A SUN LABS RESEARCH PROJECT

Sun SPOT System:

Turning Vision into Reality

By simplifying the development of wireless transducer applications, the Sun SPOT (Small Programmable Object Technology) system from Sun Labs will help transform the potential of wireless sensors into real-world products.

The possibilities for wireless sensors have excited scientists and researchers, the business community, military and government officials, and consumers alike for many years. The potential applications for wireless sensors and transducers (sensors combined with actuator mechanisms) are limited only by the imagination. Sensing alone is not enough for many applications—the ability to act on the sensory data is also required. A small, battery-powered platform capable of actuation is needed. Just a few examples:

- "Smart dust" networks of tiny wireless microelectromechanical sensors (MEMS) could track and report on everything from cold areas in rooms to enemy movements in a military operation.
- Wireless sensors could catch manufacturing defects by sensing out-of-range vibrations in industrial equipment, monitor patient movements in a hospital room, track fertilizer runoff from farms into lakes, or ascertain the origins of a gunshot. Used in conjunction with RFID tags and actuation mechanisms, they could intelligently control light, heat, and appliances in buildings, making rooms "come alive" just before people enter.
- "Gesture interfaces" harnessing wireless sensors could make it possible to control devices by hand gestures, eliminating the distraction of finding and turning dials and knobs.
- "Swarms" or large numbers of autonomously functioning vehicles could be deployed to carry out a prescribed mission and respond as a group to high-level management commands.

Technological Obstacles to Widespread Adoption

The technology for wireless sensors is compelling, but on the whole there is still a wide gap between vision and real-world applications. Wireless sensors have remained primitive, expensive and bulky—not ready for mass commercial deployment. There are several technical challenges that must be overcome:

- Current development tools for creating and investigating wireless sensor and transducer systems are difficult to use and unproductive.
- Security is a critical issue for many wireless sensor applications, but implementing effective security mechanisms within tight resource constraints at an affordable cost can be difficult and complex.
- More powerful processing capability is needed close to the sensor for signal analysis and control, and libraries are needed for investigating all aspects of wireless transducer applications—from hardware all the way through to network layers.
- Unique characteristics of these new small devices present challenges for networking, requiring new ways for devices to communicate with each other and the Internet. Current standards don't apply, so new standards are needed which support communication both between the new devices themselves as well as between the new devices and devices using today's standards.

Sun SPOT: Simplified Development of Wireless Transducers Using Java™ Technology

Researchers at Sun Microsystems Laboratories (Sun Labs) are developing a system that takes major strides toward solving the key challenges that are inhibiting development of wireless sensor and transducer applications.

Based on a 32 bit ARM-7 CPU and an 11 channel 2.4GHz radio, Sun SPOT radically simplifies the process of developing wireless sensor and transducer applications. The platform enables developers to build wireless transducer applications in Java™ using a sensor board for I/O, an 802.15.4 radio for wireless communication, and use familiar Integrated Development Environments (IDEs), such as NetBeans™ to write code.

The Sun SPOT system uses Java™ technology to up-level programming. Developers can write a program in Java, load it on a wireless sensor device, run it, debug it, as well as access low-level mechanisms— with standard Java IDEs. The inherent portability of Java™ makes it simpler to migrate applications among platforms and enables developers to build new wireless sensors devices using off-the-shelf hardware components. Java also eliminates or streamlines many of the low-level tasks of traditional development languages such as C, and for the millions of developers who already write code in Java there is little additional learning curve for building wireless sensor/transducer programs.

The Sun SPOT system features the “Squawk VM,” a small J2ME™ virtual machine (VM) written almost entirely in Java. It provides the ability to run wireless transducer applications “on the metal,” (directly on the CPU without any underlying OS), saving overhead and improving performance. End users also gain the flexibility to experiment with different implementations of low-level services, such as networking protocols, which are typically buried inside an OS. A set of Java libraries under development will provide access to the sensors, the I/O pins on the sensor application board, and the integrated on-board radio. By running multiple applications on the one virtual machine, and by using a more compact representation of class files, the Squawk VM makes better use of the small memory space available on SPOT devices.

Sun Labs researchers are working on additional tools that will further simplify development of wireless transducer programs and broaden the scope of possible applications. Examples include:

- Debugging tools that allow developers to debug a wireless transducer application as it runs on the device.
- A discovery mechanism that will enable any Sun SPOT operating within the radio field and running a special “meta-isolate” application to report its status—even pause and resume applications.
- “Migratable application” capabilities that enable applications—with their complete state information—to move from one Sun SPOT device to another while they’re still running.
- Over-the-air (OTA) reprogramming capability for sensor devices deployed in large numbers, or in difficult to access or hostile environments.
- Mesh networking among the Sun SPOT devices in order to use an efficient algorithm for power efficiency and fault-tolerance in the network.
- Developing new architecture for auto-configuration of the sensor network and its global connectivity to the Internet.

