

Without the involvement of WLM, three out of the four workloads suffered from server consolidation, that is, running WLM in passive mode.

The CPU-intensive batch jobs dominated the usage of the CPU resource.

- Both OLTP benchmarks suffered from the server consolidation.
- The Payroll benchmark suffered from the server consolidation.
- The General Ledger benchmark benefited from the server consolidation.

Setting WLM active improves all three benchmarks that suffered before:

- The two OLTP benchmarks no longer suffer from the server consolidation. In fact, some performance gains were observed.
- The performance of the General Ledger benchmark improved.
- The Payroll benchmark's performance decreased even more.

Since the WLM configuration was only targeted to bring up the performance of online benchmarks, these results were expected.

The goals were accomplished with appropriate resource share allocation. Finer control can be further accomplished by observing the resource allocation of each class and making more adjustments.

Another attempt with OLTP benchmarks in tier 0 and batch benchmarks in tier 1 (p_conf_1, see Table 7 on page 189) did not accomplish the goals.

8.1.2 SAP R/3

There are at least three situations where WLM can be used to manage a large R/3 server.

Buffering R/3 from non-R/3 applications

Here, an R/3 system is running on a server with other non-R/3 applications, such as print spooling, backup, decision support, or tape library management.

In this environment, WLM manages two important issues: It guarantees the operation of the R/3 system without any interference from other non-R/3 applications, and it secures sufficient resources to keep R/3 from dominating other non-R/3 applications. This is the easiest of the situations to configure and manage WLM, because the classes are easy to define and resource allocation is relatively simple.

Using two or more R/3 instances with a single database

In the second situation, multiple R/3 server application instances for a single R/3 system are placed on a single large server.

WLM can be used to ensure that each instance always has at least the minimum required resources available. A very desirable implementation of WLM is to separate all batch activities into specific instances and put these at a lower priority than the OLTP instances.

However, you have to be aware of the fact that even though you have multiple instances of a single R/3 system on a host, they all run as the same user and group. Also, they all use the same executables. There is only one difference in the processes. The processes from each of the instances are started via a link, and the link name is related to the instance number.

A workprocess for the instance, DV01, would appear using `ps -ef` as dw.sapSID_DV01, and the instance, DV02, would appear as dw.sapSID_DV02.

Each of these would be running the same executable loaded from the same runtime directory. By executing `xmpeek -l`, you see that the exe is named disp+work. The process is started from a link in an instance private directory:

- /usr/sap/SID/DV01/work/dw.sapSID_DV01
- /usr/sap/SID/DV01/work/dw.sapSID_DV02

At the time the case study was set up, important WLM features were not available. The API of WLM released with AIX 5L (see Section Section 2.8, “WLM Application Programming Interface (API)” on page 30) allows you to set up a new process attribute that can be used as a classification criteria to differentiate between two instances.

SAP is integrating APIs into its Computing Center Management System (CCMS) modules. The CCMS Monitoring Architecture offers a read API for the usage in partners’ System Management products. The library is available as a static library, alxxrlib.[o|obj|lib], and, for some platforms, as the shared library, ccmsrdsl.[o|so|dll]. Each vendor can develop applications that interface with CCMS; for example, Tivoli uses APIs through CCMS. One approach is to check the usage of WLM API and application tagging with R/3.

If you are using the CCMS API and application tagging, you should be aware that this is not so easy to realize since it requires that new scripts be developed or code to be changed.

Another idea is to check if manual assignment (see Chapter 5, “Manual assignment” on page 141) might be a possible solution. If application tagging is not being used, WLM cannot automatically place database or R/3 instances in different classes, but, with the manual assignment function, a process or a group of processes can be manually assigned to different classes.

The ISICC team is working on this issue and look forward to finding a solution to enable a multiple instance scenario with SAP R/3 under WLM.

Using two or more R/3 instances with separate databases

This is the most common situation where users want to put multiple R/3 instances representing separate R/3 systems on a single large server. These are independent R/3 systems, such as test, development, and training systems.

Currently, SAP is very restrictive in supporting more than one production system on a single server. Also, it is not supported to put one (or several) production systems with other R/3 systems on a single server. The reason for this constraint is that it will be impossible to precisely monitor the performance of any of the systems in the CCMS modules that are totally independent of each other. In this case, the SAP Technical Competence Center (TCC) will be unable to use the existing SAP tools, such as EarlySupport, to support their customers. This is the case with or without WLM. Today, a script, called *saposcol*, is running on all instances and collects operating system information, such as CPU and memory usage, and feeds the SAP monitoring tool, CCMS.

In AIX 5L, WLM provides performance monitoring tools, such as topas and svmon (see Chapter 4, “WLM performance tools” on page 97). These tools can monitor superclasses or subclasses assigned to an R/3 system and the system utilization can be clearly separated from the other workloads running on the server.

Accordingly, since it is easy to differentiate the jobs of the various instances by user ID, this is also an easy situation to define and configure. As long as the shared server is acceptably sized, WLM could be used to ensure that each instance runs within the resource boundaries set for it.

There are at least three approaches to monitoring several R/3 systems using WLM with the SAP monitoring tool:

- Modifying the saposcol script
- Creating a new monitoring object within the CCMS modules
- Using the new CCMS agent developed for mySAP.com

The case study team will test the WLM performance monitoring tools released in AIX 5L and verify the use of WLM with these three approaches.

8.1.2.1 Case study description

The idea of this study was to install two central SAP R/3 systems, TS1 and TS2, each with its own Oracle database to drive different tests with different WLM configurations. Both 2-tier SAP R/3 systems were configured identically.

The following R/3 sessions were defined for each instance:

DIA	Six dialogue sessions
VB	Two synchronous update sessions
VB2	Two asynchronous update sessions
ENQ	One enqueue session
BTC	One batch session
SPO	One spooler session

Each instance has two standard R/3 users:

- ts1adm and orats1
- ts2adm and orats2

For each instance, separate logical volumes and filesystems were defined over five physical SSA disks.

8.1.2.2 Case study method

Table 19 lists the hardware configuration used for this case study.

Table 19. SAP case study HW configuration

Function	Model	CPU	Memory
Central instance TS1	RS/6000 H70	4 Way	6 GB
Central instance TS2	RS/6000 H70	4 Way	6 GB

The following list shows the software configuration used for this case study:

- AIX 4.3.3.0
- SAP R/3 Rel. 4.0B patchlevel 631
- Oracle 8.0.4

The Sales and Distribution (SD) Benchmark driver was used to load both instances. It simulates different levels of user activity. The SD benchmark is one of the most CPU-consuming benchmarks. It is, primarily, used for hardware sizing and upper limit studies on new hardware. The dialog steps of the standard SD Benchmark are shown in Figure 73.

0	Logon		11	Call /nvl02	(Change delivery)
1	Main screen		12	[F9]	(Posts goods issue)
2	Call /nva01	(Create customer order)	13	Call /nva05	(List orders)
3	1st screen		14	[Enter]	
4	2nd screen	(with 5 items)			
5	[F11 - Save]		15	Call /nvf01	(Create invoice)
			16	[F11 - Save]	
6	Call /nvl01	(Create a delivery)			
7	1st screen		17	Call /nend	
8	[F11 - Save]		18	Confirm logoff	
9	Call /nva03	(Display customer order)			
10	[Enter]				

Dialog steps 2 to 16 are repeated n times (15 dialog steps --> min. 150 sec duration).

Business aspect:
One run (dialog steps 2 to 16) corresponds to the selling of 5 items

Figure 73. Dialog steps SD benchmark

8.1.2.3 WLM configuration

Like the PeopleSoft Case Study, several WLM configurations were tried with various share and limit combinations.

A list of classes follows:

Default	The WLM default class
System	The WLM system class
TS1	Instance TS1
TS2	Instance TS2
LOADER	Sample non-R/3 application
ORATS1	Oracle processes of instance TS1
ORATS2	Oracle processes of instance TS2
TS1Gp1	R/3 instance 00 of TS1
TS1Gp2	R/3 instance 01 of TS1

User and groups were standard R/3 user. For the non-R/3 application, a user (test), was created.

The WLM configuration is described in the following tables.

WLM configuration s_conf_1 (see Table 20 on page 204) contains:

- All classes: tier=0
- Classes TS1 and TS2: CPU min=0 percent, max=100 percent, share=45
- Classes TS1 and TS2: Memory min=0 percent, max=100 percent, share=45
- Class System: CPU min=0 percent, max=100 percent, share=10
- Class System: Memory min=0 percent, max=100 percent, share=10
- Class Default: CPU min=0 percent, max=100 percent, share=1
- Class Default: Memory min=0 percent, max=100 percent, share=1

Table 20. s_conf_1

Tier	Class	User	CPU	Memory
0	TS1	ts1adm, orats1	min=0 max=100 share=45	min=0 max=100 share=45
0	TS2	ts2adm, orats2	min=0 max=100 share=45	min=0 max=100 share=45
0	System	root	min=0 max=100 share=10	min=0 max=100 share=10
0	Default	-	min=0 max=100 share=1	min=0 max=100 share=1

The WLM configuration s_conf_2 (see Table 21 on page 205) contains:

- All classes: tier=0
- Classes TS1, TS2, ORATS1, and ORATS2: CPU min=0 percent, max=100 percent, share=45
- Classes TS1, TS2, ORATS1, and ORATS2: Memory min=0 percent, max=100 percent, share=45
- Class System: CPU min=0 percent, max=100 percent, share=10
- Class System: Memory min=0 percent, max=100 percent, share=10
- Class Default: CPU min=0 percent, max=100 percent, share=1

- Class Default: Memory min=0 percent, max=100 percent, share=1

Table 21. s_conf_2

Tier	Class	User	CPU	Memory
0	TS1	ts1adm	min=0 max=100 share=45	min=0 max=100 share=45
0	TS2	ts2adm	min=0 max=100 share=45	min=0 max=100 share=45
0	ORATS1	orats1	min=0 max=100 share=45	min=0 max=100 share=45
0	ORATS2	orats2	min=0 max=100 share=45	min=0 max=100 share=45
0	System	root	min=0 max=100 share=10	min=0 max=100 share=10
0	Default	-	min=0 max=100 share=1	min=0 max=100 share=1

The WLM configuration is described in the following tables.

The WLM configuration, s_conf_3 (see Table 22 on page 206), contains:

- All classes: tier=0
- Classes ORATS1, TS1Gp1, and TS1Gp2: CPU min=0 percent, max=75 percent, share=30
- Classes ORATS1, TS1Gp1, and TS1Gp2: Memory min=0 percent, max=100 percent, share=30
- Class TS1Gp1: Application=/usr/sap/TS1/DV00/work/dw.sapTS1_DV00
- Class TS1Gp2: Application=/usr/sap/TS1/DV01/work/dw.sapTS1_DV01
- Class System: CPU min=0 percent, max=100 percent, share=10
- Class System: Memory min=0 percent, max=100 percent, share=10
- Class Default: CPU min=0 percent, max=100 percent, share=1

- Class Default: Memory min=0 percent, max=100 percent, share=1

Table 22. s_conf_3

Tier	Class	User	Application	CPU	Memory
0	ORATS1	orats1	-	min=0 max=75 share=30	min=0 max=100 share=30
0	TS1Gp1	ts1adm	/usr/sap/TS1/ DV00/work/ dw.sapTS1_ DV00	min=0 max=75 share=30	min=0 max=100 share=30
0	TS1Gp2	ts1adm	/usr/sap/TS1/ DV01/work/ dw.sapTS1_ DV01	min=0 max=75 share=30	min=0 max=100 share=30
0	System	root	-	min=0 max=100 share=10	min=0 max=100 share=10
0	Default	-	-	min=0 max=100 share=1	min=0 max=100 share=1

The WLM configuration, s_conf_4 (see Table 23 on page 206), contains:

- All classes: tier=0
- Class TS1: CPU min=0 percent, max=100 percent, share=50
- Class TS1: Memory min=0 percent, max=50 percent, share=10
- Class LOADER: CPU min=0 percent, max=30 percent, share=30
- Class LOADER: Memory min=0 percent, max=30 percent, share=30
- Class System: CPU min=0 percent, max=100 percent, share=10
- Class System: Memory min=0 percent, max=100 percent, share=10
- Class Default: CPU min=0 percent, max=100 percent, share=1
- Class Default: Memory min=0 percent, max=100 percent, share=1

Table 23. s_conf_4

Tier	Class	User	CPU	Memory
0	TS1	ts1adm	min=0 max=100 share=50	min=0 max=50 share=10

Tier	Class	User	CPU	Memory
0	LOADER	test	min=0 max=30 share=30	min=0 max=30 share=30
0	System	root	min=0 max=100 share=10	min=0 max=100 share=10
0	Default	-	min=0 max=100 share=1	min=0 max=100 share=1

The WLM configuration, s_conf_5 (see Table 24), contains:

- All classes: tier=0
- Class TS1: CPU min=0 percent, max=100 percent, share=70
- Class TS1: Memory min=0 percent, max=100 percent, share=50
- Class LOADER: CPU min=0 percent, max=50 percent, share=100
- Class LOADER: Memory min=0 percent, max=50 percent, share=100
- Class System: CPU min=0 percent, max=100 percent, share=10
- Class System: Memory min=0 percent, max=100 percent, share=10
- Class Default: CPU min=0 percent, max=100 percent, share=1
- Class Default: Memory min=0 percent, max=100 percent, share=1

Table 24. s_conf_5

Tier	Class	User	CPU	Memory
0	TS1	ts1adm	min=0 max=100 share=70	min=0 max=100 share=50
0	LOADER	test	min=0 max=100 share=50	min=0 max=100 share=50
0	System	root	min=0 max=100 share=10	min=0 max=100 share=10
0	Default	-	min=0 max=100 share=1	min=0 max=100 share=1

8.1.2.4 Two R/3 instances with separate databases

For this test, the WLM configuration, s_conf_1 (see Table 20 on page 204), was used. Workload was generated by loading from 50 to 150 users per instance driving the system to 95 percent CPU. Each Oracle instance used a separate listener, which insured the integrity of shadow process classification.

