Dynamic Load Balance for Optimized Message Logging in Fault Tolerant HPC Applications

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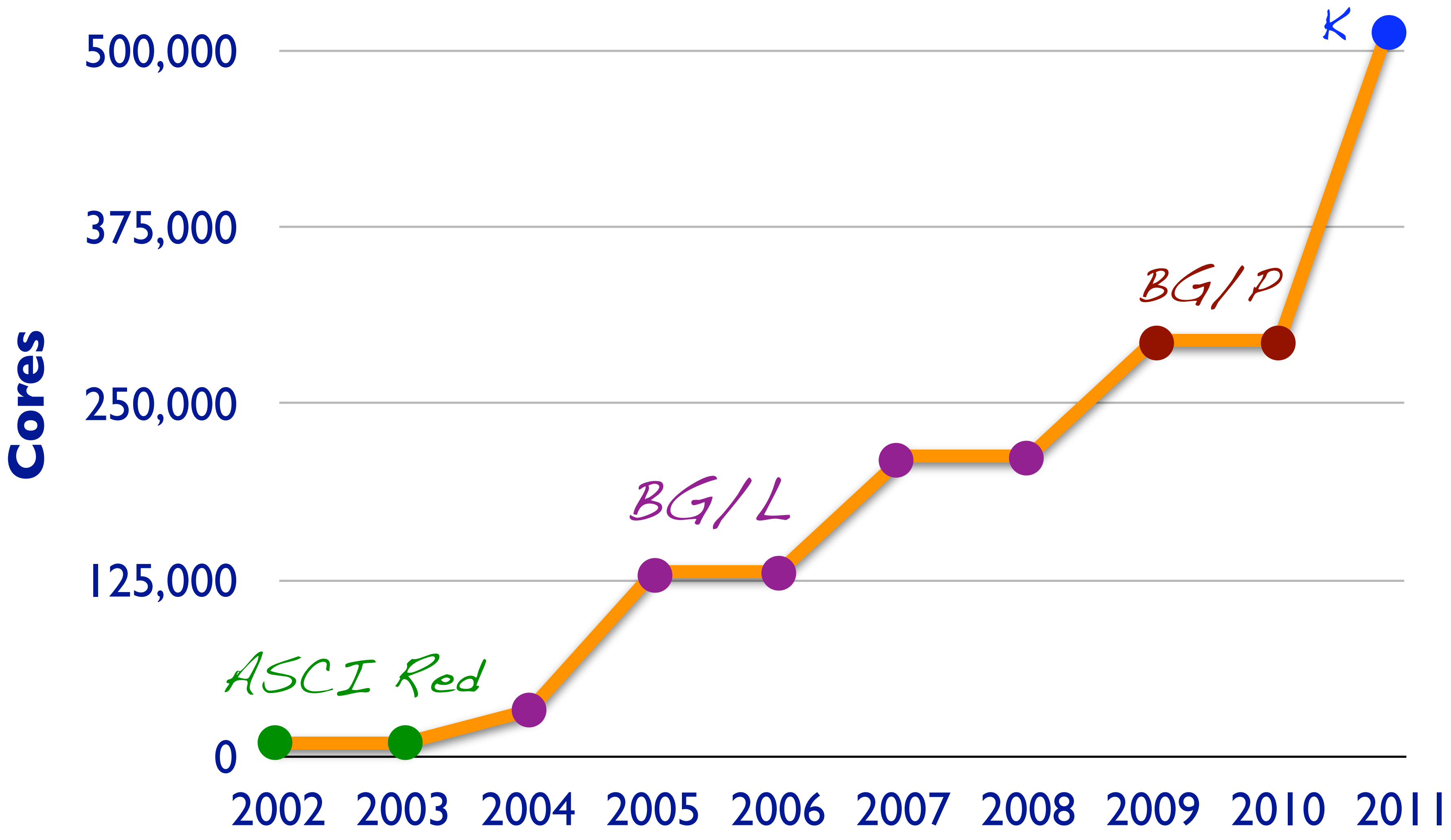


Frequent Failures

Sequoia	Exascale
1.6 million cores	100 million cores?
2012	2018

A key challenge is to adapt to the unavoidable variability in time and space (processes/processors) of future applications and systems
International Exascale Software Project

→

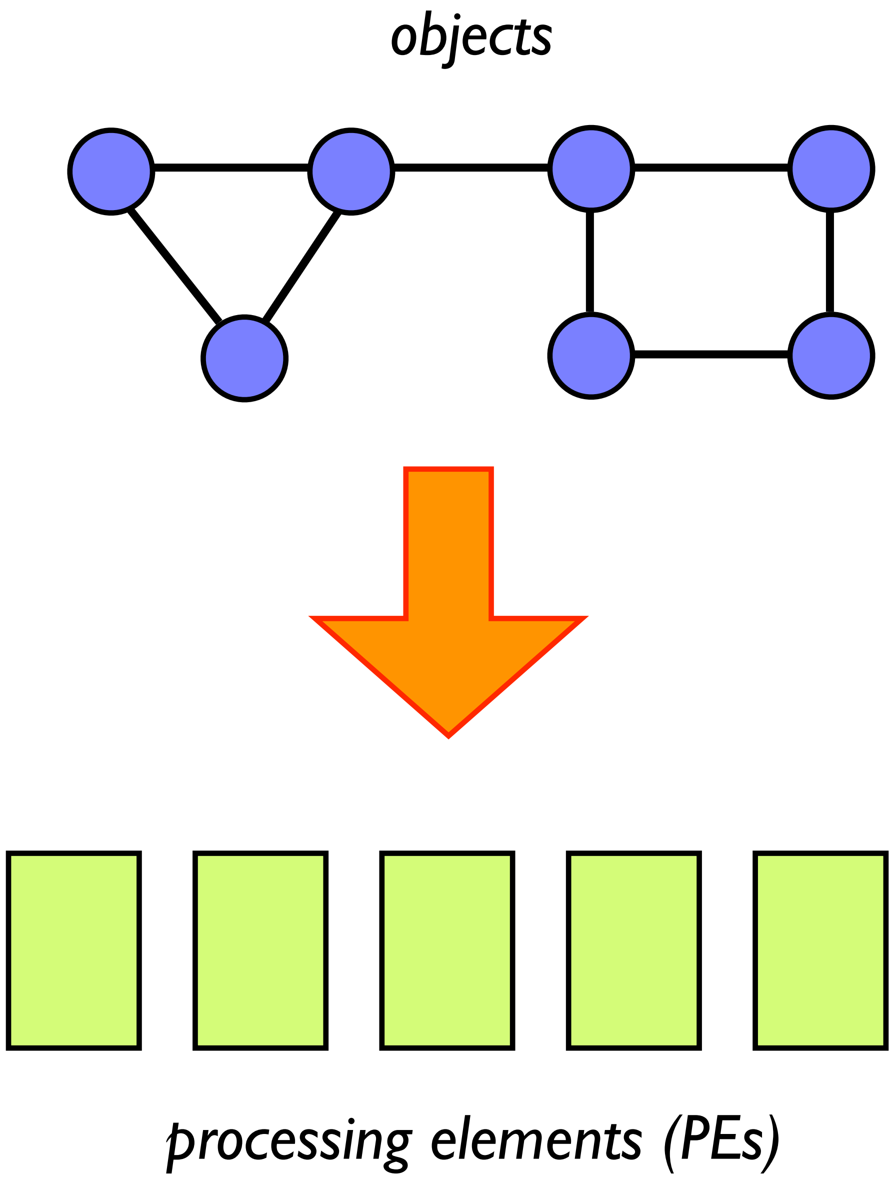
Leverage Load Balancing Infrastructure for Fault Tolerance

