SILICON VALLEY WORLD INTERNET CENTER

SMART ITEMS BUSINESS FORUM
WORKING GROUP

BUSINESS APPLICATIONS OF DISTRIBUTED SENSORS AND SENSOR NETWORKS

TUESDAY, JULY 22, 2003

SUMMARY

BACKGROUND

Sensor Nets are one aspect of research and commercial development in the area known as "Smart Items." These networks make use of sensory information gathered from a number of point sources and build an overall picture of the situation. Recently, wireless technology, including 802.11 wi-fi and low power standards such as Blue-Tooth and 802.15.4 have opened the economic feasibility of low-cost, wireless-based ad-hoc networks.

On July 22, 2003, the Silicon Valley World Internet Center convened a Working Group to explore commercial business applications of distributed sensors and sensor-net technology. For the purpose of the 2.5-hour discussion, the group of 23 experts assumed the availability of multi-hop radio technology. The primary objective of the discussion was to identify existing or emerging commercial applications that might serve enterprise-level business needs. Additionally, participants had the opportunity to rank their top choices for financially viable applications for distributed sensors and/or sensor networks in any vertical market. The results of this discussion and ranking are explored in this Working Group Summary and also appended, in detail.

Participating in the Working Group were:

- Motorola, Inc.
- NASA/Ames Research Center
- Eou.com
- IBM
- Hewlett-Packard Laboratories
- PARC (Palo Alto Research Center)
- DaimlerChrysler Research and Technology North America, Inc.
- Walmart.com
- Cogenia Partners LLC
- Stanford University
- Intel Research, Berkeley
- Dust, Inc.
- SRI Consulting Business Intelligence, Inc.
- Sun Microsystems
- Sensoria Corporation
- Aether Wire & Location, Inc.
- SAP Corporate Research
- DSSC

INTRODUCTION

The Working Group generated enterprise-level business applications, which could be well addressed by distributed sensors and sensor networks. These included:

- inventory management (including supply chain and perishables management);
- transportation and maintenance;
- resource monitoring;
- process monitoring;
- asset management;
- security;
- critical utilities and infrastructure monitoring, especially in emergencies
- financial transactions; and
- people tracking (for elderly care and amusement parks).

700 Welch Road, Suite 250 Palo Alto, CA 94304 • Tel: 650.462.9800 • Fax: 650.462.9818 • www.worldinternetcenter.com

Additionally, each participant ranked their top three choices for what they consider sensor-net applications that would have the greatest return on investment in the next three to five years. The number-one choices in this latter area were:

- homeland defense and military applications;
- enterprise-level asset management;
- middleware for intelligent processing of sensor-net data;
- sensor-assisted health care;
- industry controlled manufacturing process monitoring, and
- environmentally-oriented, sensor-net-based information systems for locating people, cars, etc.

The Working Group predicted that the price of nodes will lower to where broad adoption of the technology will be economically feasible by 2005, with a per-node price of about $10. Participants discussed that at some point in the future the quality of information gathered by sensor nets may reach a very high level that could replace human decision-making. At the very least, sensor-net technology and software will continue to refine and provide ever greater levels of information from data -- information which can be used reliably to assist with enterprise-level decision making.

WHAT'S NEW AND IMPROVED WITH SENSORS?

When addressing the value of what sensors and sensor networks can bring to enterprises that is new, several participants underlined that asset management and the quality of information that is delivered via machines versus via people can be brought to new levels of sophistication. While static radio frequency identification (RFID) tags can be used to manage inventory, asset management is enhanced by the use of sensor networks. These more active, intelligent networks can tell management where something *is* as well as where it *is not supposed to be*. So when items go missing, or otherwise are not where they should be, management can use sensor nets to track them. For security purposes, sensors could be very useful. For example, in the shipping industry sensors could be used to flag certain types of materials, such as explosives, that might be surreptitiously lurking in closed shipping containers.