This test confirmed that WLM worked to allocate resources between two SAP R/3 systems.

However, an improperly-configured WLM setup could degrade performance on a host with two or more perfectly tuned R/3 instances.

A second test was performed similar to test 1 but with two additional classes for the Oracle processes (see WLM configuration s_conf_2, Table 21 on page 205). No advantage was seen for this configuration, but there was a slightly higher overhead for WLM.

8.1.2.5 Two R/3 instances with a single database

This test was driven by using the WLM configuration, s_conf_3 (see Table 22 on page 206), without using multiple Oracle listeners.

It was very difficult to use program names as a way of including or excluding processes from a class because R/3 makes extensive use of links, and most processes actually run the same procedure.

As was mentioned in Section 8.1.2, “SAP R/3” on page 199, this scenario will be tested by using the API of WLM and setting up an application tag that can be used as a classification criteria to distinguish between two instances. The possibility of manual assignment solving the problem will also be checked.

8.1.2.6 R/3 and non-R/3 application

Here, only one R/3 instance was run against a locally-written load generation program that spawned multiple processes, each loading lists of files found on the server into memory arrays.

This test confirmed that WLM can easily be used to manage the allocation of resources between an R/3 instance and a non-R/3 application sharing a single host. Basically, this use of WLM is the best way to prevent non-R/3 applications from taking over system resources.

8.1.2.7 Special considerations for using WLM with R/3

SAP R/3 is designed to use memory to achieve maximum performance and throughput. Therefore, memory is very important to an R/3 installation and can have a dramatic impact on performance.

Shared memory is not a problem since most memory sharing is within an instance. When multiple R/3 instances run on a common host, some memory is shared across instances. Minimum resources are used by saposcol, for example, and the fact that it will be placed in a single class is of little consequence.

Memory management is of vital concern. Memory planning becomes even more critical when using WLM. This is especially true if WLM memory limits are to be used to restrict memory availability to an R/3 instance (when partitioning memory between multiple R/3 instances). If more memory is defined within the R/3 configuration than is made available through WLM memory management, unnecessary page stealing can occur resulting in declining system performance. Also, if too little memory is available to an R/3 system, extensive swapping can occur. The effect is a dramatic performance degradation. Therefore, it is easier to guarantee minimum memory availability to instances.

If WLM is planned for use on a R/3 Central Instance host supporting multiple R/3 instances and databases, it is a requirement to classify processes by instance. The standard installation of an SAP R/3 instance or of an Oracle database installs and configures a single listener process, regardless of how many Oracle databases are installed. The Oracle listener process spawns Oracle processes to talk to the database (shadow processes).

There is, generally, one shadow process spawned for each R/3 work process associated with that instance. Because WLM classifies processes based on the process that spawns them, in a standard setup, these processes are all assigned to the same class as the listener, regardless of the instance they belong to. To correctly classify shadow processes, processes have to be identified by their unique job names rather than just by user.

Although, DB2 was not tested, these special considerations would also effect instances using DB2 databases.

For the latest information about SAP's position regarding the usage of WLM in SAP R/3 or mySAP.com scenarios, please refer to SAP R/3 note 21960. R/3 notes are available on the SAP service marketplace (former SAPNet) under the following URL:

http://service.sap.com

8.2 Customer experience - WLM and a compute server for research

The following chapter describes how WLM is used on a central AIX server in a research environment where interactive and batch work is done on the same machine.

When WLM was presented by IBM at the SHARE conference (IBM user organization) in Anaheim, CA in March 2000, it was obvious that WLM was the long awaited tool to overcome some problems in managing AIX, especially distributing resources according to installation-specified policies. In April, WLM was installed and ran successfully in passive mode. In May 2000, it was decided to use WLM on the production system in active mode.

8.2.1 The installation

The Forschungszentrum Jülich GmbH (Research Center Jülich), one of 16 Helmholtz research centers in Germany, links all its work to the common denominator, “The future is our mission”. A staff of 4300 are devoted to investigating current issues in the areas of energy, environment, life, information, and matter in one of the largest research institutes in Europe. In Jülich, scientists from many different disciplines including physics, chemistry, biology, medicine, and engineering work closely together. This work results in contributions to basic research and long-term programs, applied research, and key technologies. For more information about the Jülich Research Center, visit the following Web site:

http://www.fz-juelich.de

The Central Institute for Applied Mathematics (ZAM) within Forschungszentrum Jülich is responsible for the planning, installation, and operation of the supercomputers and central server systems and of the campus-wide computer networks and communication systems. The services comprise all functions of a computer center including user support.

As part of the John von Neumann Institute for Computing (NIC), ZAM provides supercomputer resources for the scientific community in Germany. For more information about the Central Institute for Applied Mathematics, visit the following Web site:

http://www.fz-juelich.de/zam

ZAM runs one of the most powerful scientific computer centers in Europe with six supercomputers, an IBM server, and a series of systems for special purposes, such as visualization and communications.

For a detailed configuration, see the following Web site:
`http://www.fz-juelich.de/zam/CompServ/services/config.html`

8.2.2 The central AIX system

The central computing system offers a wide spectrum of application software. It is used interactively and offers batch services for long running jobs. The hardware and software configuration of the system is as follows:

- RS/6000 44P-270, 4 Way, 8GB RAM
- Operating System AIX 4.3.3-03
- Batch-System LoadLeveler V1.3
- Overall peak performance 4.8 Gigaflops
- Concurrent users (peak) approximate 150
- Joined users approximate 1650
- Disk capacity for user data 360 GB

This system allows users without local computing resources, to access Unix applications via X-terminals or PCs with an appropriate X emulation. It is an application server for software. It is available as a computing resource for scalar, interactive, and batch work. In particular, applications with demands for large virtual memory run extremely well on this machine.

8.2.3 Problems

When the same server is used for interactive and batch work, the distribution of resources between these two different workloads is a difficult task. On one side, interactive work should experience the optimum performance to give scientists the best response time for their current work. On the other side, batch jobs using several hours of CPU time should have reasonable turn-around times.

Batch jobs in this environment are typically CPU-bound.

When we tried to maximize system utilization by allowing as many batch jobs to run as there were processors, interactive users complained about excessive response times.

When the number of simultaneous batch jobs was reduced, batch users complained about idle system time and long queues for their batch jobs.

Another problem showed up during the production period: Interactive X-terminal users often started Netscape processes on the central machine because they had no other workstation or PC to browse the Internet. Depending on the Web site visited, these Netscape processes sometimes went into a tight CPU loop without doing anything useful according to the user. What is worse, these tight CPU loops were not automatically ended through the *cpu_hard* parameter in /etc/security/limits.

8.2.4 A pre-WLM solution

To overcome the problems in AIX releases without WLM, the following rules were adopted and put in place:

- Half of the CPUs are reserved for interactive work only at prime times (workdays from 8:00 a.m. to 6:00 p.m.).
- At least one CPU is reserved for interactive work all the time.
- Interactive work is limited to 30 CPU minutes per process.
- Batch jobs (submitted through LoadLeveler) can use up to 10 hours of CPU time.
- Batch jobs (submitted through LoadLeveler) run at a lower priority (higher nice values).
- Netscape processes are killed without warning if they have used 30 minutes of CPU time.

8.2.5 The WLM solution with AIX Version 4.3.3-02

The WLM files listed in Table 25 were defined for peak times (Monday through Friday, 8:00 a.m. to 6:00 p.m.).

Table 25. WLM configuration for peak time

Tier	Class	User	Application	CPU	Memory
9	slow		/usr/local/ netscape/ netscape_aix4	min=0 max=10 share=1	min=0 max=10 share=1
2	batch	batuser1		min=0 max=100 share=100	min=0 max=100 share=100

Tier	Class	User	Application	CPU	Memory
2	batch	batuser2		min=0 max=100 share=100	min=0 max=100 share=100
2	batch	batuser3		min=0 max=100 share=100	min=0 max=100 share=100
2	batch	batuser.		min=0 max=100 share=100	min=0 max=100 share=100
2	batch	batuser99		min=0 max=100 share=100	min=0 max=100 share=100
0	System	root		min=10 max=100 share=200	min=13 max=100 share=200
0	System	loadl		min=10 max=100 share=200	min=13 max=100 share=200
0	System	admusr		min=10 max=100 share=200	min=13 max=100 share=200
0	System	dispatch		min=10 max=100 share=200	min=13 max=100 share=200
1	Default			min=20 max=100 share=100	min=20 max=100 share=100

Two adjustments were made for offpeak time:

- tier value batch class = tier value Default class
- shares batch class = 1/2 shares Default class

Table 26. WLM configuration for offpeak time

Tier	Class	User	Application	CPU	Memory
9	slow		/usr/local/ netscape/ netscape_aix4	min=0 max=10 share=1	min=0 max=10 share=1

Tier	Class	User	Application	CPU	Memory
1	batch	batuser1		min=0 max=100 share=50	min=0 max=100 share=50
1	batch	batuser2		min=0 max=100 share=50	min=0 max=100 share=50
1	batch	batuser3		min=0 max=100 share=50	min=0 max=100 share=50
1	batch	batuser.		min=0 max=100 share=50	min=0 max=100 share=50
1	batch	batuser99		min=0 max=100 share=50	min=0 max=100 share=50
0	System	root		min=10 max=100 share=200	min=13 max=100 share=200
0	System	loadl		min=10 max=100 share=200	min=13 max=100 share=200
0	System	admusr		min=10 max=100 share=200	min=13 max=100 share=200
0	System	dispatch		min=10 max=100 share=200	min=13 max=100 share=200
1	Default			min=20 max=100 share=100	min=20 max=100 share=100

With these definitions, WLM was started in passive mode, and the `wlmstat` output was analyzed. After some minor adjustments, WLM was run in active mode:

Peak time (Monday till Friday, 8 am to 6 pm): `wlmcntrl -d peak`

Other: `wlmctrnl -d offpeak`

The 30 minutes CPU time limit for interactive processes was still in effect in /etc/security/limits.

8.2.5.1 Major advantages of this solution

More batch jobs could be started without disturbing interactive users because, in peak times, the batch jobs with their lower tier value could just absorb the CPU cycles of the machine that would go idle otherwise. In this way, a higher batch load could take advantage of the overlaps of I/O and CPU demands.

The priority of Netscape processes can now never be higher than any other processes.

8.2.5.2 Disadvantage of this solution

Sometimes, batch users wanted to do some interactive work at the same time. Because their user ID was defined in the rules file belonging to the batch class they had to use different user IDs to prevent the system from running their interactive work with the batch tier.

This is, of course, not practical and creates an administrative nightmare. So, the inheritance feature of WLM allowing the class inheritance of processes started by LoadLeveler was really needed badly.

8.2.6 The second WLM solution with AIX 5L

Among many additional features, the new functions of WLM released in AIX 5L allow the class inheritance of processes started by a batch system (that is LoadLeveler). With this enhancement, the definition of the WLM files is now very easy. Table 27 shows the WLM configuration with AIX 5L.

Table 27. WLM configuration with AIX 5L

Tier	Class	Inheritance	User	Application	CPU	Memory
9	slow	no		/usr/local/ netscape/ netscape_aix4	min=0 max=10 share=1	min=0 max=10 share=1
2	batch	yes		~loadl/bin/ LoadL_starter	min=0 max=100 share=100	min=0 max=100 share=100
0	System	no	root		min=10 max=100 share=200	min=13 max=100 share=200

Tier	Class	Inheritance	User	Application	CPU	Memory
0	System	no	loadl		min=10 max=100 share=200	min=13 max=100 share=200
0	System	no	admusr		min=10 max=100 share=200	min=13 max=100 share=200
0	System	no	dispatch		min=10 max=100 share=200	min=13 max=100 share=200
1	Default	no			min=20 max=100 share=100	min=20 max=100 share=100

These changes allow batch processes to inherit the class characteristics of the LoadLeveler starter process. They combine the advantages of the previous WLM release and get rid of its disadvantages.

8.2.7 Conclusion

WLM allows an installation to administer the system in a much more flexible way compared to previous AIX releases. There is no additional effort to install WLM because it is included in the AIX kernel. Configuring WLM is very easy:

1. Start up with a simple model.
2. Run WLM in passive mode.
3. Do some refinements.
4. Repeat the last two steps a few times.
5. Run WLM in active mode.
6. Collect statistics with wlmstat to see if the defined goals are achieved.
7. Modify shares, rules, and tiers.
8. Go to step 6.
9. Decide which is your best WLM configuration.

This process could be done over a few days. It is a powerful tool to allow resources to be distributed to users in an installation-defined policy. For the first time, service level agreements can be negotiated and enforced in a production environment.

Appendix A. AIX Workload Manager API routines

The WLM API routines are described in this appendix from a technical viewpoint, for practical utilization purposes.

A.1 The Include file - sys/wlm.h

Purpose

Defines the constants, data structures and function prototypes used by the Workload Manager Application Programming Interface (API) routines.

Description

The wlm.h file defines the *wlm_args*, *wlm_assign*, *wlm_info* and *wlm_bio_class_info* structures, which are used by the WLM API functions in libwlm.a.

Data structures

The *wlm_args* structure is used to pass class information to WLM when using the API functions to create, modify or delete a class.