Contents

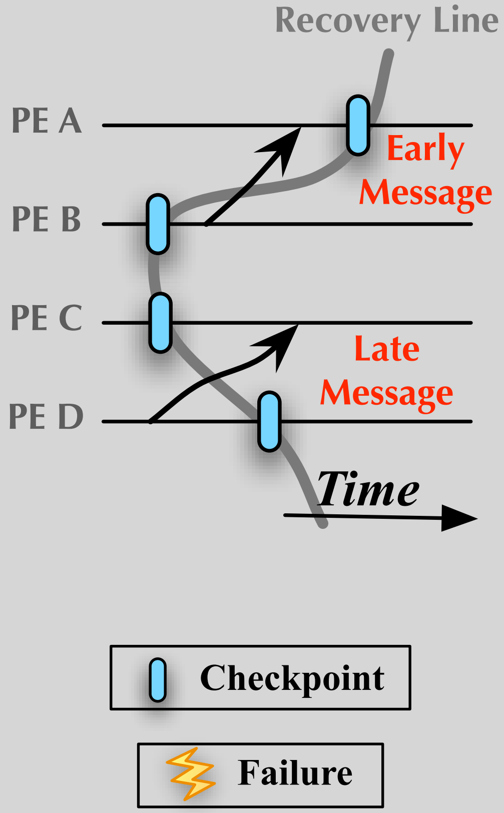
- Rollback-Recovery
- Load Balancing
- Optimized Message Logging
- Experiments
- Conclusions and Future Work

Model

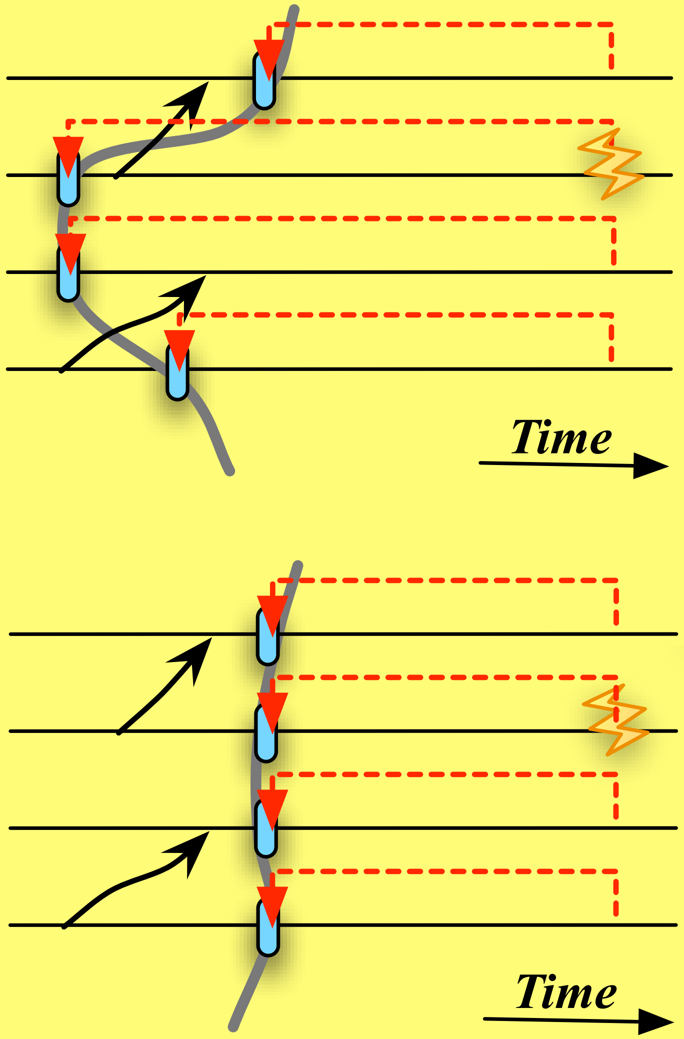
- Object-based over-decomposition.
- Asynchronous method invocation.
- Migratable-objects runtime system.
- Non-FIFO channels.
- Charm++ and Adaptive MPI.
- Fail-stop crashes, user-level checkpoint.



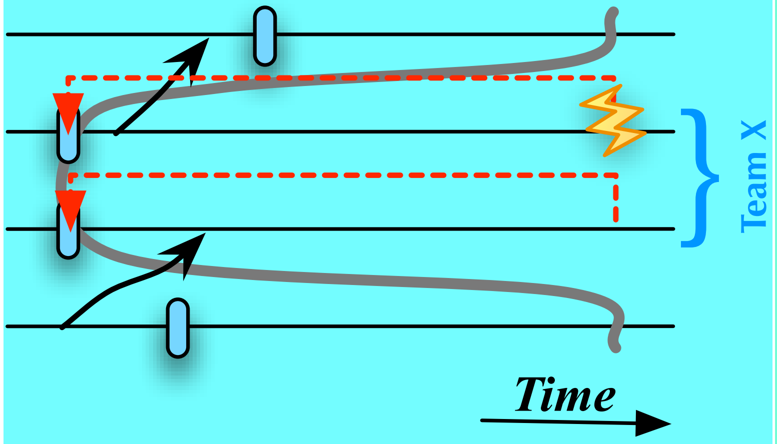
Rollback-Recovery



Checkpoint/Restart

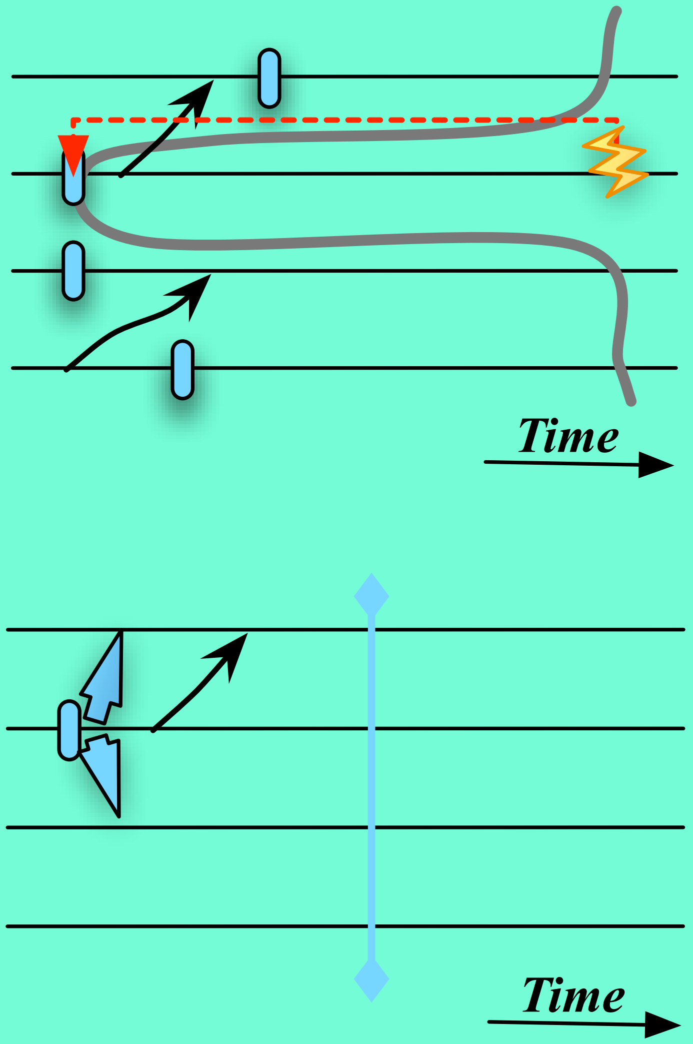


Team-based Message Logging



team = group of PEs

Message Logging



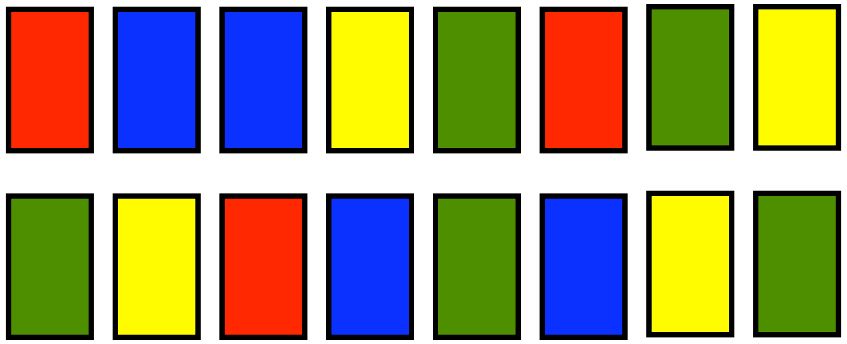
Expensive Recovery

How do you form teams?