Participants underlined that the quality of information for decision-making can be enhanced by sophisticated sensor networks. The group discussed that although humans have always had the ability to provide quality information, sensors have not. They provide data that needs interpretation by humans to become information. But if sensor networks could interact in a fashion that provided the enterprise with high-quality information, this could be of significant value. A participant pointed out that any time one has to send a person to gather information, as on the floor of a retail enterprise, there is a cost-saving opportunity to design a sensor net that can gather that information, instead.

SYSTEMS THAT LEARN

The question was raised as to whether there is an intelligence emerging in sensor networks apart from the networking of individual nodes, themselves, that will find application in the enterprise. According to Brock Hinzmann, Technology Navigator at SRI Consulting Business Intelligence, Inc., work is currently being done through DARPA funding (Defense Advanced Research Projects Agency) to program systems to anticipate what is going to happen based on experience. The question being addressed is, "How do you use the network to anticipate the unanticipated?" The goal is to teach security systems to know when the system is being hacked. "How do you teach the system to understand the difference between itself and a foreign or new thing that is happening?" quizzed Hinzmann. Software is being written to help the system identify what is coming in that is new or an anomaly and different from what has been going on before, recognize it and alert the system to do something about it.

700 Welch Road, Suite 250 Palo Alto, CA 94304 • Tel: 650.462.9800 • Fax: 650.462.9818 • www.worldinternetcenter.com

Along this vein, the group called for the development of software that will be applied to sensors to allow them to function in ways that add value to the data that is being collected and help turn that data into some level of information for decision making or controls. Learning systems and neural networks learn over time from adding more and more data and being able to learn the associations between those bits of data. Greater granularity is added all along the system, and the software draws associations between those finer and finer grains of data. It then *learns* that something is happening and makes automatic changes to the system without having a human interfere in the process. The group discussed a new generation of software applications, which must be developed to control networks and gather data. These applications bring value to the enterprise by organizing data dynamically for process and tracking functions. The group agreed that sensors in the process-manufacturing arena are valuable for delivering information to temperature regulators, for instance, that keep liquid processes flowing smoothly and contribute to a consistently high-quality manufactured product. And in asset tracking, as mentioned above, software will be developed to interpret data and turn it into information used to track an enterprise's equipment and other assets.

PRICE POINTS AND THE COST OF INFORMATION

Over the last two years, an on-going conversation has been taking place in sessions at the World Internet Center around technology's ability to turn data into information that can be used by business for improved decision-making. Sensor nets are seen by many as a possible tool for gathering more precise data than has been possible in the past.

But at what price comes this valuable information? The group agreed that the human management of sensor nets is their most expensive component. Beyond administration, the price of the individual devices or "nodes," themselves is the critical cost. Applications that do not require ad-hoc networks exist today.

The cost is $200 to $1,000 per node, depending on installation and other costs. The group agreed that, when assessing the cost of information, the organization must ask itself what information it truly needs and what the value of the information really is to the business. "If the cost is too high," opined one participant, "the application will fail."

The group also projected that, as time goes by, the costs for individual nodes will fall. "Today," said Dust, Inc. founder Kris Pister, "the nodes cost about $100 each." Pister projected that by 2005 that cost would be down to $10 a node, at which time sensor nets should become widely affordable. And by 2010, the cost should be at about $1 per node.

WIRED VERSUS WIRELESS

The group agreed that it is important for an enterprise to understand under which circumstances it makes sense to use ad-hoc, self-organizing sensor networks instead of wired systems to get the data to the network. Many systems that exist today are wired, and the installation and wiring of these systems can be costly. The wireless systems, therefore, are less expensive to install. It was agreed that when mobility is necessary, wireless networks are superior to wired. If one is working with a data center, for instance, and is using nodes to sense temperatures of machines, a wireless network allows servers to be moved around on the racks and around the room. Wires, however, will restrict movement and, therefore, the options of data-center management for locating various machines in a room. The results will be higher costs and/or lost production. "Any situation in which you need a lifetime of more than a handful of months," said one participant, "and you have sensor data that is in the less-than-kilobits-per-second range, that is when wireless sensors are going to take over."