The *wlm_args* structure has the following fields:

Field	Description
`versflags`	The four high order bits contain a version number used by the API to maintain binary compatibility in the event of future modifications of the data structures. The rest of the integer will be used to pass flags to the API functions when needed. This field should be initialized with a logical OR between the version number, WLM_VERSION, and whatever flags are needed by the target function. One flag common to all the API call is WLM_MUTE, which is used to suppress the output of error messages from the WLM library on stderr.
`confdir`	Null-terminated string. This field must be initialized with the name of the WLM configuration the target API function applies to (when applicable - see individual API subroutines). Alternatively, this field can be set to a null string (\0) to indicate that the class addition/modification is to be applied only to the WLM kernel data and not to the class description files.

Field	Description
`class`	This field is a structure of type struct, *class_definition*, which contains all the information pertaining to the superclass or subclass needed by the target API function. The fields in this structure can be initialized by a call to `wlm_init_class_definition` so that programmers will only have to initialize the fields they wish to modify.

The main structure in *class_definition* is the class description, struct *class_descr* with the following fields:

Field	Description
`res`	An array of type struct wlm_bounds containing for each resource type: *min*: Minimum limit: value between 0 (default) and 100. *shares*: Shares number: value between 1 and 65535. The value -1 (default) indicates that the given resource is not managed by WLM for this class. *softmax*: Soft maximum limit: value between 0 and 100 (default). Must be greater than or equal to min. *hardmax*: Hard maximum limit: value between 0 and 100 (default). Must be greater than or equal to min and softmax. The resource types are defined as WLM_RES_CPU, WLM_RES_MEM and WLM_RES_BIO. Each value represents the index in the array of the element corresponding to the type of resource.
`tier`	Tier number for the class: value between 0 (default) and 9.
`inheritance`	Flag to indicate whether a new process should be automatically classified on `exec` using the assignment rules (value 0, which is the default), or just inherit the class from its parent process (value 1).
`assign_uid`	User ID of the user allowed to manually assign processes to this class. When specified, it must be a valid user ID. The default when this attribute is not specified is that no user is authorized (WLM_NOGUID).

Field	Description
`assign_gid`	Group ID of the group of users allowed to manually assign processes to this class. When specified, it must be a valid group ID. The default when this attribute is not specified is that no group is authorized (WLM_NOGUID). If both assign_uid and assign_gid are left to their default value (WLM_NOGUID), only root can assign processes to the class.
`admin_uid`	The user ID of the user allowed to administrate the subclasses of the superclass (superclass only).
`admin_gid`	Group ID of the users allowed to administrate the subclasses of the superclass (superclass only). If both admin_uid and admin_gid are left to their default value (-1), only root can administrate the subclasses of this superclass.
`name`	The null-terminated full name of the class in the form supername, for a superclass and *supername.subname* for a subclass. The superclass name, supername, and the subclass names, subname, above are both limited to 16 characters. There is no default value for this field.

In addition to the class description, *class_definition* adds two fields:

Field	Description
`rset_name`	A null-terminated character string containing the name of the resource set (partition) the class is restricted to (when applicable). The default is that the class can access all the resources on the system.
`descr_field`	A null-terminated character string containing the description text of the class. This is an optional field; there is no default.

The *wlm_assign* structure is used to manually assign processes or groups of processes to a specified superclass or subclass using the `wlm_assign` routine. The *wlm_assign* structure has the following fields:

Field	Description
`wa_versflags`	The four high order bits contain a version number used by the API to maintain binary compatibility in the event of future modifications of the data structures. The rest of the integer will be used to pass flags to the API functions when needed. This field should be initialized with the version number, WLM_VERSION. The flag, WLM_MUTE, can be used to suppress the output of error messages from the WLM library on stderr.
`wa_pids`	The address of an array containing the process identifiers (pid's) of the processes to be manually assigned.
`wa_pid_count`	The number of pid's in the array above.
`wa_pgids`	The address of an array containing the process group IDs (pgid's) of the process groups to be manually assigned.
`wa_pgid_count`	The number of pgid's in the array above.
`wa_classname`	The full name of the superclass (supername) or the subclass (*supername.subname*) of the class to which you want to manually assign processes.

The *wlm_info* structure is used to extract information about the current configuration parameters and current resource utilization of the active classes using the function `wlm_get_info`.

The *wlm_info* structure has the following fields:

Fields	Description
`i_descr`	The class description of type struct, *class_descr,* described above.

Fields	Description
`i_regul`	A per-resource type array of structures of type struct *wlm_regul* containing the following fields: *consum*: The resource consumption of the class expressed as a percentage of the total resource available. *total*: This 64 bit number represents the total amount of the resource consumed by the class since its creation (or since WLM started). The unit is CPU ticks for CPU, a number of pages * seconds for memory and the total number of 512 byte blocks for disk I/O. The indexes into the array of the various resources are defined as above by WLM_RES_CPU, WLM_RES_MEM, and WLM_RES_BIO.
`i_class_id`	Class identifier (index of internal kernel class related to classes, *class_control_block* (*ccb[]*) table).
`i_cl_pri`	Priority delta applied to the threads in the class (CPU regulation).
`i_cl_inuse`	The current number of processes in the class.
`i_cl_npages`	The number of memory pages currently allocated to the class.
`i_cl_mem_hwm`	The maximum number of (resident) memory pages this class had since its creation (memory high water mark).
`i_cl_change_level`	Incremented every time there is a change in the current WLM configuration. For use by the WLM monitoring tools.

There are two structures used to get the I/O statistics using `wlm_get_bio_stats` depending on whether the application wants per-class or per-device statistics.

The *wlm_bio_class_info_t* structure is used to gather I/O statistics per class and per device. This structure contains the following fields:

Field	Description
`wbc_dev`	Device identifier (dev_t).

Field	Description
`wbc_cid`	Class identifier (index of the internal kernel class related to classes *class_control_block* (*ccb[]*) table). The connection between the class ID and the class name can be done using `wlm_get_info`, which returns both the class name (in field i_descr) and the class ID (in i_class_id) in the *wlm_info* structure.
`wbc_regul`	A structure of type struct, *wlm_regul*, already described, containing the disk I/O statistics for the given class and device: Resource utilization expressed as a percentage of the total available throughput of the device (consum) and the total number of 512 byte blocks read/written from and to the device by processes in the class since the creation of the class or since WLM started (whichever happened last).
`wbc_delay`	Delay (in milliseconds) imposed to the I/Os of the processes in the class to the device in order to limit the utilization of this device by the processes in this class when this is consuming more than its entitlement.

The *wlm_bio_dev_info_t* structure is used to gather the global statistics for a given device (takes into account all I/Os to and from the device by all the classes accessing the device). This structure contains the following fields:

Field	Description
`wbd_dev`	Device identifier (dev_t).
`wbd_active_cntrl`	Number of classes actively accessing the device.
`wbd_in_queue`	Number of requests in the device queue.

Field	Description
wbd_last	Device statistics for the last second. This field is an array of integer values. Symbolic values defined in the header file describe each index in the array: *WBS_OUT_RTHRPUT*: Number of blocks actually read from the device (I/O completed). *WBS_OUT_WTHRPUT*: Number of blocks actually written to the device (I/O completed). *WBS_IN_RTHRPUT*: Requested number of blocks to read from the device. *WBS_IN_WTHRPUT*: Requested number of blocks to write to the device. *WBS_REQUESTS*: Number of requests (read/write). *WBS_QUEUED*: Number of requests queued. *WBS_STARVED*: Number of requests starved (not serviced during the time interval). For the wbd_last field, those numbers represent activity during the last second (for instance, the number of requests queued during the last second).
wbd_max	This field contains the maximum values observed since the device was first used (after WLM started) for all the entries of the array described above (for instance, the maximum number of blocks actually read from the device in one second since the device was first accessed).
wbd_av	This field contains the average values for all the entries in the array (for instance, the average number of requests in the device queue).
wbd_total	This field is an array of 64 bit integers parallel to the arrays above which contains, for all the entries, the total of all the values measured every second since the device was first accessed (for instance the total number of blocks written to the device since the device was first accessed).

A.2 WLM API functions error codes

The various API functions may return one or several of the following error codes:

WLM_BADVERS	Bad Version number passed in versflags.
WLM_NOTINITED	No prior call to `wlm_initialize`.
WLM_ALREADYINIT	There already have been a prior call to `wlm_initialize`.
WLM_UNSUPP	Operation or flags value not supported.
WLM_OPENERR	A file could not be opened.
WLM_CREATERR	A file could not be created.
WLM_MKDIRERR	A directory could not be created.
WLM_WRITERR	An attempt to write in a file did not succeed.
WLM_REMERR	An attempt to remove a file did not succeed.
WLM_RENAMERR	An attempt to rename a file did not succeed.
WLM_SYMLERR	An attempt to create a symbolic link did not succeed.
WLM_NOMEM	Not enough memory.
WLM_NOCLASS	The specified class does not exist.
WLM_RNOCLASS	A class specified in the rules file does not exist.
WLM_EXISTS	The specified class already exists.
WLM_MAXCLASSES	The maximum number of classes has been reached.
WLM_RMPREDEF	Predefined classes, such as Default and System, cannot be removed.
WLM_NOSUBS	The target superclass has no subclasses.
WLM_HASSUBS	The target superclass has subclasses.
WLM_SHAREDSUB	Shared superclass cannot have subclasses.
WLM_SHAREDLIM	Shared class can have shares and limits set only for memory.
WLM_BADDEFSHR	Default shares value specified in the shares file is invalid.
WLM_BADDEFLIM	Default limits value specified in the limits file is invalid.
WLM_BADLIMFMT	Value specified for minimum or maximum resource limit invalid.
WLM_BADSHRFMT	Value specified for resource shares is invalid.
WLM_BADTIER	Tier values must be between 0 and 9.
WLM_BADSHARES	Shares values must be between 1 and 65535.
WLM_BADMIN	Minimum resource limits values must be between 0 and 100.
WLM_BADSMAX	The soft maximum limit values must be between 1 and 100.
WLM_BADHMAX	The hard maximum limit values must be between 1

	and 100.
WLM_BADCNAME	Class names must be alphanumeric.
WLM_TOOLONG	The specified class name is too long.
WLM_MINSMAX	The minimum limit cannot be greater than the soft maximum limit.
WLM_SMAXHMAX	The soft maximum limit cannot be greater than the hard maximum limit.
WLM_SUMMINS	The sum of the minimum limits for a given resource and a given tier cannot exceed 100 percent.
WLM_BADINHER	The value specified for the class inheritance attribute is invalid.
WLM_LOADERR	A class cannot be loaded into the kernel.
WLM_RULESERR	The assignment rules table cannot be loaded into the kernel.
WLM_SETERR	The WLM state transition requested is illegal.
WLM_QUERYERR	Cannot query wlm state.
WLM_MANYRULES	Too many assignment rules.
WLM_MANYITEMS	Too many items in an assignment rule.
WLM_RULERR	An assignment rule has an invalid format.
WLM_BADLIST	The process attribute list of an assignment rules is invalid.
WLM_BADUSR	The specified user ID is not valid on the system.
WLM_BADRUSR	A user name specified in the rules file is invalid on the system.
WLM_BADUID	The specified user ID is not valid on the system.
WLM_BADGRP	The specified group ID is not valid on the system.
WLM_BADRGRP	A group name specified in the rules file is invalid on the system.
WLM_BADGID	The specified group ID is not valid on the system.
WLM_BADTAG	An invalid tag is specified in a rule.
WLM_BADTYP	An invalid type is specified in a rule.
WLM_NOSHRRULE	Cannot specify the rule for a Shared class.
WLM_NOWILDCRD	Wildcards are not allowed in this field.
WLM_STATERR	One (or more) file names specified in the application field of an assignment rule could not be accessed. The corresponding names are ignored (warning).
WLM_EMPTYRULE	None of the file names specified in the application field of an assignment rule could be accessed. The rule is ignored (warning).
WLM_RUNERR	The WLM library was not able to execute a command needed for the specific function. This is not an application error but, most likely, a system

	administration problem. The commands used by the library are basic AIX commands, such as `lsuser`, `lsgroup`, `echo`, and `grep`.
WLM_BADCONFIG	Invalid configuration name.
WLM_CLASSMIS	No class definition found.
WLM_EMPTYATTR	No valid attributes found in attributes string for `wlm_classify`.
WLM_MULTATTR	Multiple specifications not allowed in attributes string for `wlm_classify`.
WLM_EXCLATTR	Exclusions not allowed in attributes string for `wlm_classify`.
WLM_ATTERR	Attribute format error in attributes string for `wlm_classify`.
WLM_BADATTUSR	Unknown user in attributes string for `wlm_classify`.
WLM_BADATTGRP	Unknown group in attributes string for `wlm_classify`.
WLM_BADATTAPP	Application file in attributes string for `wlm_classify` could not be accessed.
WLM_BADATTTAG	Invalid tag in attributes string for `wlm_classify`.
WLM_BADATTTYP	Invalid type in attributes string for `wlm_classify`.
WLM_TOOMANYATT	Too many items in attributes string for `wlm_classify`.
WLM_WILDCRDATT	Wildcards not allowed in attribute field.
WLM_RUNERRATT	Cannot expand attribute.
WLM_BADLISATT	Invalid list in attributes string for `wlm_classify`.
WLM_TOOLONGATT	Attribute list for `wlm_classify` too long.
WLM_EFAULT	Bad parameter address.
WLM_NOTCOMPLETE	Warning: could not assign all processes (`wlm_assign` was partially successful).
WLM_NOTRUNNING	WLM is not running.
WLM_ESRCH	No such processes.
WLM_TOOMANYPID	Process ID list too long.
WLM_EPERM	Permission denied.
WLM_CANTASSIGN	Internal error: Could not make assignment.
WLM_TAGTOOLONG	Tag is too long.
WLM_BADFLAGS	Invalid flags value.
WLM_CANTSETTAG	Internal error: Could not set tag.
WLM_CANTCHECK	Unable to check the configuration.
WLM_TOOSMALL	Output buffer too small.
WLM_BADRSET	Bad Rset attribute for a class.
WLM_CHOWNERR	Cannot change file owner.
WLM_LOCKERR	Cannot take file lock.
WLM_ERRNO	A system call returned an error.
WLM_BADCLNAME	Class name invalid: Some class names cannot be used for internal reasons. For instance, Default.