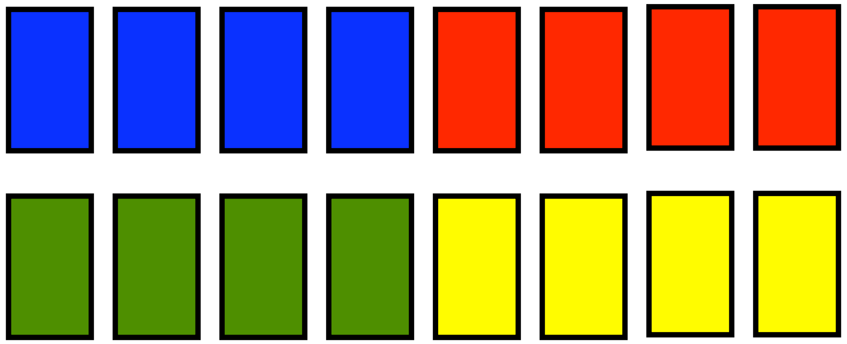
Memory Overhead

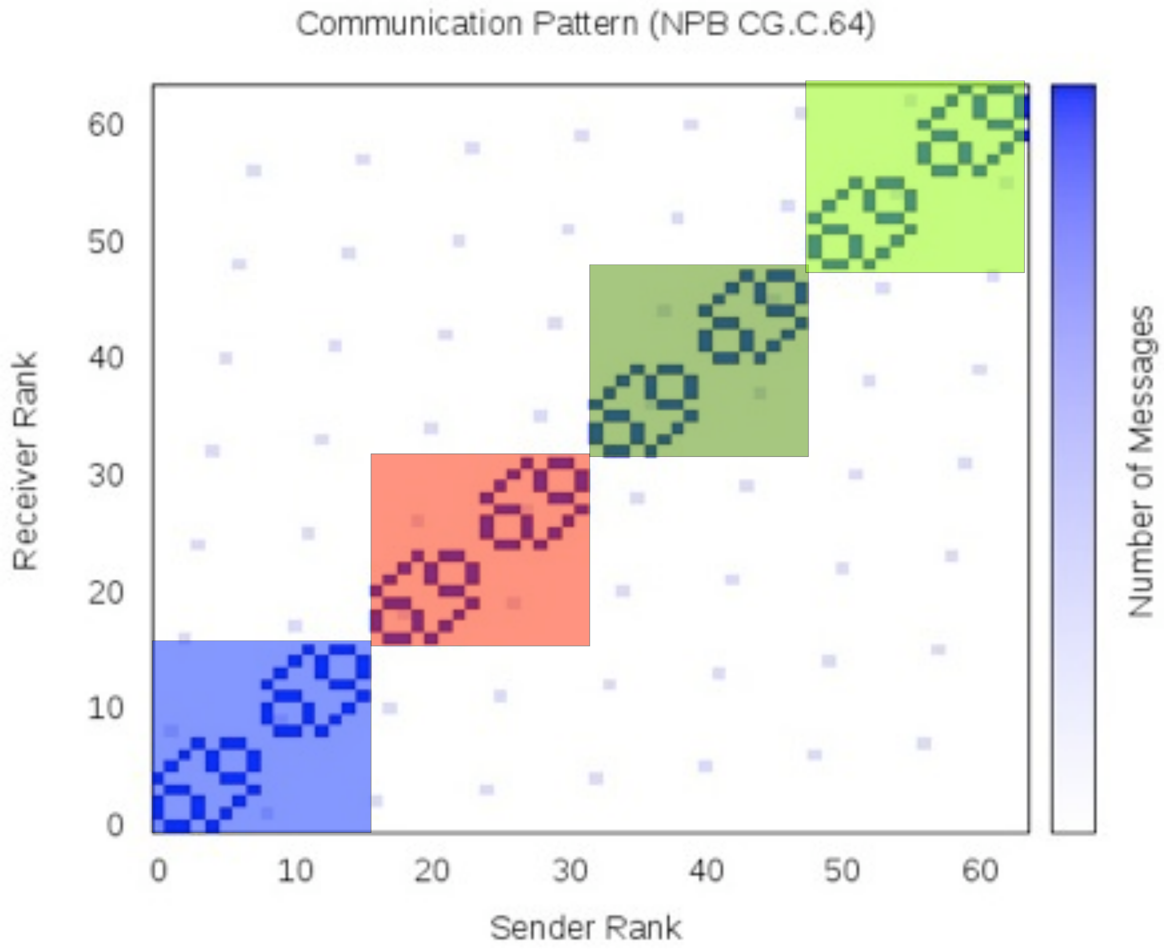
Forming Teams

Random

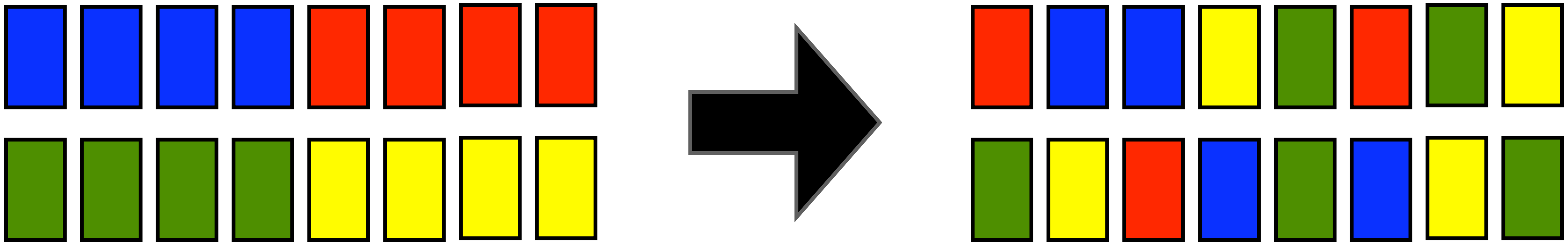


Static

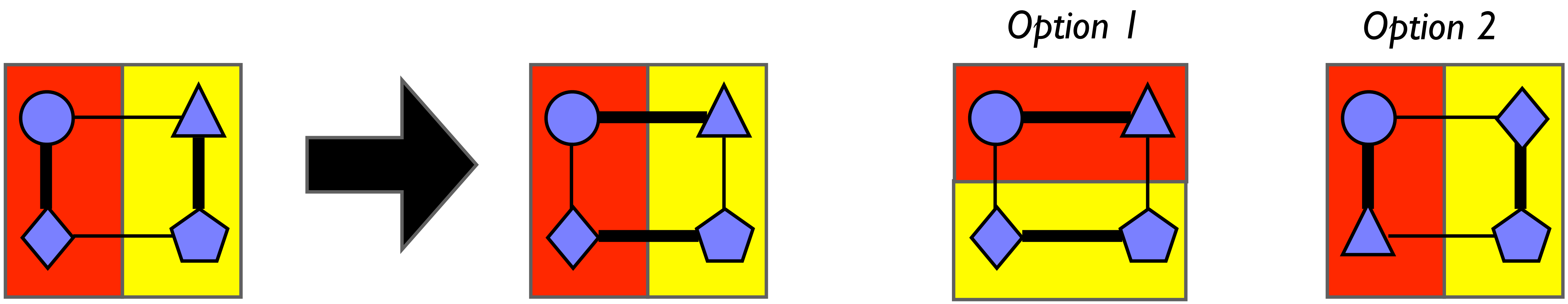