Strong Security for Small Devices

Security is particularly important for wireless transducer applications—and particularly challenging. With limited memory and computational capabilities, a limited energy supply, and the need to operate in potentially hostile or hazardous environments with unattended operation, wireless transducers require strong security with extremely small overhead.

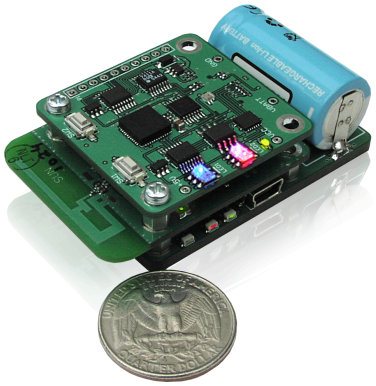
Sun Labs has unique expertise in several security technologies and is applying this expertise to wireless sensors and transducers. One such technology is public-key cryptography which is essential for bootstrapping secure communication between a large number of devices, a problem referred to as scalable key management. The technology is also used in digital signatures for authenticating communicating entities and digital content (both code and data).

Public-key cryptography is widely believed to be beyond the capabilities of sensor devices. However, Sun Labs has recently demonstrated highly optimized, implementations of RSA that perform much

better than any reported previously. Sun Labs has also developed implementations of Elliptic Curve Cryptography (ECC), a resource efficient alternative to RSA, that provide an additional order of magnitude performance improvement on 8-bit CPUs. These implementations power a small-footprint, secure Web server stack (including HTTP and SSL), nicknamed Sizzle, that can be embedded inside a wide array of tiny devices, allowing them to be monitored and controlled securely via a Web browser. According to Prof. David Wagner of U.C. Berkeley, this work represents the “biggest breakthrough in sensor network security in the last year.”

Sun SPOT Specifications

This is an ongoing Sun Labs research project. All specifications and features are subject to change without notice.



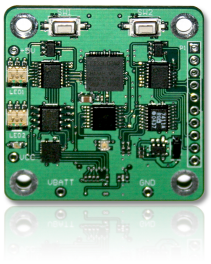
Hardware:

A Sun SPOT system is composed by stacking a Sun SPOT Main Board with other optional boards.

Sun SPOT Main Board

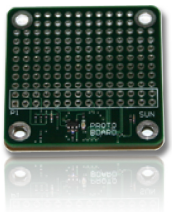
- 32 bit ARM7 core - 256K RAM/2M Flash
- Chipcon CC2420 802.15.4 radio
- Integrated antenna
- Double sided connector for stackable boards
- Can be powered from a variety of power sources including 1.5V batteries
- Requires 25-90mA of power depending on operation
- 35x25 mm in size

General Purpose Sensor Application Board



- 3D accelerometer
- 9 I/O Pins (PWM capable)
- Temperature sensor
- Light sensor
- 2 3-color LEDs
- 2 momentary switches
- Mainly for experimental purposes
  - –All SPI driven peripherals
  - –Experimental application boards available

Test Board



- Provides JTAG, RS-232 and USB interface with power monitoring
- Used to provision Sun SPOTs
- Provides basic I/O and test fixture support

Hardware (cont.):

Serial Battery Board

- Holds 2 AA batteries (Batteries widely available)
- Provides RS-232 serial port for provisioning/programming
- On/Off switch, Reset button
- Power LED
- Can be configured with power regulator to support other power sources

USB Battery Board

- Holds single 3.6v lithium-ion battery
- Provides USB port for provisioning/programming
- Battery is charged via USB port
- On/Off switch, Reset button
- Power/Battery charge/Tx/Rx LEDs
- Smaller than Serial Battery Board

Software:

Squawk Virtual Machine

- Fully capable J2ME-level Java VM with OS functionality
- Currently 80K RAM for VM
- Can execute directly out of flash memory
- Libraries 270K flash including most of the Java components of the VM
- Device drivers written in Java

Developer Tools

- Use standard IDEs. e.g. NetBeans™, to create Java code
- Simple scripted build and deploy process (Ant based)
- Simple debugger available (soon JDWP compliant)
- Deployment Options
  - Wired Serial or USB connection to battery board
  - Wired USB connection to Test board
  - Over-the-air deployment of Java code to Sun SPOTs
  - Sun SPOTs wired via USB or Serial to a computer can act as a base-station
  - Integrates with J2SE™ applications

Standard Libraries:

- CLDC 1.0 libraries
- 802.15.4 compliant MAC layers
- Hardware and Sensor integration/control libraries

About Sun Labs

Established in 1990, Sun Microsystems Laboratories is the applied research and advanced development arm of Sun Microsystems, Inc., with locations in California and Massachusetts. Sun Labs is one of the ways Sun invests in the future, and is responsible for many of the technology advancements and inventions that have made Sun a technology powerhouse—including asynchronous and high-speed circuits, optical interconnects, 3rd-generation Web technologies, sensors, network scaling and Java technologies. Although many companies have R&D groups, Sun Labs can claim one of the highest rates of technology transfer in the industry.

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