WLM_BADSUPER	Bad superclass for subclass assignment.
WLM_NOTASSGND	Process has not been manually assigned to a class.
WLM_RULTOOLNG	Rule exceeds 4096 characters in length (WLM_RULE_LEN).
WLM_NOADMINSUB	adminuser/admingroup attributes not applicable to subclasses.

A.3 Initialization routines

There are two initialization routines in the API: `wlm_init_class_definition` and `wlm_initialize`.

wlm_init_class_definition

Purpose: Initializes a variable of type struct *class_definition*, defined in <sys/wlm.h> for use as an argument to WLM API function calls.

Library: Workload Manager Library (libwlm.a)

Syntax:
```
#include <sys/wlm.h>
int wlm_init_class_definition (wlmargs)
struct wlm_args *wlmargs;
```

Description: The `wlm_init_class_definition` subroutine initializes (or reinitializes) the data structure of the type struct, *class_definition*, which is part of the argument of type struct *wlm_args* pointed to by wlmargs (field class), so that this data structure can be used as an argument for the class management subroutines of the WLM API library. The purpose of this call is to allow applications to initialize only the fields that are relevant for the operation they execute. For example, to change a CPU limit or share for an existing class, after a call to `wlm_init_class_definition`, the application will just have to initialize the fields corresponding to the values it wishes to modify. This routine initializes all values to specific invalid values so that the WLM library routines can find out which fields have been explicitly initialized by the user. This way, they can set or modify only the corresponding attributes.

When creating a class, for instance, it is different to leave a class attribute at its invalid value set by `wlm_initialize` than to set its value to the current default value for the attribute. In the former case, the attribute will not appear in the property file. In the latter, it will appear and be set with the value passed. This makes a difference if a WLM administrator decides to change the default value for an attribute using the special stanza, *default*, in a property file. For instance, the system default for the inheritance attribute is *no*. If, at some point in time, a WLM administrator wants the inheritance to be *yes* by default, using this special stanza, all the classes in the classes property file, for which the inheritance attribute has not been specified will now use the default of *yes*. Those for which the inheritance attribute has been specified with its old default of *no* will not have inheritance.

Parameter:

`wlmargs`	The address of the struct *wlm_args* data structure containing the *class_definition* structure to be initialized. Only the `versflags` field of the *wlm_args* structure passed needs to be initialized with WLM_VERSION.

Return Values: Upon successful completion, a value of 0 is returned. If the `wlm_init_class_definition` subroutine is unsuccessful, a non 0 value is returned.

Error Codes: There are two possible error codes returned by `wlm_init_class_definition`:

BADVERSION	The value of the versflags parameter is not a supported version number.
NOTINITED	The WLM API has not been initialized by a prior call to `wlm_initialize`.

wlm_initialize

Purpose: Prepares WLM for use by an application.

Library: Workload Manager Library (libwlm.a)

Syntax:
```
#include <sys/wlm.h>
int wlm_initialize (flags)
int flags;
```

Description: The `wlm_initialize` subroutine initializes the WLM API for use with an application program. It is mandatory to call `wlm_initialize` prior to using the WLM API. Otherwise, all other WLM API function calls will return an error. If `wlm_initialize` is used in a multi-threaded application, the routine should be called by the main thread before additional threads are started.

Parameter:

`flags`	The format is the same as the `versflags` field of the *wlm_args* structure: The value for the argument must have the version number in the upper 4 bits (WLM_VERSION) possibly ORed with a flag in the lower 28 bits.

Return Values: Upon successful completion, a value of 0 is returned. If the `wlm_initialize` subroutine is unsuccessful, a non 0 value is returned.

Error Codes: There are two possible error codes returned by `wlm_initialize`:

BADVERSION	The value of the flags parameter is not a supported version number.
WLMINITED	There has already been a previous call to `wlm_initialize`.

A.4 Application tag

The routine described in this section is the one used to tag a process: `wlm_set_tag`.

wlm_set_tag

Purpose: Sets the current process' tag and related flags

Library: Workload Manager Library (libwlm.a)

Syntax:

```
#include <sys/wlm.h>
#include <sys/user.h>
int wlm_set_tag (tag, flags)
char *tag;
int *flags;
```

Description: The tag is a new attribute of a process that can be set using the WLM function `wlm_set_tag`. This tag is a character string with a maximum length of WLM_TAG_LENGTH (not including the null terminator). Process tags can be displayed using the `ps` command. The tag is also one of the process attributes used in the assignment rules to automatically assign a process to a given class. The main utilization of the tag attribute is to allow WLM administrators to discriminate between several instances of the same application, which, typically, have the same user and group IDs, execute the same binary, and, therefore, would end up in the same class using the standard classification criteria. When an application sets its tag using `wlm_set_tag`, it is automatically reclassified according to the current assignment rules, and the new tag is taken into account when doing this reclassification. In addition to the tag itself, the application can also specify flags indicating to WLM whether a child process should inherit the tag from its parent after a `fork` and/or an `exec` system call. A process does not require any special privileges to set its tag.

Parameters:

`tag` The address of a character string. An error will be returned if this tag is too long.

`flags` The address of an integer interpreted in a manner similar to the versflags field of the *wlm_args* structure passed to other API routines. The integer pointed to by flags should be initialized with WLM_VERSION. In addition, one or more of the following values can be ORed to WLM_VERSION:

SWLMTAGINHERITFORK	The children of this process will inherit the parent's tag on `fork`.
SWLMTAGINHERITEXEC	The process will retain its tag after a call to `exec`. Both flags can be set to specify that the children of a tagged process will inherit the tag on `fork` and then retain it on `exec`.

Return Values: Upon successful completion, a value of 0 is returned. In case of error, a non zero value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h in Section A.1, “The Include file - sys/wlm.h” on page 217.

A.5 Class management

The class management routines are `wlm_read_classes`, `wlm_create_class`, `wlm_change_class`, and `wlm_delete_class`.

wlm_read_classes

Purpose: Read the characteristics of superclasses or subclasses.

Library: Workload Manager Library (libwlm.a)

Syntax:

```
#include <sys/wlm.h>
int wlm_read_classes (wlmargs, class_tbl, nclass)
struct wlm_args *wlmargs;
struct class_definition *class_tbl
int *nclass
```

Description:The `wlm_read_classes` subroutine is used to get the characteristics of the superclasses or of the subclasses of a given superclass of a WLM configuration. If the name of a configuration is passed in the *confdir* field, the subroutine, `wlm_read_classes`, will read the property files of the classes of the specified configuration. If confdir is set to a null string (\0), `wlm_read_classes` will read the property files of the in-core classes if WLM is on. If WLM is off, `wlm_read_classes`, with a null string as the configuration name, will fail. Note that if WLM is on and a null string was passed in the confdir field, `wlm_read_classes` will return the characteristics of the classes as they are known by WLM at the time of the call. These values may be different from the values in the property files of the configuration pointed to by /etc/wlm/current. For instance, a WLM administrator has modified the property files for the configuration pointed to by /etc/wlm/current but has not refreshed WLM yet. Another example would be if applications dynamically created or modified classes through the API without saving the changes in the current configuration property files. If your application specifically needs to access the properties of the classes as described in the /etc/wlm/current configuration, you must specify *current* as the configuration name in confdir. If the name of a valid superclass of the given configuration is passed in the name field of the *class_descr* substructure of *wlm_args*, `wlm_read_classes` will read the property files for the subclasses of this superclass. If a null string (\0) is passed in the name field, `wlm_read_classes` will read the property files for the superclasses of the WLM configuration described above. When `wlm_read_classes` is successful, the characteristics of the superclasses or subclasses are copied into the array of *class_definition* structures pointed to by *class_tbl*. The integer value pointed to by *nclass* indicates the maximum number of class definitions to be copied. Upon successful return from the function, this value reflects the actual number of classes read. If the number of elements copied by `wlm_read_classes` is strictly smaller than the number of elements passed as an argument, this means that all the classes have been read. If it is equal, it may mean that some classes were not copied into the class_tbl array because its size is too small. The maximum number of classes read by `wlm_read_classes` is 32 when reading superclasses and 10 when reading subclasses characteristics. Upon successful return from `wlm_read_classes`, the substructure class of type struct *class_definition*, of the structure pointed to by wlmargs contains the default values of the various class attributes for the returned set of classes. This operation does not require any special privileges and is accessible to all users.

Parameters:

`wlmargs` The address of a struct *wlm_args* data structure. The following fields of the *wlm_args* structure and the embedded substructures need to be provided:

- `versflags` Needs to be initialized with WLM_VERSION.
- `confdir` The name of a WLM configuration. It must be either the name of a valid subdirectory of /etc/wlm or a null string (starting with \0).
- `name` The name of a superclass existing in the specified configuration, or a null string.

All the other fields can be left uninitialized.

`class_tbl`	The address of an array of structures of type struct *class_definition*. Upon successful return from `wlm_read_classes`, this array will contain the characteristics of the classes read.
`nclass`	The address of an integer containing the maximum number of elements (class definitions) for `wlm_read_classes` to copy into the array above. If the call to `wlm_read_classes` is successful, this integer will contain the number of elements actually copied.

Return Values: Upon successful completion, a value of 0 is returned. If the `wlm_read_classes` subroutine is unsuccessful, a non 0 value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Section A.1, “The Include file - sys/wlm.h” on page 217.

wlm_create_class

Purpose: Creates a new WLM class.

Library: Workload Manager Library (libwlm.a)

Syntax:
```
#include <sys/wlm.h>
int wlm_create_class (wlmargs)
struct wlm_args *wlmargs;
```

Description: The `wlm_create_class` subroutine creates a new class for a given WLM configuration using the values passed in the data structure of type struct *wlm_args* pointed to by `wlmargs`. If the name of a configuration is passed in the *confdir* field, the subroutine updates the WLM properties files for the target configuration. When creating the first subclass of a superclass, the subroutine will create the WLM property files in a subdirectory of /etc/wlm/<confdir> with the name of the superclass. The newly-created property files will have entries for the Default and Shared subclasses automatically created in addition to entries for the new subclass. If a null string (\0) is passed in the confdir field, the new superclass or subclass will be created only in the in-core WLM data. No WLM property file will be updated. The structure of type struct *class_definition,* which is part of struct *wlm_args,* has normally been initialized with a call to `wlm_init_class_definition`. Once this has been done, programmers just need to initialize the fields of this structure that have no default value (for example, the name of the new class) or for which the desired value is different from the default value. For a description of the possible values for all the class attributes and their default values, refer to the description of wlm.h in Appendix A.1 on page 217.

The caller must have root authority to create a superclass and must have administrator authority on a superclass to create a subclass of the superclass.

Parameter:

`wlmargs` The address of the struct *wlm_args* data structure containing the *class_definition* structure for the new class to be created. The following fields of the *wlm_args* structure and the embedded sub-structures need to be provided:

- `versflags` Needs to be initialized with WLM_VERSION.
- `confdir` The name of the WLM configuration the new class is to be added to. It must be either the name of a valid subdirectory of /etc/wlm or an empty string (starting with \0). If the name is a valid subdirectory, the new class data will be added to the given WLM configuration's class description files. If the name is a null string, no description files will be updated. The new class will be created and the data passed to the kernel immediately.
- `name` The name of the superclass or of the subclass to be created. If this is a subclass name, it must be of the form, *supername.subname*. There is no default for this field.

All the other fields can be left at their default value if the user does not wish to use specific values.

Return Values: Upon successful completion, a value of 0 is returned. If the `wlm_create_class` subroutine is unsuccessful, a non 0 value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Appendix A.1 on page 217.

wlm_change_class

Purpose: Changes some of the attributes of a class.

Library: Workload Manager Library (libwlm.a)

Syntax: `#include <sys/wlm.h>`

```
int wlm_change_class (wlmargs)
struct wlm_args *wlmargs;
```

Description: The `wlm_change_class` subroutine changes attributes of an existing superclass or subclass. The attributes of the class that can be dynamically modified by a call to `wlm_change_class` are the tier number, class inheritance, class description string, resource shares and limits, and the resource set name (all attributes, except, of course, the name of the class). If the name of a valid configuration is passed in the *confdir* field, the subroutine updates the WLM property files for the target configuration. If a null string (\0) is passed in the confdir field, the changes are applied only to the in-core WLM data. No WLM property files will be updated. The structure of type struct *class_definition,* which is part of struct *wlm_args*, should be initialized with a call to `wlm_init_class_definition`. Once this has been done, programmers just need to initialize the fields of this structure that are required (for example, the name of the class to be modified) and the fields corresponding to the class attributes one wants to modify. For a description of the possible values for the various class attributes and their default values, refer to the description of wlm.h in Appendix A.1 on page 217.

The caller must have root authority to change the attributes of a superclass and must have administrator authority on a superclass to change the attributes of a subclass of the superclass.

Parameter:

`wlmargs` The address of the struct *wlm_args* data structure containing the *class_definition* structure for the new class to be created. The following fields of the *wlm_args* structure and the embedded substructures need to be provided:

`versflags` Needs to be initialized with WLM_VERSION.