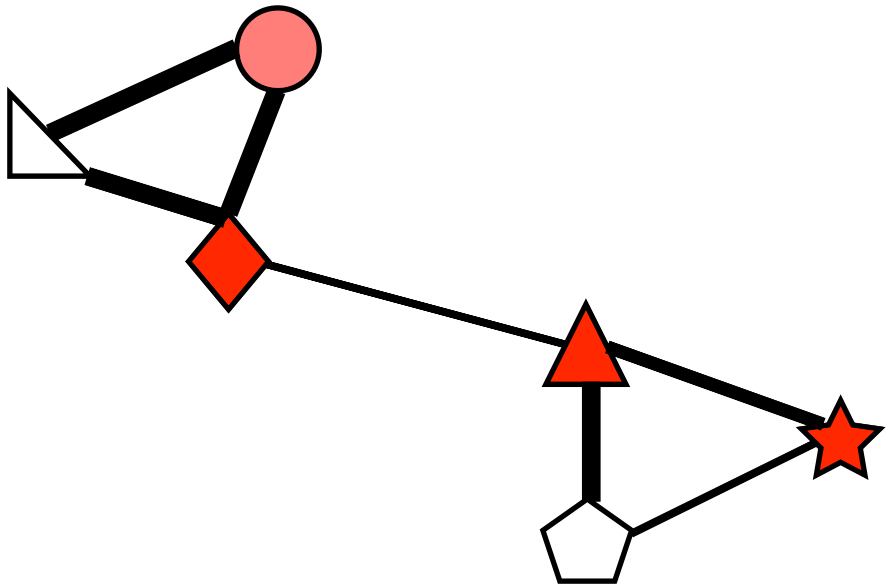
Dynamic



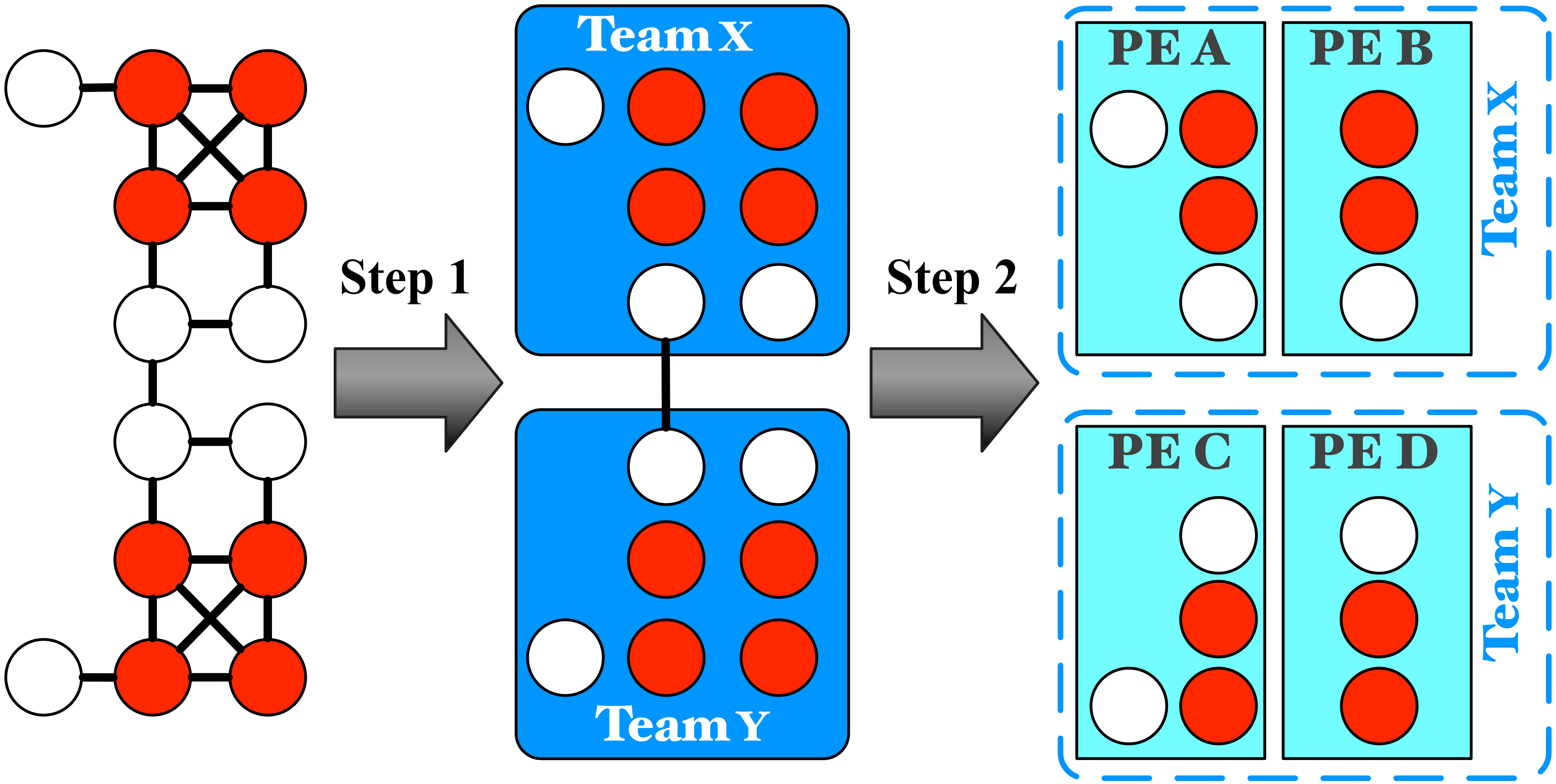
Load Balancing



- Runtime system collects statistics about objects:
  - Computational load.
  - Communication graph.