STANDARDS

In a short discussion of standards, the group agreed that the requirements for sending data from sensors to networks will be for both high and low bandwidth, depending on the application. "We have a fragmented application base," said one participant. "There will be no 'one-size-fits-all' in supplying these networks." So, as much as 802.11, 802.15.4 and Blue-Tooth technologies were discussed, there seems to be no clear alternative at this point. As a result, although they agreed that standards would be helpful, they will be difficult to apply across the board.

CONCLUSION

Participants in the July 22, 2003 Smart Items Business Forum Working Group concluded that sensor networks will become more and more affordable as time goes on, reaching a price point for broad adoption by 2005. Companies need to assess carefully where to apply expensive self-organizing networks, and where simple RFID technology will serve the need. Companies must also have a clear understanding of when to use wired systems versus unwired systems. And although some participants stated during the session that inventory management would not be a prime target for sensor nets, others gave very high marks to employing the technology for tracking inventory, especially along the supply chain in real-time and just-in-time manufacturing inventory, with emphasis on arrival of raw materials and also on perishable goods. Asset management in military and homeland security applications also rated highly.

700 Welch Road, Suite 250 Palo Alto, CA 94304 • Tel: 650.462.9800 • Fax: 650.462.9818 • www.worldinternetcenter.com

APPENDIX A

BUSINESS APPLICATIONS OF DISTRIBUTED SENSORS AND SENSOR NETWORKS

The following represent the key enterprise-level business applications identified by the Working Group participants.

INVENTORY MANAGEMENT

- Realtime inventory management (including track & trace in logistics chain)
- Computer/equipment inventory
- Retail product (or customer) tracking
- Inventory tracking
- Inventory management
- Location and arrival of raw materials for just-in-time manufacturing
- Logistics, where items have special monitoring needs (temperature, “droppage”, etc.)
- Shipping/distribution
- Any time you send a person to check status of items on a regular schedule

SUPPLY CHAIN MANAGEMENT

- Just-in-time supply chain planning
- Supply perishable goods, precise locations

PERISHABLES

- Food/perishables: transport & acceptance & sales quality control
- Time and temperature for perishable inventory

TRANSPORTATION & MAINTENANCE

- Make “dumb” devices visible to network (e.g. tooling, machine, instrument)
- Condition monitoring (e.g. temperature, diagnostics, etc.)
- Condition-based maintenance
- Transportation management
- Vehicle maintenance
- Car networks

RESOURCE MONITORING

- Energy monitoring & control
- Environment monitoring & resource planning
- Environmental regulatory compliance
- Fine-grained weather detection for transport, real estate & agricultural planning & operations
- Agriculture, water and chemicals in fields
- Coherent estimation of business/factory condition – what’s up/busy/down
- Sensor network for replacing conventional network

700 Welch Road, Suite 250 Palo Alto, CA 94304 • Tel: 650.462.9800 • Fax: 650.462.9818 • www.worldinternetcenter.com

PROCESS MONITORING
- Manufacturing process monitoring
- Manufacturing/production
- Process monitoring
- Realtime manufacturing, data capture
- Chemical process control/manufacturing automation (pressure, temperature, limit switches, etc.)
- Industrial monitoring (data centers, etc.)
- Process control (including manufacturing, HVAC, environmental monitoring)
- HVAC/Lighting/Building control

ASSET MANAGEMENT
- Asset management for safety and security: Oil & Gas/Utilities/Military/Aerospace
- Asset management in the area without network connections
- Asset monitoring
- Mobile asset tracking
- Asset location

SECURITY
- Security & visibility of mission critical areas, people, equipment & processes
- Physical security
- Privacy compliant enterprise (retail) security/safety
- Security user authentification
- Security of spaces and items (extends to Homeland Security)

CRITICAL UTILITIES & INFRASTRUCTURE MONITORING
- Public safety: firefighters, HazMat teams – biometric information/health
- Public works – utilities

TRANSACTIONS
- Notification of co-location of stuff & people (i.e. tokens, payment, etc.)