`confdir` The name of the WLM configuration the target class belongs to. It must be either the name of a valid subdirectory of /etc/wlm or an empty string (starting with \0). If the name is a valid subdirectory, the relevant class description files in the given configuration will be modified. If the name is a null string, no description files will be updated. The modified class attributes will be passed immediately to the kernel.

`name` The name of the superclass or of the subclass to be modified. If this is a subclass name, it must be of the form *supername.subname*. There is no default for this field. All the other fields can be left at their initial value as set by `wlm_init_class_definition`, if the user does not wish to change their current values.

Return Values: Upon successful completion, a value of 0 is returned. If the `wlm_change_class` subroutine is unsuccessful, a non-zero value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Section A.1, “The Include file - sys/wlm.h” on page 217.

wlm_delete_class

Purpose: Deletes a class.

Library: Workload Manager Library (libwlm.a)

Syntax:

```
#include <sys/wlm.h>
int wlm_delete_class (wlmargs)
struct wlm_args *wlmargs;
```

Description: The `wlm_delete_class` subroutine deletes an existing superclass or subclass. A superclass cannot be deleted if it still has subclasses other than Default and Shared defined. If the name of a valid configuration is passed in the *confdir* field, the subroutine updates the WLM property files for the target configuration, removing all references to the class to be deleted. If a null string (\0) is passed in the confdir field, the changes are applied only to the in-core WLM data. No WLM property file will be updated.

The caller must have root authority to delete a superclass and must have administrator authority on a superclass to delete a subclass of the superclass.

Parameter:

`wlmargs` The address of the struct *wlm_args* data structure containing the information about the class to be deleted. The following fields of the *wlm_args* structure and the embedded sub-structures need to be provided:

`versflags` Needs to be initialized with WLM_VERSION.

`confdir` The name of the WLM configuration the target class belongs to. It must be either the name of a valid subdirectory of /etc/wlm or an empty string (starting with \0). If the name is a valid subdirectory, the relevant class description files in the given configuration will be modified. If the name is a null string, no description files will be updated. The class will be removed immediately from the kernel WLM data structures.

`name` The name of the superclass or of the subclass to be deleted. If this is a subclass name, it must be of the form *supername.subname*. There is no default for this field.

All the other fields can be left uninitialized for this call.

Return Values: Upon successful completion, a value of zero is returned. If the `wlm_delete_class` subroutine is unsuccessful, a non-zero value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file sys/wlm.h in Appendix A.1 on page 217.

A.6 WLM management

The WLM management routines are `wlm_set`, `wlm_load` and `wlm_assign`.

wlm_set

Purpose: Changes or queries the state of WLM.

Library: Workload Manager Library (libwlm.a)

Syntax:

```
#include <sys/wlm.h>
int wlm_set (flags)
int *flags;
```

Description: The `wlm_set` subroutine is used to set, change, or query the mode of operations of WLM. The state of WLM can be:

- *OFF*: WLM does not classify processes, monitor, or regulate resource utilization.
- *ON in passive mode*: WLM classifies the processes and monitor their resource usage, but does no regulation.
- *ON in active mode*: This is the normal operating mode where WLM classifies processes, and monitors and regulates the resource usage.

Parameter:

`flags` The address of an integer interpreted in a manner similar to the versflags field of the *wlm_args* structure passed to the other API routines. The integer pointed to by *flags* should be initialized with WLM_VERSION. In addition, one or more of the following values can be ORed to WLM_VERSION:

- WLM_TEST_ON to just query the state of WLM without altering it.
- WLM_OFF to turn WLM off.
- WLM_ACTIVE to turn WLM on in active mode, or transition from passive to active mode.
- WLM_PASSIVE to turn WLM on in passive mode or transition from active to passive mode.
- WLM_BIND_RSETS to requests that WLM takes the resource set bindings into account.

Not all combinations of the aforementioned flags are valid:

- WLM_OFF, WLM_ACTIVE and WLM_PASSIVE are mutually exclusive.
- WLM_BIND_RSETS is ineffective when used together with WLM_OFF.
- Only WLM_TEST_ON is allowed to non root users.

Return Values: Upon successful completion, a value of 0 is returned and the current state of WLM is returned in the integer pointed to by flags. The return value will be WLM_OFF, WLM_ACTIVE or WLM_PASSIVE. When WLM was on in either active or passive mode, the WLM_BIND_RSETS flag is added when WLM uses resource sets bindings.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Section A.1, “The Include file - sys/wlm.h” on page 217.

wlm_load

Purpose: Loads a WLM configuration into the kernel.

Library: Workload Manager Library (libwlm.a)

Syntax:

```
#include <sys/wlm.h>
int wlm_load (wlmargs)
struct wlm_args *wlmargs;
```

Description: The `wlm_load` subroutine loads into the kernel the property files for the WLM configuration passed in the *confdir* field of the *wlm_args* structure. If no superclass name is given in the name field of the *class_definition* substructure, the routine loads the class properties for all the superclasses of the target configuration. If a superclass name is given, only the subclasses of the given superclass are refreshed. Flags passed in the flags portion of the versflags field can be used to modify the mode of operation of WLM. The values are identical to the flag values passed to the `wlm_set` API routine. Not all combinations of parameters are allowed, and different combinations may require different levels of privilege as explained below:

- The name of a configuration must be passed in the confdir field in order to start or update WLM. `wlm_load` updates or starts WLM using the properties files from the given configuration. Only root can specify the name of a configuration different from the currently active configuration (specified as *current* in confdir).
- When WLM is on (the operation is an update), if the name of the configuration passed in the confdir field of the *wlm_args* structure is the name of the currently-active configuration, the name of a superclass can be given in the name field in order to update only the subclasses of the given superclass. This functionality is accessible to root and to users with administration privileges on the subclasses of the superclass. `wlm_load` cannot be used in this context to alter the state of WLM (start, stop, or switch between active and passive modes).
- If the caller of `wlm_load` has root privileges and does not specify a superclass, the flags passed in versflags can be used to alter WLM's mode of operation: Start WLM in active or passive mode; switch between active and passive modes, and/or enable/disable the rset bindings.

Parameter:

`wlmargs` The address of the struct *wlm_args* data structure containing the *class_definition* structure. The following fields of the *wlm_args* structure and the embedded sub-structures can be provided:

`versflags` Needs to be initialized with WLM_VERSION. Optionally, some of the flags used when calling `wlm_set` in order to change the mode of operation of WLM can be given by the root user. The valid values are WLM_ACTIVE, WLM_PASSIVE and WLM_BIND_RSETS. Of course, WLM_ACTIVE and WLM_PASSIVE are mutually exclusive. The flag, WLM_SAME_STATE, should be used if the application does not wish to change the current mode of operation of WLM.

`confdir` The name of the WLM configuration to be loaded into the kernel. It must be either the name of a valid subdirectory of /etc/wlm or the string *current* to refer to the active configuration.

`name` The name of a superclass. This is used to refresh only the subclasses of a given superclass.

Return Values: Upon successful completion, a value of 0 is returned. If the `wlm_load` subroutine is unsuccessful, a non 0 value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Section A.1, “The Include file - sys/wlm.h” on page 217.

wlm_assign

Purpose: Manually assigns processes to a class or cancels prior manual assignments for processes.

Library: Workload Manager Library (libwlm.a)

Syntax:
```
#include <sys/wlm.h>
int wlm_assign (args)
struct wlm_assign *args;
```

Description: The `wlm_assign` function is used to:

- Assign a set of processes specified by their process identifiers (pids) or process group identifiers (pgids) to a specified superclass or subclass, thus, overriding the automatic class assignment or a prior manual assignment.
- Cancel a previous manual assignment, allowing the processes to be subjected to the automatic assignment rules again.

The target processes are identified by their process ID (pid) or by their process group ID (pgid). The `wlm_assign` subroutine allows you to specify processes using a list of pids, a list of pgids, or both.

A manual assignment will remain in effect (and a process will remain in its manually assigned class) until:

- The process terminates.
- WLM is stopped. When WLM is restarted, the manual assignments in effect when WLM was stopped are lost.

- The class the process has been assigned to is deleted.
- The manual assignment for the process is canceled.
- A new manual assignment overrides a prior one.

The name of a valid superclass or subclass must be specified to manually assign the target processes to a class. The assignment can be done or canceled at the superclass level, the subclass level, or both. Flags in the wa_versflags field described below are used to specify whether the requested operation is an assignment or cancellation and at which level.

In order to assign a process to a class or cancel a prior manual assignment, the caller must have authority both on the process and on the target class. These constraints translate into the following:

- The user root can assign any process to any class.
- A user with administration privileges on a given superclass (that is, the user or group name matches the user or group names specified in the attributes, adminuser and admingroup, of the superclass) can manually reassign any process from one of the subclasses of this superclass to another subclass of the superclass.
- A user can manually assign his/her own processes (same real or effective user ID) to a superclass or a subclass for which he/she has manual assignment privileges (that is, the user or group name matches the user or group names specified in the attributes, authuser, and authgroup of the superclass or the subclass).

This defines three levels of privilege among the persons who can manually assign processes to classes, root being, of course, the highest. In order for a user to modify or terminate a manual assignment, he/she must be at the same level of privilege or higher than the person who issued the last manual assignment.

Parameter:

`args` The address of the struct *wlm_assign* data structure containing the parameters for the desired class assignment. The following fields of the *wlm_assign* structure and the embedded sub-structures can be provided:

`wa_versflags` Needs to be initialized with WLM_VERSION. The flags values available, defined in the header file <sys/wlm.h>, are the following: WLM_ASSIGN_SUPER, WLM_ASSIGN_SUB,

WLM_ASSIGN_BOTH, WLM_UNASSIGN_SUPER, WLM_UNASSIGN_SUB and WLM_UNASSIGN_BOTH.

`wa_pids` The address of the array containing the process identifiers (pid’s) of processes to be manually assigned. When this list is empty, a NULL pointer can be passed together with a count of zero (0).

`wa_pid_count` The number of elements (pids) in the above array.Could be zero (0) if using only pgid's to identify the processes.

`wa_pgids` The address of the array containing the process group identifiers (pid's) of processes to be manually assigned. When this list is empty, a NULL pointer can be passed together with a count of zero (0).

`wa_pgid_count` The number of elements (pgids) in the above array.Could be zero (0) if using only pid's to identify the processes. If both pid's and pgid's counts are zero, no process will be assigned, but the operation will be considered successful.

`wa_classname` The full name of the superclass, *supername*, or the subclass, *supername.subname*, of the class you want to manually assign processes to. The class name field is ignored when canceling an existing manual assignment.

Return Values: Upon successful completion, a value of zero (0) is returned. If the `wlm_assign` subroutine is unsuccessful, a non-zero (0) value is returned. A *partial success* return code will be returned if some of the target processes are not found (to account for process terminations). If none of the processes in the lists can be found, this will be considered an error.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Appendix A.1 on page 217.

A.7 WLM statistics

The WLM statistics routines are `wlm_get_info` and `wlm_get_bio_stats`.

wlm_get_info

Purpose: Read the characteristics of superclasses or subclasses.

Library: Workload Manager Library (libwlm.a)

Syntax:
```
#include <sys/wlm.h>
int wlm_get_info (wlmargs, info, count)
struct wlm_args *wlmargs;
struct wlm_info *info
int *count
```

Description: The `wlm_get_info` subroutine is used to get the characteristics of the classes defined in the active WLM configuration together with their current resource usage statistics. For a detailed description of the fields of the structure, *wlm_info*, refer to the description of the header file, <sys/wlm.h>, in the Files Reference documentation. By default, the scope of the `wlm_get_info` subroutine is all the superclasses and all the subclasses. This scope can be limited to a subset of the classes using flags in the versflags field of *wlm_args* and/or a superclass or subclass name in the name field of the substructure, *class_definition* of *wlm_args*. The information related to the superclasses and subclasses within the scope of `wlm_get_info` will be copied to the array of *wlm_info* structures pointed to by *info*. The total number of classes for which information is copied to the array at info is limited to the value of the integer pointed to by *count*. If the routine is successful, the value of the integer pointed to by count is set to the actual number of classes copied. If the value passed to the routine for the count is equal to zero (0), `wlm_get_info` does not copy any class statistics but sets this count to the number of classes in scope for the specific set of parameters. This is a way of finding out how big an array is needed to get all the information for a given set of classes (superclasses and/or subclasses).

`wlm_get_info` does not require any special privileges and is accessible to all users. `wlm_get_info` will fail if WLM is off.

Parameters:

`wlmargs` The address of a struct *wlm_args* data structure. The following fields of the *wlm_args* structure and the embedded sub-structures need to be provided:

`versflags` Needs to be initialized with WLM_VERSION. Optionally, the following flag values can be ORed to WLM_VERSION:

- *WLM_SUPER_ONLY*: Limits the scope to superclasses only.
- *WLM_SUB_ONLY*: Limits the scope to subclasses only.

- *WLM_VERBOSE_MODE*: Shows the system defined subclasses, Default and Shared, even if they have not been modified by a WLM administrator.
- WLM_SUPER_ONLY and WLM_SUB_ONLY are mutually exclusive.

`name` This field must contain either a null string, or the name of a valid superclass or subclass (in the form Super.Sub). This field can be used in conjunction with the flags to further narrow the scope of `wlm_get_info`:

- If the name of a subclass is provided, `wlm_get_info` will return the statistics only for the specified subclass.
- If the name of a superclass is provided and none of the WLM_SUPER_ONLY and WLM_SUB_ONLY flags are provided, `wlm_get_info` will return the statistics for the specified superclass and all its subclasses.
- If the name of a superclass is provided together with WLM_SUPER_ONLY, `wlm_get_info` will return only the statistics for the specified superclass.
- If the name of a superclass is provided together with WLM_SUB_ONLY, `wlm_get_info` will return the statistics for all the subclasses of the specified superclass.