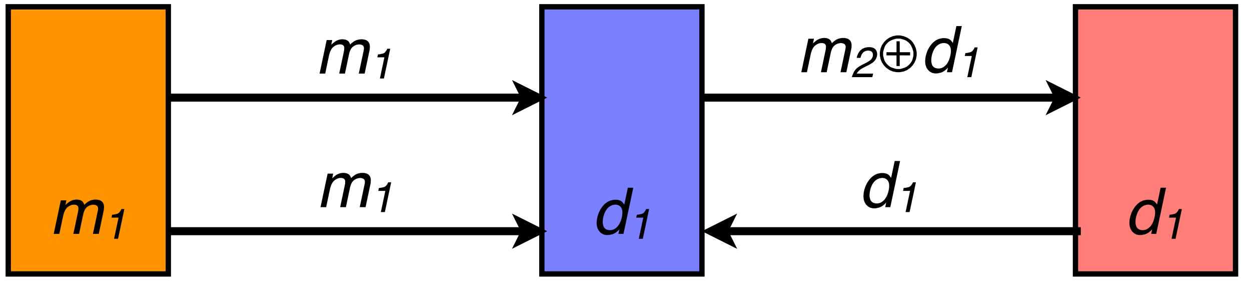


Load Balancer



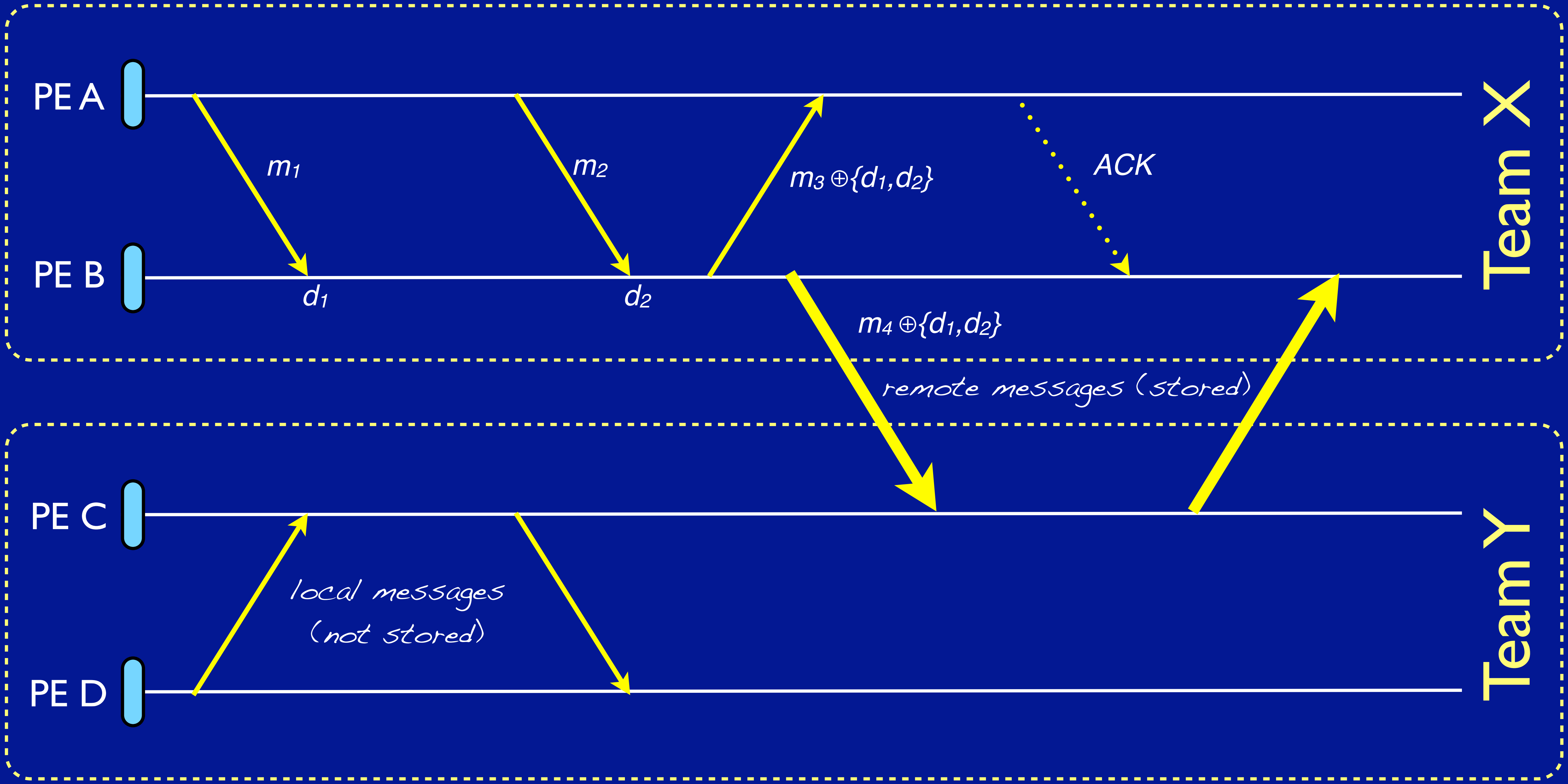
Optimized Message Logging

- Every non-deterministic event generates a determinant (message reception).
- Simple Causal Message Logging:
  - Messages stored at sender's memory.
  - Determinants stored at receivers (at least once).



- Optimization: synchronized checkpoint.

Protocol


PE A
PE B
PE C
PE D
m1
m2
m3 ⊕{d1,d2}
ACK
d1
d2
m4 ⊕{d1,d2}
remote messages (stored)
local messages
(not stored)
Team X
Team Y

Experiments

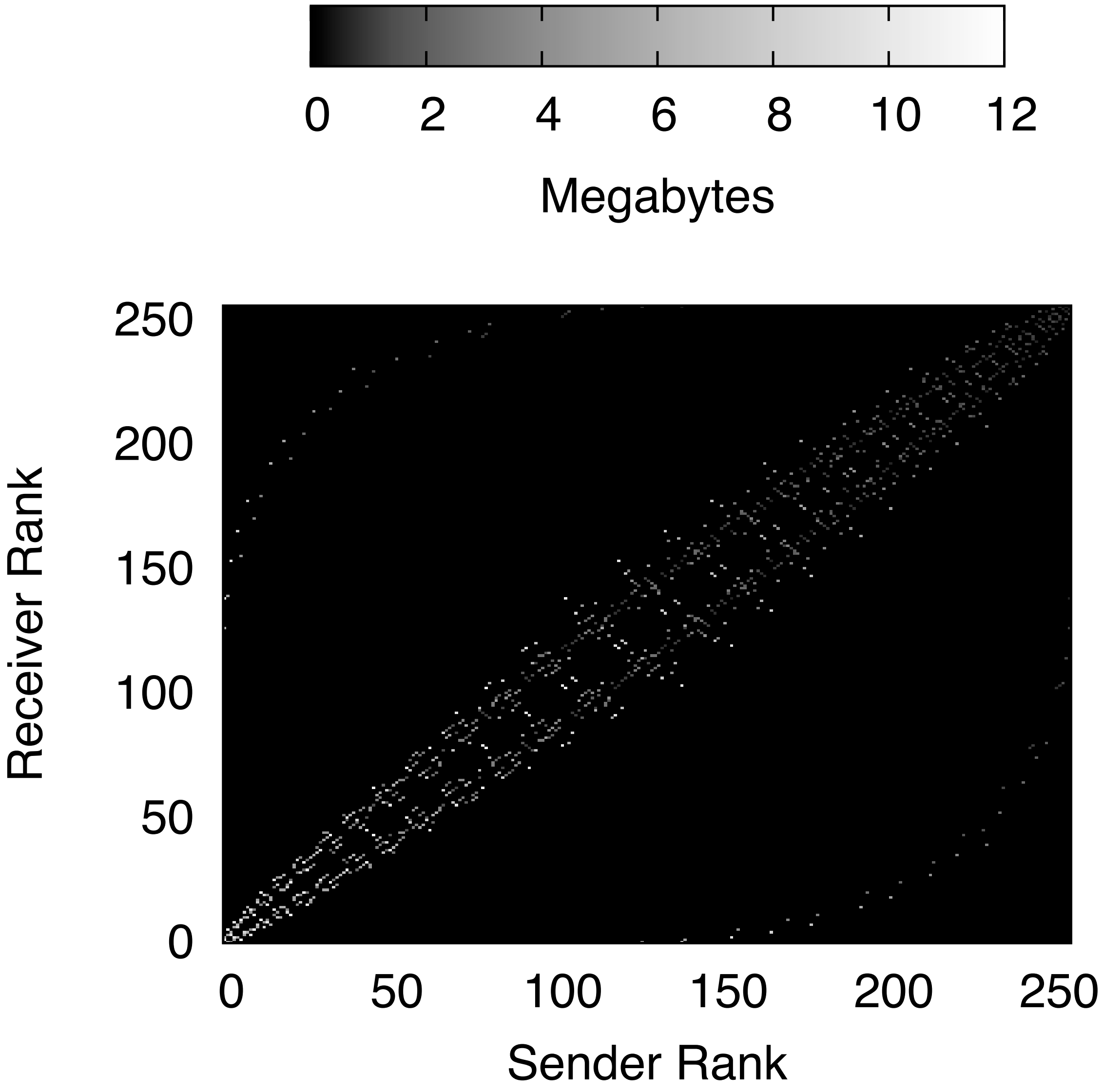
- Overhead of load balancer with team formation.
- Smart team formation benefits.
- Team size vs memory overhead.

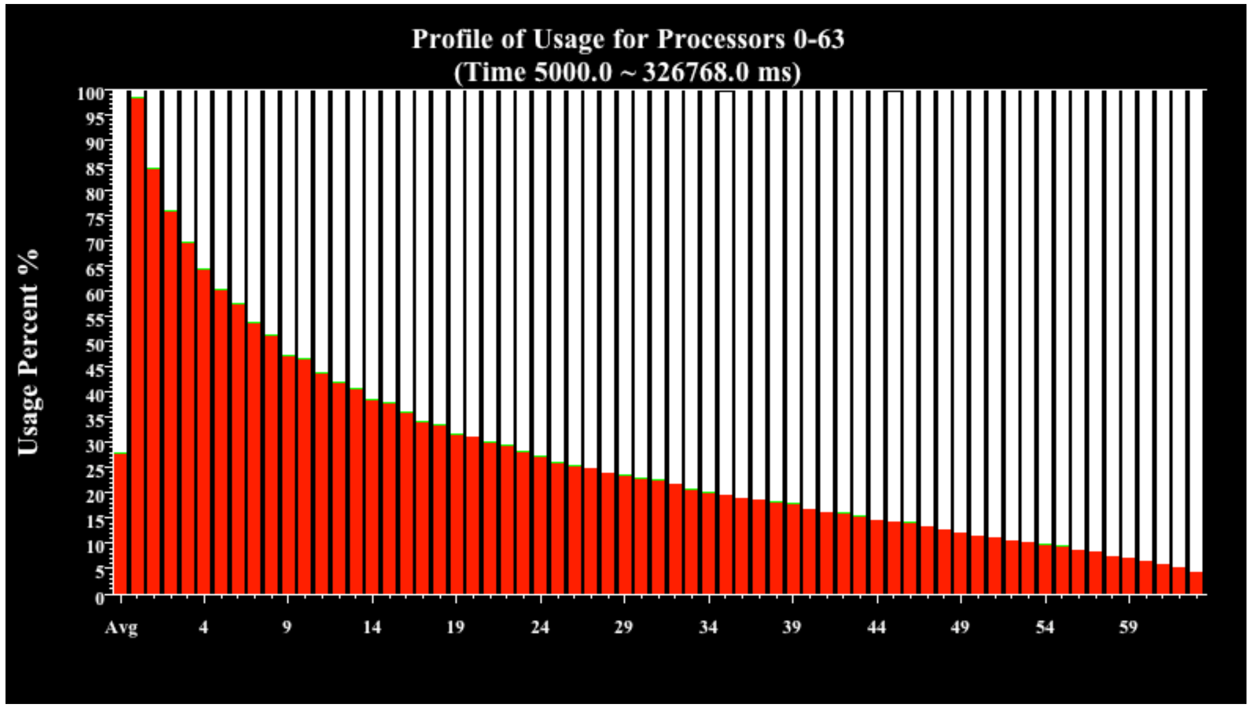
Application	Language	Load Imbalance
NPB-BT-MZ	MPI	Static
Mol3D	Charm++	Dynamic