PEOPLE TRACKING
- Elderly care
- Amusement park: tracking children for access control, billing, health, etc.

700 Welch Road, Suite 250 Palo Alto, CA 94304 • Tel: 650.462.9800 • Fax: 650.462.9818 • www.worldinternetcenter.com

APPENDIX B

THE VC PICK: THE HOTTEST SENSOR NET APPLICATION IN THE NEXT 3-5 YEARS

Participants were asked to choose what they would consider the "hottest" sensor or sensor net-supported application that would have the greatest return on a financial investment in the next 3-5 years by a fantasy venture capitalist. Each participant has one "first choice," one "second choice," and one "third choice." Below is the compilation of those choices, noting the quantity and the specific application as chosen by individual participants.

SECURITY & DEFENSE APPLICATIONS

1st
- Homeland defense (security/safety)
- Homeland security – critical infrastructure monitoring
- Asset management – security & defense applications
- Asset management in security and defense
- Asset management/tracking in security and defense
- Enterprise – asset management for security and safety
- Battleground visibility
- Boundary conditions sensors (e.g. extent of biohazard)
- Police/Fire/HazMat public safety – tracking personnel

2nd
- Security / HLD
- Asset management for safety & security
- Transportation: asset monitoring, fleet management, safety & security
- Self-configurable sensor nets for defense
- Homeland security – power, gas, earthquake sensor nets
- Sensor net for rapid ad hoc military applications

3rd
- Environmental asset management for safety and security
- Homeland security technology

ENTERPRISE-LEVEL BUSINESS APPLICATIONS

1st
- Asset management
- Asset management
- Qualify control and liability assessment in enterprise supply chain
- Enterprise: asset monitoring & condition monitoring

2nd
- Asset management
- Enterprise business spoilage sensors

3rd
- Asset tracking (objects of value)

700 Welch Road, Suite 250 Palo Alto, CA 94304 • Tel: 650.462.9800 • Fax: 650.462.9818 • www.worldinternetcenter.com

INDUSTRIAL/COMMERCIAL APPLICATIONS

1st
- Middleware for intelligent processing of aggregate sensor net data
- Non-critical monitoring

2nd
- Industrial control – process control: pressure, temperature, chemical – process info
- Commercial building automation
- Sensor nets for improved tolerances in various applications (e.g. mining applications, lean packaging)
- Commercial condition-based maintenance
- Vehicle maintenance; equipment maintenance
- Industrial control process management

3rd
- None

MEDICAL APPLICATIONS

1st
- Sensor-assisted healthcare

2nd
- Medical monitoring
- Asset management in medical

3rd
- Tracking equipment, patients, doctors in hospitals
- In-home, mobile health monitoring
- Medical asset tracking
- Health sensor net for classes of people – nurses exposures
- Advanced home automation (e.g. ultra-healthy houses for the elderly)
- Data discovery & testing
- Medical managed care monitoring
- Allergy/allergen detection networks

INDUSTRIAL CONTROL APPLICATIONS

1st
- Industry-specific commercial sensor control & data collection/modeling software
- Industry control: manufacturing process monitoring

2nd
- Industrial control: environmental building control (HVAC, etc.)
- Industrial control applications: HVAC

3rd
- Industrial machine diagnostics
- Process management in industrial control
- Industrial/commercial: temperature, asset tracking
- Industrial applications: process control; building automation; manufacturing control

ENVIRONMENTAL APPLICATIONS

1st
- Sensor Net-based Information System (location of cars, people, …)

2nd
- None

3rd
- Environment monitoring
- Asset management tracking

700 Welch Road, Suite 250 Palo Alto, CA 94304 • Tel: 650.462.9800 • Fax: 650.462.9818 • www.worldinternetcenter.com