All the other fields of the *wlm_args* structure can be left uninitialized.

`info` The address of an array of structures of type struct *wlm_info*. Upon successful return from `wlm_get_info`, this array will contain the WLM statistics for the classes selected.

`count` The address of an integer containing the maximum number of elements (of type *wlm_info*) for `wlm_get_info` to copy into the aforementioned array. If the call to `wlm_get_info` is successful, this integer will contain the number of elements actually copied. If the initial value is equal to zero (0), `wlm_get_info` will set this value to the number of classes selected by the specified combination of versflags and name above.

Return Values: Upon successful completion, a value of zero is returned. If the `wlm_get_info` subroutine is unsuccessful, a non-zero value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Section A.1, “The Include file - sys/wlm.h” on page 217.

wlm_get_bio_stats

Purpose: Read the WLM disk I/O statistics per class or per device.

Library: Workload Manager Library (libwlm.a)

Syntax:
```
#include <sys/types.h>
#include <sys/wlm.h>
int wlm_get_bio_stats (dev, array, count, class, flags)
dev_t dev;
void *array;
int *count;
char *class;
int flags;
```

Description: The `wlm_get_bio_stats` subroutine is used to get the WLM disk I/O statistics. There are two types of statistics available:

- The statistics about disk I/O utilization per class and per devices, returned by `wlm_get_bio_stats` in *wlm_bio_class_info_t* structures.
- The statistics about the disk I/O utilization per device, all classes combined, returned by `wlm_get_bio_stats` in *wlm_bio_dev_info_t* structures.

The type of statistics returned by the function are related to the value of the *flags* argument. The flags argument, together with the *dev* and *class* arguments, is used to restrict the scope of the function to a class or a set of classes and/or a device or a set of devices. It is also used to restrict the statistics to superclasses only, subclasses only, and to a set of devices.

`wlm_get_bio_stats` does not require any special privileges and is accessible to all users. `wlm_get_bio_stats` will fail if WLM is off.

Parameters:

`flags` Needs to be initialized with WLM_VERSION. Optionally, the following flag values can be OR'ed to WLM_VERSION:

- WLM_SUPER_ONLY: Limits the scope to superclasses only.
- WLM_SUB_ONLY: Limits the scope to subclasses only.
- WLM_BIO_CLASS_INFO: Per class statistics requested.
- WLM_BIO_DEV_INFO: Per device statistics requested.

- WLM_BIO_ALL_DEV: Requests statistics for all devices. When this flag is set, the value passed in the dev argument is ignored.
- WLM_BIO_ALL_MINOR: Requests statistics for all devices associated with a given major number. When this flag is set, only the major number part of the value passed in the dev argument is used.
- WLM_VERBOSE_MODE: Shows the system-defined subclasses, Default and Shared, even if they have not been modified by a WLM administrator.

One of the flags, WLM_BIO_CLASS_INFO or WLM_BIO_DEV_INFO (and only one), must be specified. WLM_SUPER_ONLY and WLM_SUB_ONLY are mutually-exclusive.

`dev` Device identification (major, minor) of a disk device.

- If dev is equal to 0, the statistics for all devices are returned (even if WLM_BIO_ALL_DEV is not specified in the flags argument).
- If dev is not equal to 0 and WLM_BIO_ALL_MINOR is specified in the flags argument, the statistics for all disk devices with the same major number specified in dev are returned.
- If dev is not equal to 0 and WLM_BIO_ALL_MINOR is not specified in the flags argument, only the statistics for the disk device with the major and minor numbers specified in dev are returned.

`array` Pointer to an array of *wlm_bio_class_info_t* structures (when WLM_BIO_CLASS_INFO is specified in the flags argument) or an array of *wlm_bio_dev_info_t* structures (when WLM_BIO_DEV_INFO is specified in the flags argument).

`count` The address of an integer containing the maximum number of elements to be copied into the array above. If the call to `wlm_get_bio_stats` is successful, this integer will contain the number of elements actually copied.

`class` A pointer to a character string containing the name of a superclass or subclass. If class is a pointer to an empty string (""), the information for all classes is returned. The class parameter is taken into account only when the flag, WLM_BIO_CLASS_INFO, is set.

Return Values: Upon successful completion, a value of 0 is returned and the value pointed to by *count* is set to the number of elements copied into the array of structures pointed to by *array*. If the `wlm_get_bio_stats` subroutine is unsuccessful, a non-zero value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file, sys/wlm.h, in Section A.1, “The Include file - sys/wlm.h” on page 217.

A.8 WLM classification

The WLM classification routines are `wlm_check` and `wlm_classify`.

wlm_check

Purpose: Checks automatic assignment rules and/or determines the class a process with a specified set of attributes will be classified in.

Library: Workload Manager Library (libwlm.a)

Syntax:

```
#include <sys/wlm.h>
int wlm_assign (config)
char *config;
```

Description: The `wlm_check` function checks the coherency of the assignment rules files (syntax, existence of the classes, validity of user and group names, application path names, and other consistency checks) for the configuration whose name is passed as an argument. If *config* is a null pointer or points to an empty string, `wlm_check` performs the checks on the configuration files in the configuration pointed to by /etc/wlm/current.

Parameter:

`config` — A pointer to a character string. This pointer should be:

- The address of a character string representing the name of a valid configuration (a subdirectory of /etc/wlm)
- A null pointer
- A pointer to a null string ("")

If config is a null pointer or a pointer to a null string, the configuration files in the directory pointed to by /etc/wlm/current (active configuration) will be checked for errors. Otherwise, the configuration files in the directory, /etc/wlm/<config_name>, will be checked.

Return Values: Upon successful completion, a value of 0 is returned. If the `wlm_check` subroutine is unsuccessful, a non-zero value is returned.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file sys/wlm.h. in Section A.1, “The Include file - sys/wlm.h” on page 217.

wlm_classify

Purpose: Given a list of process attributes, `wlm_classify` determines which class or classes this process will be assigned to.

Library: Workload Manager Library (libwlm.a)

Syntax:
```
#include <sys/wlm.h>
int wlm_classify (config, attributes, class, len)
char *config;
char *attributes;
char *class;
int *len;
```

Description: This routine must receive the name of a valid configuration and a set of process attributes in a format identical to the one of the rules file (assignment rules). On output, the names of the classes are copied into the area pointed to by class. The integer pointed to by *len* contains the size of the class names area on input, and the number of matches on output. If the area pointed to by class is not big enough to contain the names of all the potential matches, an error is returned.

The normal use of this routine is to explicitly provide all the process classification attributes: User name, group name, application path name, and tag (when applicable). This should give a match to a single class, but, in order to implement what-if scenarios, the interface allows some of the attributes unspecified by putting a hyphen (-) instead. This may lead to multiple classes the process could be assigned to, depending on the values of the unspecified attributes. If all the attributes are left unspecified, an error is returned.

The attributes string is provided in a format identical to the one of the attributes in the rules file: A list of attribute values separated by spaces. The order of the attributes in the assignment rules is:

1. Reserved: must be a hyphen (-)
2. User name
3. Group name
4. Application pathname
5. Process type
6. Tag

A valid specification for the attributes string could be:

```
- bob staff /usr/bin/emacs -
```

or:

```
- - devlt /usr/bin/cc -
```

The class names returned by the function in the class buffer will be fully-qualified, null-terminated class names of the form, *supername.subname*.

This function does not require any special privileges and can be called by all users.

Parameters:

`config`	A pointer to a string containing the name of a valid WLM configuration (the name of a subdirectory of /etc/wlm). If a null string (\0) is given, `wlm_classify` will use the in-core class and rules definitions.
`attributes`	The address of a string, with the format described above, containing a list of values for the process attributes used for automatic classification of processes.
`class`	A pointer to a buffer where the name of the class or classes the process could be assigned to are returned as consecutive, null-terminated character strings.
`len`	A pointer to an integer containing the length, in bytes, of the buffer pointed to by class when calling `wlm_classify`, and the actual number of class names copied into the class buffer upon successful return.

Return Values: Upon successful completion, a value of zero is returned. In case of error, a non zero value is returned. When a non-zero value is returned, the content of the class buffer and the value of the integer pointed to by len are unspecified.

Error Codes: For a list of the possible error codes returned by the WLM API functions, see the description of the header file sys/wlm.h, in Section A.1, “The Include file - sys/wlm.h” on page 217.

Appendix B. Sample workload program

This appendix describes the sample program that was used to generate workload during the development of this redbook. It launches a number of CPU bound threads, creates network traffic, allocates memory, and generates disk I/O.

The sample program hog.c:

```
static char sccsid[] = "@(#)93  1.0  hog.c 8/30/99 11:30";
/*
 * COMPONENT_NAME: hog
 *
 * WRITTEN BY: Tim Leo
 *
 * FUNCTIONS: Exercises SMP CPU Load (utilization), Disk I/O and Memory Usage

 *            To be used for testing AIX WLM (Workload Manager)
 *
 * OBJECT CODE ONLY SOURCE MATERIALS
 * (C) COPYRIGHT International Business Machines Corp. 1989, 1991
 * All Rights Reserved
 *
 * US Government Users Restricted Rights - Use, duplication or
 * disclosure restricted by GSA ADP Schedule Contract with IBM Corp.
 *
 * Copyright (c) 1980 Regents of the University of California.
 * All rights reserved.  The Berkeley software License Agreement
 * specifies the terms and conditions for redistribution.
 */
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>
#include <strings.h>
#include <errno.h>
#include <stdlib.h>
#include <locale.h>
#include <sys/limits.h>
#include <nl_types.h>
#include <sys/param.h>


/* Start of Global Vars  ************************************************/
char    *cp;                  /* Current Program name */
int     login;          /* true if invoked as login shell */
char    firstchar;      /* first char of name of prog invoked as */

extern int optind;
extern char *optarg;


usage()        /* Prints help info for hog Program */
```

```
{
        printf("%s: usage is %s [-t thread_count [-n iptarget]] [-m memory_valu
e] [-d] [-?]  \n",cp,cp);
        printf("\n\nARGUMENTS: \n");
        printf("-t thread_count : Launch a number of CPU Bound Threads  \n");
        printf("                  where thread_count is an integer specifying\n
");
        printf("                  the number of threads to launch.\n\n");
        printf("-m memory_value : Determines the amount of working memory to be
 allocated and\n");
        printf("                  utilized by the main program to be touched co
ntinuously,\n");
        printf("                  where memory_value is an integer specifying t
he number \n");
        printf("                  of MB (MegaBytes) to allocate.\n\n");
        printf("-d              : Generates Disk I/O.\n\n");
        printf("-n iptarget     : Threads should generate network I/O.\n");
        printf("                  where iptarget is either an IP address or hos
tname\n");
printf("                  (the default iptarget is loopback) \n");
        printf("-?              : Obtains this screen of help info and exit. \n
");
}

/* More Global Vars ************/


int loop_stat;
pthread_mutex_t m;
char  *waste_of_space=NULL;
size_t megs=0;

struct arg {
        char *string;
        int  net;
};
typedef struct arg arg_t;

/* Sample Memory Grabber Thread Routine *****************/
void *Memory_Thread(void *x)
{
  printf("Starting memory scan...\n");
  while(1)
  {
     if ((waste_of_space =(char *)calloc(megs,1))==NULL)
        printf("%s: Could not allocate memory...errno was %d\n",cp,errno);
     else {
       system("date");
       printf("%s has allocated a %d byte array of storage...\n",cp,(int)megs);
       sleep(10);
free(waste_of_space);
     }
  }
}
```

```
/* Sample Disk I/O Generator Thread Routine ************/

void *Gen_File_IO(void *x)
{
  while (1)
  {
   system ("dd if=/unix of=/wlm_fs1/test1 count=10000 2>/dev/null" );
   system ("dd if=/wlm_fs1/test1 of=/wlm_fs2/test2 count=10000 2>/dev/null");
   /* system ("run_disks 4"); */
   system ("date");
   printf("%s: Finished a Disk Cycle...\n",cp);
  }
  pthread_exit( (void *)1);

}
/* Sample CPU Bound Thread Routine ************/

void *Thread(void *x)
{
        int l;
          while (1)
        {
               /*  l=0; while (l < 1000) l++;   Delay loop */
                usleep(5);
                pthread_mutex_lock(&m);
                        loop_stat++;
pthread_mutex_unlock(&m);
                if ((loop_stat%1000)== 0){
                   system ("date");
                   printf("%d transactions so far...\n",loop_stat);
                }
                /* Turn on network traffic */
                if (((arg_t*)x)->net==1) system( ((arg_t *)x)->string);

        }
        pthread_exit( (void *)1);

}



/* hog main program ****************************************************/
main(argc, argv)
        char **argv;
        int argc;
{

/* Start of Local Vars for Main  *************/
#ifdef PATH_MAX
#undef PATH_MAX
#endif
#define PATH_MAX   257  /* Maximum path +\0 */
```

```
 register int i, j;
        int tp, thread_max;
        int mflag=0;
int dflag=0;
        int tflag=0;
        pthread_t h_th[32000];
        pthread_t d_th;
        pthread_t m_th;
        arg_t arg_th;
        char *iptarget="`hostname`";
        char temp[PATH_MAX];

        arg_th.net=0;
        system("date");
        (void) setlocale (LC_ALL,"");

        login = (argv[0][0] == '-');
        cp = rindex(argv[0], '/');
        firstchar = login ? argv[0][1] : (cp==NULL) ? argv[0][0] : cp[1];
        cp = argv[0];   /* for Usage */

        printf("\n");
        printf("%s Beta test version.\n",cp);
        printf(" (C) COPYRIGHT International Business Machines Corp. 1999\n");
        printf(" All Rights Reserved\n");
        if (argc==0) {usage(); exit(1);}
        while ((tp = getopt(argc, argv,"t:n:m:d?" )) != EOF)
                switch(tp) {
                        case 't':
                                if (tflag==1) { printf("%s: Multiple -t switch
ignored \n",cp); break; }

                                if (*optarg==0) {
printf(
                                   "%s: The number of threads to launch was not
 specified with the '-t' option \n", cp);
                                   printf("%s: By default 1 thread will be laun
ched.\n",cp);
                                   thread_max=1;
                                }
                                else thread_max=atoi(optarg);
                                /* check for errors here */
                                if ((thread_max < 1)||( thread_max > 32000)) {
                                   printf(
                                   "%s: invalid number of threads requested (mu
st be between 1 and 32000)\n",cp);
                                   usage();
                                   exit(1);
                                }
                                tflag=1;
                                break;

                        case 'n':
                                if (tflag==0) {printf("%s: -t switch must be sp
ecified first to use -n option\n",cp);
                                              usage(); exit(2);
                                             }
```

```
 if (arg_th.net==1) { printf("%s: Multiple -n sw
itch ignored \n",cp); break; }
                                if (*optarg != 0) iptarget = optarg;
                                if(sprintf(temp,"spray %s -l 1024 -c 50 2> /dev
/null > /dev/null",iptarget)) printf("%s: sprintf errno was %d\n %s\n",cp,errno
,temp);
                                arg_th.string=temp;
arg_th.net=1;
                                break;

                        case 'm':
                                if (mflag==1) { printf("%s: Multiple -m switch
ignored \n",cp); break; }

                                if (*optarg==NULL) {
                                   printf(
                                   "%s: Memory value must be specified with 'm'
 option \n", cp);
                                   usage();
                                   exit(1);
                                }
                                else megs=atoi(optarg);
                                /* check for errors here */
                                if ((megs < 0)||(megs >= 64000)) {
                                   printf(
                                   "%s: invalid memory value requested (must be
 between 0 and 64000) MB\n",cp);
                                   usage();
                                   exit(1);
                                }
                                megs *= (size_t)(1024*1024);
                                mflag=1;
                                break;

                        case 'd':
                                if (dflag==1) { printf("%s: Multiple -d switch
ignored \n",cp); break; }
                                dflag=1;
break;

                        case '?':
                                usage();
                                exit(1);
                                break;

                        default:
                                printf("%s: Bad flag '%s' option ignored\n",cp,
tp);
                        }
/* End of argument finder */
/* Debug routine */
#ifdef DEBUG
printf("\n%s: debug active : thread_max=%d, tflag=%d, mflag=%d, dflag=%d \n meg
s=%d, arg_th.string=%s, arg_th.net=%d \n Normal debug exit \n",cp,thread_max,tf
lag,mflag, dflag, megs, arg_th.string, arg_th.net);
exit(0);
#endif
```

```
        printf("\n%s: Configuration Summary \n",cp);
        /* CPU Bound Thread Launch Stuff */
        if (tflag==1) {
           pthread_mutex_init(&m, NULL);
           for (i=0,j=1;i<thread_max;i++) {
              if (pthread_create(&h_th[i], NULL, Thread, &arg_th))
              {
                j=0;
                printf("Launched %d threads so far...Error Launching more, errn
o was %d\n",i,errno);
                break;
}
            }
            if (j==1) printf("Launched %d thread(s) \n",--i);
         } else printf("No CPU Bound Threads Launched...\n");

         /* Disk I/O Stuff */
         if (dflag==1)
              if (pthread_create(&d_th, NULL, Gen_File_IO, &arg_th))
                 printf("%s: Couldn't create Disk I/O Thread...errno was %d\n",
cp,errno);
                 else printf("Launched I/O Generator Thread \n");
         /* End of Thread Launching */

         /* Memory Use Stuff */
         if (mflag==1) {
              if (pthread_create(&m_th, NULL, Memory_Thread, &arg_th))
                 printf("%s: Couldn't create Memory Thread...errno was %d\n",cp
,errno);
                 else printf("Launched Memory Allocator Thread \n");
         }
        pthread_exit(0);
        printf("%s:Normal Exit",cp);
        system("date");
        exit(0);
}
```