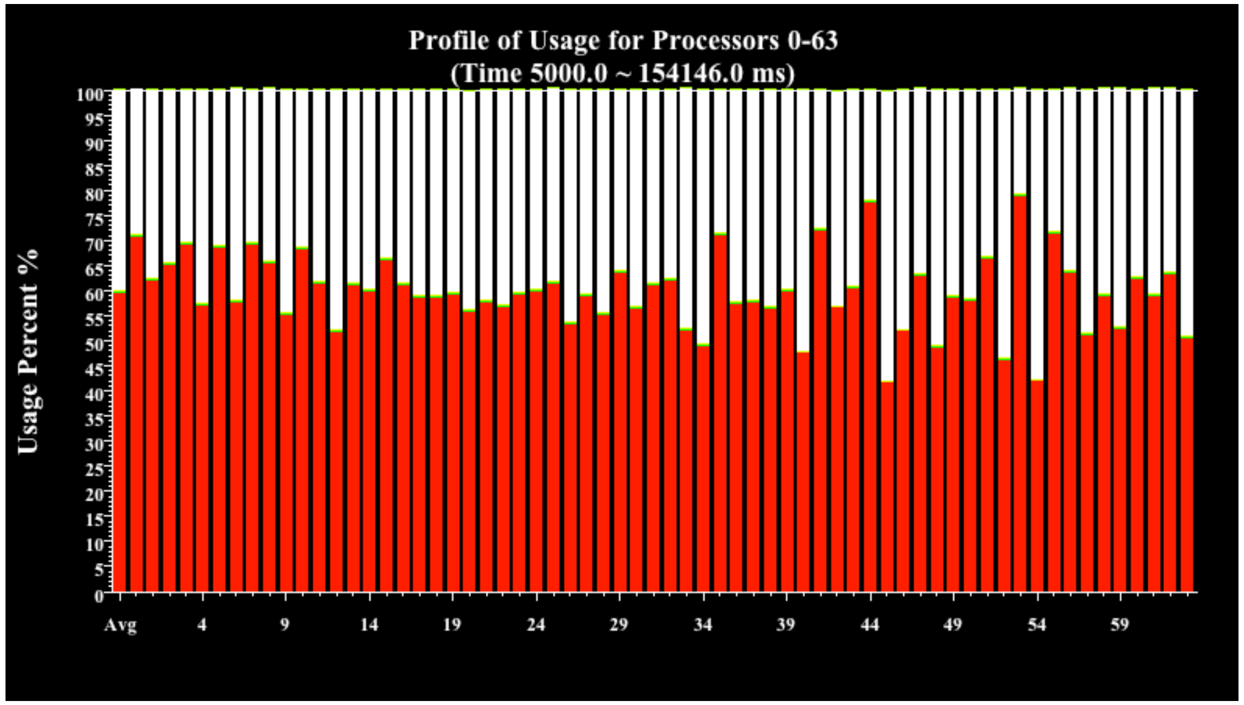
Testbed

- Steele@RCAC
- 893 8-core nodes
- 16 GB RAM per node
- Gigabit Ethernet

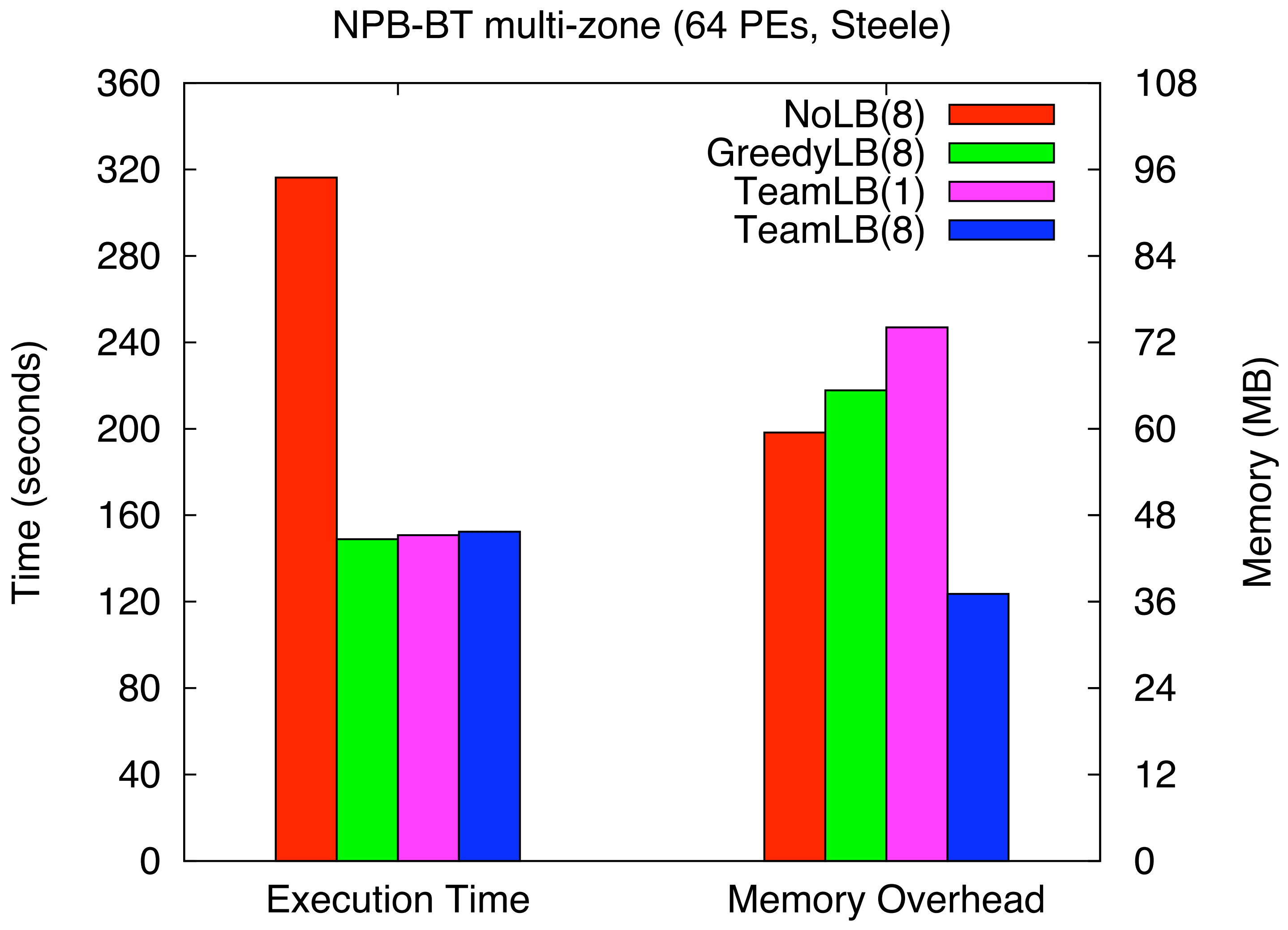
Result: Load Balance







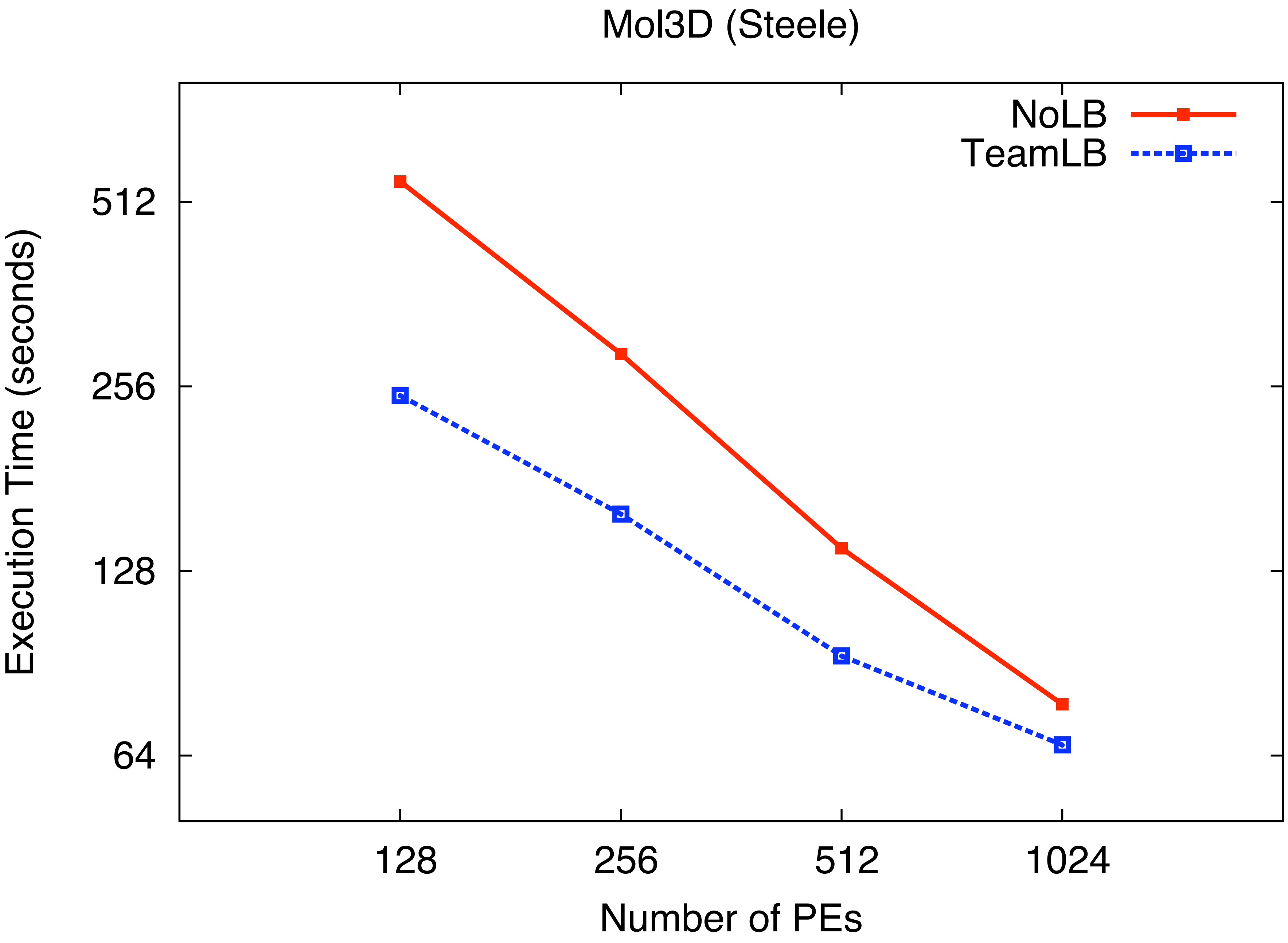
Result: Low Overhead



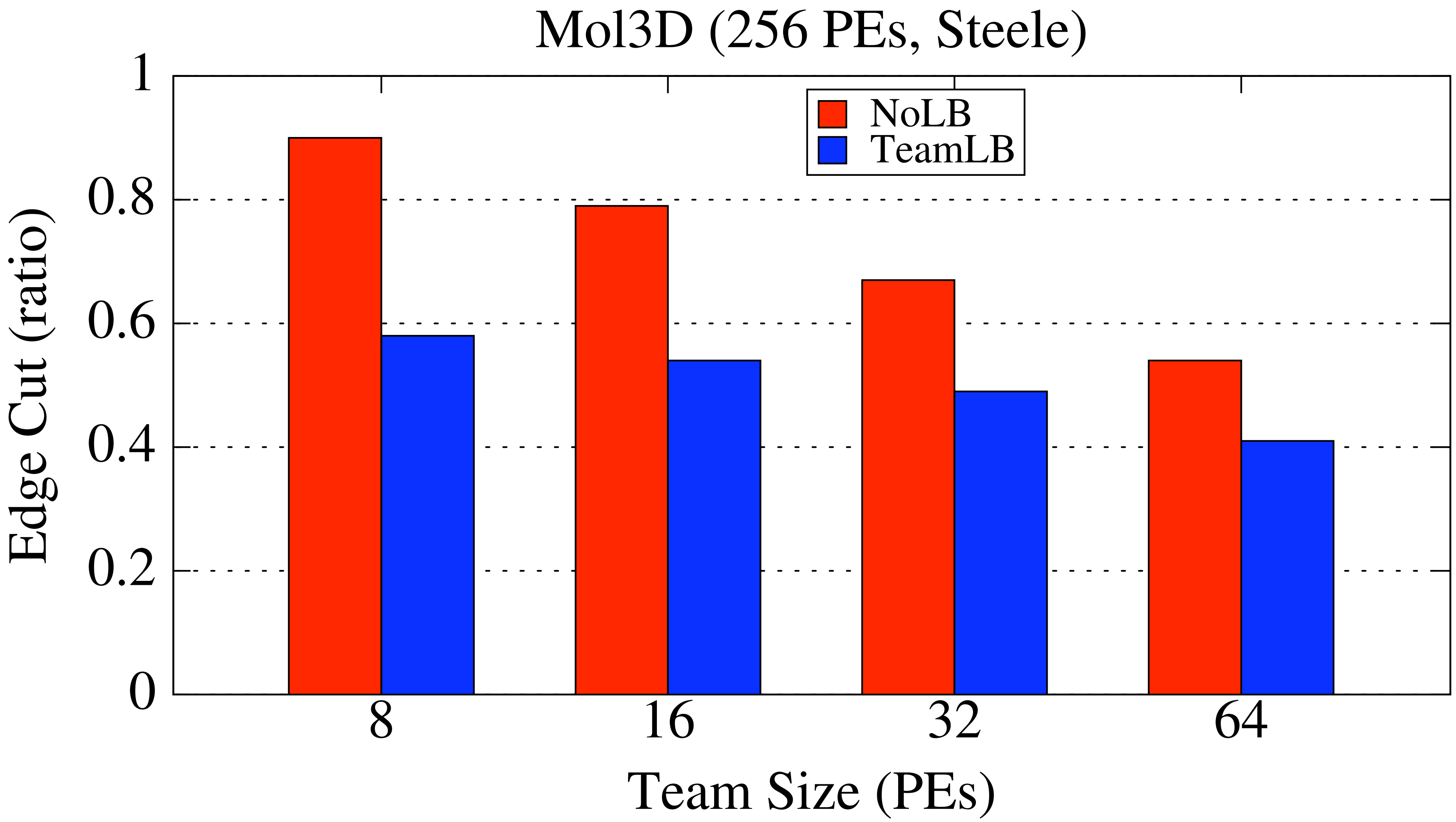
edge-cut ratio = 0.26

Clusters	
Number	8
Objects	256
Average Size	32
St. Dev. Size	13.76
Coeff. Variation	0.43
Max Size	53
Min Size	19

Result: Strong Scaling



Result: Team Size



Conclusions

- Migratable objects as a framework to provide fault tolerance and load balancing.
- Graph partitioning tools effective to drastically reduce memory overhead in message logging.
- Team size is a tradeoff parameter.

Contributions

- An extension to load balancing framework to dynamically form processor teams.
- A team-based algorithm for simple causal message logging.

Future Work

- More applications:
  - Adaptive mesh refinement.
  - Weather simulation.
- Incorporate team-based approach into SMP version.
- Test system with faster networks (Infiniband).
- Processor teams vs object teams.

Thank you!