This script was compiled with the following make file:

```
#Make file for loadgen benchmarks.


clean:
        rm dssserver oltpserver backupserver loadgen

all: hog.c
        cc_r -g -o loadgen hog.c -bD:0x80000000 -lm
        cp loadgen /home/dssadm/dssserver
        cp loadgen /home/oracle/oltpserver
        cp loadgen /home/adsm/backupserver

(0)itsosrv1:/wlm/scripts#
```

- Three users were created to run this test: *oracle*, *dssadm*, and *adsm*.
- Two groups were created: *dba* and *admin*.
- Two filesystems were created on different disks: */wlm_fs1* and */wlm_fs2*.
- Due to the test system being a 12-way SMP with 1 GB Memory, the arguments displayed in the next screenshot were chosen to start the different workloads, *OLTP*, *DSS*, and *backup*.

The goal was that the OLTP workload always has enough resources. This workload mainly consumes CPU and memory resources and is, therefore, competing with the backup and the DSS workload over these resources.

The backup workload consumes mainly disk I/O resources next to CPU and memory.

The DSS workload consumes CPU, memory, and disk I/O resources.

```
(0)itsosrv1:/# cat /home/oracle/oltp.sh
oltpserver -t 100 -n 9.3.240.10 -m 128 >> ~oracle/oracle.log
(0)itsosrv1:/# cat /home/dssadm/dss.sh
dssserver -t 50 -m 256 -d >> ~dssadm/dss.log
(0)itsosrv1:/# cat /home/adsm/back.sh
backupserver -t 25 -m 256 -d >> ~adsm/back.log
(0)itsosrv1:/#
```

Parameters used to start the different workloads:

`-t thread_count`	Launch a number of CPU Bound threads where `thread_count` is an integer specifying the number of threads to launch.
`-n iptarget`	Threads should generate network I/O where `iptarget` is either an IP address or hostname.
`-m memory_value`	Determines the amount of working memory to be allocated and utilized by the main program. Memory will be touched continuously, where `memory_value` is an integer specifying the number of MB (Megabytes) to allocate.
`-d`	Generates disk I/O.

After defining the parameters, the three scripts, oltp.sh, dss.sh, and back.sh, were started by executing the start.sh script:

```
(0)itsosrv1:/wlm/scripts# pg start.sh
/usr/samples/kernel/vmtune -P 30
su - oracle -c "~oracle/oltp.sh & "
su - dssadm -c "~dssadm/dss.sh & "
su - adsm  -c "~adsm/back.sh & "
(0)itsosrv1:/wlm/scripts#
```

Important:
In /etc/security/limits the *data file* entry was set to -1 (for unlimited).

Suggestions:
It proved to be helpful to first take the actual WLM configuration and run WLM in passive mode. Get a performance report for all classes every 10 seconds and this for five minutes as shown in the following screenshots:

```
^C(130)itsosrv1:/# wlmstat 10 30
         CLASS CPU MEM BIO
  Unclassified   0   0   0
     Unmanaged   0   0   0
       Default   0   0   0
        Shared   0   1   0
        System   0   8   0
          oltp   0   0   0
oltp.Default     0   0   0
 oltp.Shared     0   0   0
  oltp.spray     0   0   0
           dss   0   0   0
        backup   0   0   0
.....
.....
```

To collect more detailed information, the following statistics can be run:

```
(0)itsosrv1:/# wlmstat -c -v
            CLASS tr i #pr CPU sha min smx hmx des  rap urap pri
     Unclassified  0 0   1   0  -1   0 100 100 100    0   97  10
        Unmanaged  0 0   0   0  -1   0 100 100   0    0   97  10
          Default  0 0   1   0  -1   0 100 100   0    0   97  97
Default.Default    0 0   1   0   1   0 100 100 100  100   48  48
 Default.Shared    0 0   0   0  -1   0 100 100   0    0   96  96
           Shared  0 0   0   0  -1   0 100 100   0    0   97  97
 Shared.Default    0 0   0   0   1   0 100 100 100  100   48  48
  Shared.Shared    0 0   0   0  -1   0 100 100   0    0   96  96
           System  0 0  44   0  10  10 100 100 100  100    0   0
 System.Default    0 0  44   0   1   0 100 100 100  100    0   0
  System.Shared    0 0   0   0  -1   0 100 100   0    0   48  48
             oltp  0 0   0   0  50   0 100 100  47  100    0   0
   oltp.Default    0 0   0   0  -1   0 100 100 100    0   23  23
    oltp.Shared    0 0   0   0  -1   0 100 100   0    0   23  23
     oltp.spray    1 0   0   0  30   0 100 100  61  100   97  97
              dss  0 0   1   0  20   0 100 100 100  100    0   0
    dss.Default    0 0   1   0   1   0 100 100 100  100    0   0
     dss.Shared    0 0   0   0  -1   0 100 100   0    0   48  48
           backup  0 0   0   0  35   0 100 100  63  100    0   0
 backup.Default    0 0   0   0   1   0 100 100 100  100    0   0
  backup.Shared    0 0   0   0  -1   0 100 100   0    0   48  48
(0)itsosrv1:/#
```

```
(130)itsosrv1:/# wlmstat -m -v
            CLASS tr i #pr MEM sha min smx hmx des  rap urap    npg
     Unclassified  0 0   1   0  -1   0 100 100 100    0  511      0
        Unmanaged  0 0   0   0  -1   1 100 100   0  100    0      2
          Default  0 0   1   0  -1   0 100 100   0    0  511    240
Default.Default    0 0   1   0   1   0 100 100 100  100  255    240
 Default.Shared    0 0   0   0  -1   0 100 100   0    0  510      0
           Shared  0 0   0   1  -1   0 100 100 100    0  511   3230
 Shared.Default    0 0   0   1   1   0 100 100 100   98  260   3230
  Shared.Shared    0 0   0   0  -1   0 100 100   0    0  510      0
           System  0 0  44   8  10  10 100 100  99  100    0  30720
 System.Default    0 0  44   8   1   0 100 100 100   85   38  30753
  System.Shared    0 0   0   0  -1   0 100 100   0    0  255      0
             oltp  0 0   0   0  50   0 100 100  44  100    0      0
   oltp.Default    0 0   0   0  -1   0 100 100 100    0  127      0
    oltp.Shared    0 0   0   0  -1   0 100 100   0    0  127      0
     oltp.spray    1 0   0   0  30   0 100 100  86  100  512      0
              dss  0 0   1   0  20   0 100 100  30  100    0      0
    dss.Default    0 0   1   0   1   0 100 100 100  100    0      0
     dss.Shared    0 0   0   0  -1   0 100 100   0    0  255      0
           backup  0 0   0   0  35   0 100 100  77  100    0      0
 backup.Default    0 0   0   0   1   0 100 100 100  100    0      0
  backup.Shared    0 0   0   0  -1   0 100 100   0    0  255      0
(0)itsosrv1:/#
```

After the first run, the shares and tiers were changed, and further observations with `wlmstat` were made before WLM was turned into active mode.

General recommendations

An easy way to analyze a system running WLM is:

1. Start with a simple model.
2. Run WLM in passive mode.
3. Do some refinements.
4. Repeat the last two steps a few times.
5. Run WLM in active mode.
6. Collect statistics, via `wlmstat`, to see if the defined goals are achieved.
7. Modify shares, rules, and tiers.
8. Go to step 6.
9. Decide which is your best WLM configuration.

Appendix C. Sample Korn shell scripts for manual assignment

In this appendix, the scripts used for the manual assignment examples of Chapter 5, “Manual assignment” on page 141, are listed. They are also available for practical use on the floppy disk provided with the redbook.

C.1 Oracle example script

This is the script used in the Oracle example described in Section 5.3, “Examples” on page 152:

```
#/bin/ksh
# Sample script to perform manual assignment of processes whose different
# instances can be differentiated by their output in ps -ef.
# Examples of this kind of processes are ORACLE database instances.
#
# Create a configuration file /etc/wlm/ma.conf with the following format:
# One line for each combination of:
#              <Instance name> <Class> <Inheritance>
# where:
#              o Instance Name is the ORACLE instance.
#              o Class is the name of the class to assign the processes to;
#                Either ‘supername’ for superclasses or ‘supername.subname’
#                for subclasses.
#              o Inheritance is a flag, which should be set to yes if you
#                want all processes belonging to a process group, whose
#                leader is the process being manually assigned, to be
#                manually assigned too, or no, otherwise.
# MANUAL is an array of three positions, which one of them being:
#              o Position 0: Instance name.
#              o Position 1: Class name.
#              o Position 2: Inheritance flag.

##
# DIRECTORIES
##
WLMDIR=/etc/wlm

##
# VARIABLES
##
CONFFILE=$WLMDIR/ma.conf
PATH=/usr/bin:/usr/sbin:$PATH

##
# FUNCTIONS
##
```

```
getpids()
{
       echo `ps -ef | grep $1 | grep -v grep | awk '{ print $2 }'` | sed \
           's/ /,/g'
}

##
# MAIN
##
(while read LINE
do
       set -A MANUAL $LINE

       echo "Changing the inheritance attribute on class ${MANUAL[1]}..."
       OLDINH=`lsclass -f ${MANUAL[1]} | grep inheritance | awk '{ print \
          $3 }' | sed "s/\"//g"`
       [ ! "$OLDINH" ] && OLDINH="no"
       chclass -a inheritance=${MANUAL[2]} ${MANUAL[1]}
       echo "Refreshing WLM..."
       wlmcntrl -u

       echo "Getting PIDS' list for instance ${MANUAL[0]}..."
       PIDLIST=$(getpids ${MANUAL[0]})

       if [ -z "$PIDLIST" ]
       then
           echo "No processes found for class ${MANUAL[1]}, skipping \
          assignment ..."
       else
           echo "Manually assigning the processes to class ${MANUAL[1]}..."
           wlmassign ${MANUAL[1]} $PIDLIST
       fi

       echo "Resetting old inheritance value on class ${MANUAL[1]}..."
       chclass -a inheritance="$OLDINH" ${MANUAL[1]}
       echo "Refreshing WLM..."
       wlmcntrl -u
done
) < $CONFFILE
```

C.2 DB2 UDB example script

This is the script used for the DB2 UDB example of Section 5.3, “Examples” on page 152:

```
#/bin/ksh
# Sample script to perform manual assignment
```

```
# of processes whose different instances
# can be differentiated by an environmental variable.
# Examples of this kind of processes are DB2 database instances.
#
# Create a configuration file /etc/wlm/ma.conf with the following format:
# One line for each combination of:
#             <Instance name> <Class> <Inheritance>
# where:
#             o Instance Name is the DB2 instance name.
#             o Class is the name of the class to assign the processes to;
#               Either ‘supername’ for superclasses or ‘supername.subname’
#               for subclasses.
#             o Inheritance is a flag, which should be set to yes if you
#               want all processes belonging to a process group, whose
#               leader is the process being manually assigned, to be
#               manually assigned too, or no, otherwise.
# MANUAL is an array of three positions, which one of them being:
#             o Position 0: Instance name.
#             o Position 1: Class name.
#             o Position 2: Inheritance flag.
# APP is a string naming the application in question, in the format that
# matches the launched processes in the process table (db2, in this
# example).
# VARIABLE is the name of the environmental variable that establishes the
# difference between instances (DB2INSTANCE, in this example).

##
# DIRECTORIES
##
WLMDIR=/etc/wlm

##
# VARIABLES
##
CONFFILE=$WLMDIR/ma.conf
PATH=/usr/bin:/usr/sbin:$PATH
APP="db2"
VARIABLE="DB2INSTANCE"

##
# FUNCTIONS
##
getpids()
{
       unset PIDLIST
       for PID in ‘ps -ef | grep $APP | grep -v grep | awk ‘{ print $2 }’‘
       do
           (ps eww $PID | grep "$VARIABLE=$1" > /dev/null ) && \
```

```
            if [ ! "$PIDLIST" ]
            then
                PIDLIST=$PID
            else
                PIDLIST="$PIDLIST,$PID"
            fi
        done
        print $PIDLIST
}

##
# MAIN
##
(while read LINE
do
        set -A MANUAL $LINE

        echo "Changing the inheritance attribute on class ${MANUAL[1]}..."
        OLDINH=`lsclass -f ${MANUAL[1]} | grep inheritance | awk '{ print \
            $3 }' | sed "s/\"//g"`
        [ ! "$OLDINH" ] && OLDINH="no"
        chclass -a inheritance=${MANUAL[2]} ${MANUAL[1]}
        echo "Refreshing WLM..."
        wlmcntrl -u

        echo "Getting PIDS' list for instance ${MANUAL[0]}..."
        PIDLIST=$(getpids ${MANUAL[0]})

        if [ -z "$PIDLIST" ]
        then
            echo "No pids found for class ${MANUAL[1]}, skipping \
            assignment ..."
        else
            echo "Manually assigning the processes to class ${MANUAL[1]}..."
            wlmassign ${MANUAL[1]} $PIDLIST
        fi

        echo "Resetting old inheritance value on class ${MANUAL[1]}..."
        chclass -a inheritance="$OLDINH" ${MANUAL[1]}
        echo "Refreshing WLM..."
        wlmcntrl -u
done
) < $CONFFILE
```

Appendix D. Sample program for application tag

In this appendix, the program, settag.c, used for the application tag example of Section 6.1.3 on page 159 is listed. It is also available for practical use on the floppy disk provided with the redbook:

D.1 settag.c

```
#include <unistd.h>
#include <stdio.h>
#include <errno.h>
#include <sys/wlm.h>

/* Program for launching and tagging an application */
main (argc,argv)
   char **argv;
   int argc;
{
   int rc,flags;
   if (argc != 3) {
          usage(argv[0]);
          exit(1);
   }
   flags= WLM_VERSION|SWLMTAGINHERITFORK|SWLMTAGINHERITEXEC;
   if(wlm_initialize(WLM_VERSION)){
          perror("wlm_initialize");
          exit(1);
   }
   if(wlm_set_tag(argv[1],&flags)){
          perror("wlm_set_tag");
          exit(2);
   }
   if (execlp(argv[2],argv[2],0)){
          perror("execlp"); printf("Problem launching app...\n");
          exit(3);
   }
   exit(0);
}

usage(char *cp)
{
   printf("\n  %s takes 2 arguments:\n",cp);
   printf("Usage: %s tag_name program_name \n",cp);
   printf("where: tag_name is the rule tag that program_name will inherit \
          \n");
}
```

Appendix E. Sample for CPU resource usage calculation

A sample spread sheet that contains the CPU resource usage data of Applications A, B, C, and D from Section 7.3.2, “Examples” on page 173, is listed below. This was obtained separately by monitoring Applications A, B, C, and D respectively, which ran on a system that has a capacity of 10,000 tpm (transaction per minute). The resource usage was measured for each application at 10 minute intervals for 500 minutes. The unit of the measurement is a percentage.

Because the system capacity is 10,000 tpm, each percentage value in the spread sheet is easily converted, by multiplying by 100, to the actual tpm value that was consumed by each application at the moment of measurement.

This data is not from monitoring a real system but was simulated as a general example.

Time unit	Application A	Application B	Application C	Application D	Sum of A, B, C, D
1	11	34	2	18	65
2	14	32	3	19	68
3	12	33	5	15	65
4	16	32	3	13	64
5	25	25	4	16	70
6	39	22	2	12	75
7	56	18	1	15	90
8	21	22	3	19	65
9	12	23	4	14	53
10	9	26	2	13	50
11	15	24	1	16	56
12	18	23	2	17	60
13	11	17	3	16	47
14	21	19	2	18	60
15	46	18	1	16	81
16	51	15	2	14	82
17	16	16	3	16	51
18	12	18	2	15	47
19	17	19	3	17	56
20	18	20	4	16	58
21	16	18	5	16	55
22	15	21	3	18	57
23	42	22	2	19	85
24	54	21	4	18	97
25	35	25	2	19	81
26	22	24	1	17	64
27	21	27	2	18	68
28	18	28	2	17	65
29	15	34	3	18	70
30	23	32	1	16	72
31	21	33	3	15	72
32	15	33	2	16	66
33	12	31	3	12	58
34	8	26	3	17	54
35	6	25	2	14	47
36	7	23	1	13	44
37	8	22	2	14	46
38	6	24	5	13	48
39	6	19	35	12	72
40	7	18	54	12	91
41	8	15	57	13	93
42	6	17	55	11	89
43	5	17	56	12	90
44	8	16	57	11	92
45	9	15	54	11	89
46	8	15	53	12	88
47	7	16	55	11	89
48	7	16	55	11	89
49	7	14	56	13	90
50	6	13	51	11	81
Total	868	1116	736	745	3465

Appendix F. Using the additional material

This redbook contains additional material in diskette format. See the appropriate section below for instructions on using or downloading each type of material.

F.1 Using the diskette

The diskette that accompanies this redbook contains the following:

File name	*Description*
ma_db2.sh	Sample script for manual assignment with DB2
ma_oracle.sh	Sample script for manual assignment with Oracle
settag.c	Sample source code for Application Tag setting
settag	Sample binary for Application Tag setting

F.1.1 System requirements for using the diskette

The following system configuration is recommended for optimal use of the diskette.

Operating System:	AIX 5L for Power Version 5.0 or higher
Processor:	IBM RS/6000

F.1.2 How to use the diskette

You can access the contents of the diskette by extracting the files on the diskette with `tar -xvf /dev/fd0` into your current directory.

F.2 Locating the additional material on the Internet

The diskette material associated with this redbook is also available in softcopy on the Internet from the IBM Redbooks Web server. Point your Web browser to:

ftp://www.redbooks.ibm.com/redbooks/SG245977

Alternatively, you can go to the IBM Redbooks Web site at:

http://www.redbooks.ibm.com/

Select the **Additional materials** and open the directory that corresponds with the redbook form number.

Appendix G. Special notices

This publication is intended to help system administrators and technical support specialists implement and use AIX Workload Manager efficiently. The information in this publication is not intended as the specification of any programming interfaces that are provided by AIX 5L. See the PUBLICATIONS section of the IBM Programming Announcement for AIX 5L for more information about what publications are considered to be product documentation.

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Appendix H. Related publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this redbook.

H.1 IBM Redbooks

For information on ordering these publications see "How to get IBM Redbooks" on page 275.

- *Introducing Tivoli Application Performance Management*, SG24-5508
- *Server Consolidation on RS/6000*, SG24-5507
- *AIX 5L Differences Guide Version 5.0 Edition*, SG24-5765 (to be published in December, 2000)

H.2 IBM Redbooks collections

Redbooks are also available on the following CD-ROMs. Click the CD-ROMs button at ibm.com/redbooks for information about all the CD-ROMs offered, updates, and formats.

CD-ROM Title	Collection Kit Number
IBM System/390 Redbooks Collection	SK2T-2177
IBM Networking Redbooks Collection	SK2T-6022
IBM Transaction Processing and Data Management Redbooks Collection	SK2T-8038
IBM Lotus Redbooks Collection	SK2T-8039
Tivoli Redbooks Collection	SK2T-8044
IBM AS/400 Redbooks Collection	SK2T-2849
IBM Netfinity Hardware and Software Redbooks Collection	SK2T-8046
IBM RS/6000 Redbooks Collection	SK2T-8043
IBM Application Development Redbooks Collection	SK2T-8037
IBM Enterprise Storage and Systems Management Solutions	SK3T-3694

H.3 Other resources

These publications are also relevant as further information sources:

- *Workload Management Surges to Prominence in UNIX Servers*, D. H. Brown Associates, Inc.
- *AIX Workload Manager Technical Reference - February Update*, IBM Whitepaper
- *AIX Performance Toolbox User's Guide V1 and V2.1*, SC23-2625

H.4 Referenced Web site

The following Web site is also relevant as a further information source:

`http://www.rs6000.ibm.com/doc_link/en_US/a_doc_lib/aixgen/`
AIX online documentation

How to get IBM Redbooks

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Abbreviations and acronyms

AIX	Advanced Interactive Executive
APAR	Authorized Program Analysis Report
API	Application Programming Interface
ARM	Application Response Measurement
CCMS	Computing Center Management System
CPU	Central Processing Unit
DB	Database
DB2	Database 2
DBA	Database Administrator
DKIO	Disk I/O
GB	Gigabyte
GID	Group Identification
GL	Peoplesoft General Ledger
HACMP	High Availability Cluster Multi-Processing
HM	Hard Maximum limit
HTML	Hypertext Markup Language
IBM	International Business Machines Corporation
ID	Identification
I/O	Input/Output
IPL	Initial Program Load
ISICC	IBM SAP International Competence Center
IT	Information Technology
ITSO	International Technical Support Organization
KB	Kilo Byte
LPAR	Logical Partitioning
LRU	Least Recently Used
m	Minimum limit
MB	Mega Byte
NFS	Network File System
NIC	John von Neumann Institute for Computing
NIS	Network Information Service
NUMA	Non-Uniform Memory Access
OLAP	On-line Analytical Processing
OLTP	On-line Transaction Processing
OS	Operating System
PGID	Process Group Identifier
PID	Process Identifier
PTX	Performance Toolbox
rset	Resource set
SAP	Systems, Applications, and Products in Data Processing
SD	Sales and Distribution
SGA	System Global Area
SM	Soft Maximum limit
SMIT	System Management Interface Tool
SMP	Symmetric Multi-Processing
SPMI	System Performance Measurement Interface
SSA	Serial Storage Architecture

TAPM	Tivoli Application Performance Management
TCC	SAP Technical Competence Center
TCP	Transmission Control Protocol
TEC	Tivoli Enterprise Console
TDS	Tivoli Decision Support
TOC	Total Cost of Ownership
TPM	Transactions per minute
TTY	Teletype Terminal
UID	User Identification
URAP	Uniform Resource Access Priority
VMM	Virtual Memory Manager
WLM	Workload Manager
WSM	Web-based System Manager
ZAM	Central Institute for Applied Mathematics

Index

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Document Number **Redbook Title**	SG24-5977-00 AIX 5L Workload Manager (WLM)
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AIX 5L Workload Manager (WLM)

AIX 5L Workload Manager (WLM)

Redbooks

Effectively manage your system resources

Learn how to deploy the new functionality

Manage multiple instances of a database

Effectively managing system resources in growing UNIX server environments has become a primary task. Each workload on the server must be assured the appropriate amount of system resources without penalizing mission-critical applications. AIX 5L Workload Manager provides a great set of tools and functionalities to efficiently manage system resources on a consolidated server.

This IBM redbook exploits the entire functionality of AIX 5L Workload Manager, which has been enhanced in many ways since its first introduction with AIX V4.3.3. The new manual assignment feature allows you to separate, for example, multiple instances of a database. An API allows you to perform all the WLM administration and configuration tasks from a program. A step-by-step guide is provided for planning and configuring AIX WLM through file editing, AIX commands, the System Management Interface Tool (SMIT), or Web-based System Manager (WSM). Real-life examples have been added to demonstrate the impact and benefits of using AIX Workload Manager.

This IBM redbook is the ultimate guide for system architects, technical support specialists, and system administrators who have to plan, implement, and administer a Workload Manager solution in a consolidated server environment.

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