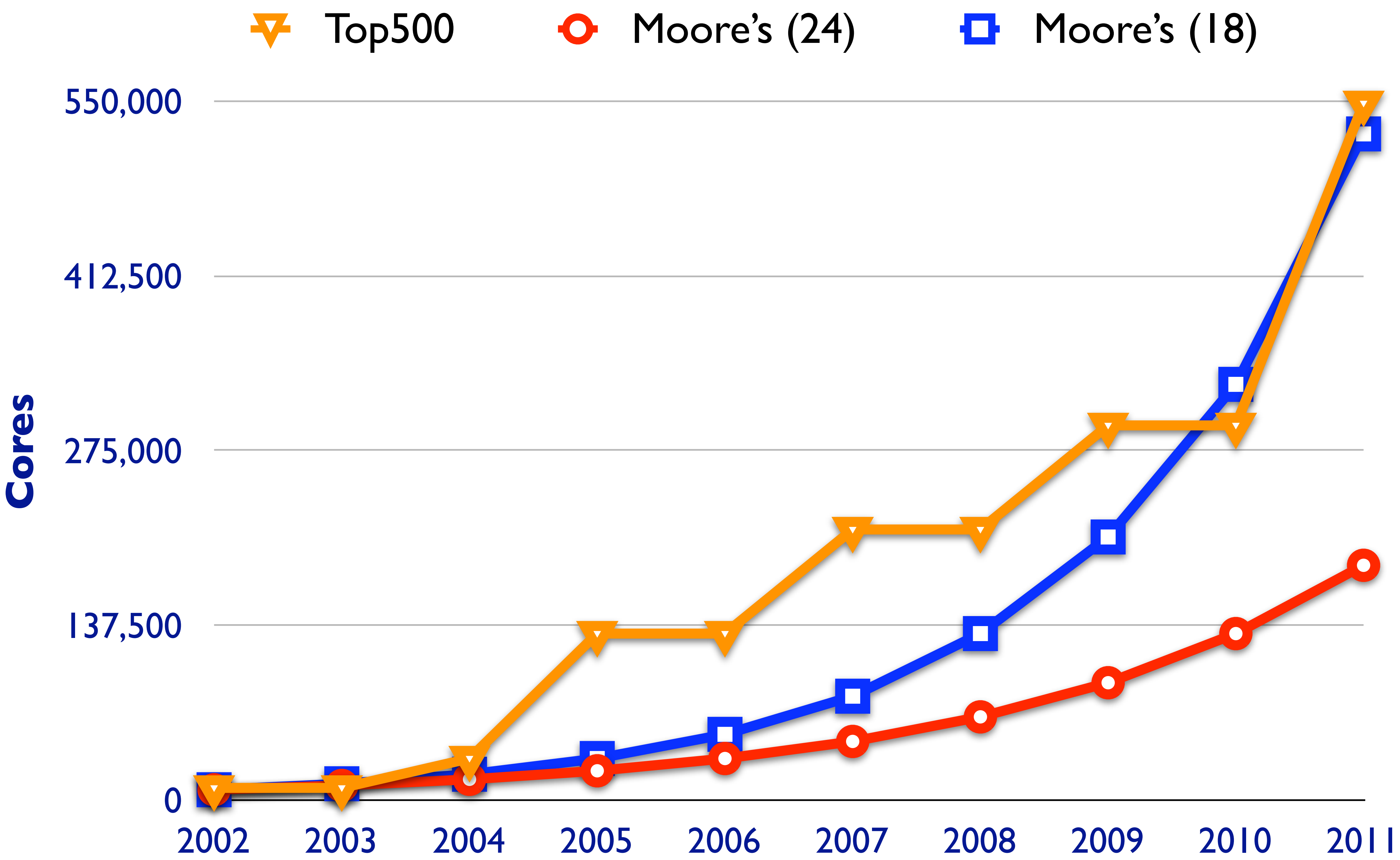
Q&A

Object Teams

- **Advantages**:
  - Natural to migratable-objects model.
  - Separation of concerns: load balance vs fault tolerance.
  - More flexibility for cluster formation.

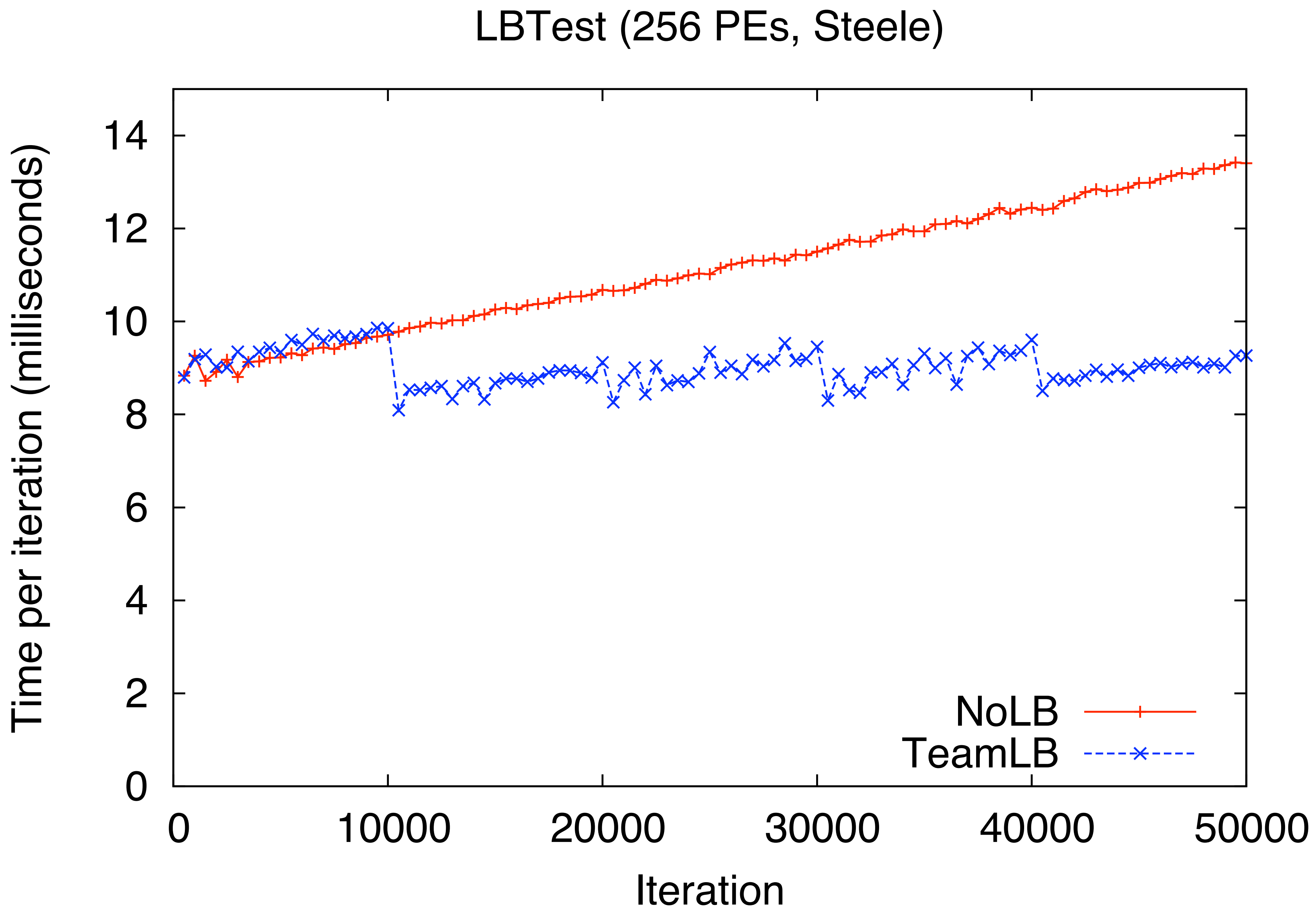
- **Disadvantages**:
  - In case of failure: unbounded number of teams to recover.
  - Some local messages have to be stored.
  - Load balancer involved in object distribution.

Moore's Law?



▽ Top500
○ Moore's (24)
□ Moore's (18)
550,000
412,500
275,000
137,500
0
Cores
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

Result: Dynamic Teams


LBTest (256 PEs, Steele)
Time per iteration (milliseconds)
Iteration
NoLB
TeamLB