Understanding wireless sensor and control networks

Service broker software offers the ideal option for overcoming the hurdles facing broader deployment of wireless sensor networks.

By Tim Enwall

Wireless sensor networks (WSNs) have been called the next great frontier in computing, with good reason. This emerging wireless technology allows computing to go places never before possible, into every nook and cranny of the physical world. Comprised of dime-sized, low-power, inexpensive wireless sensors, these networks build a bridge between the physical world and personal or enterprise computing systems. For the first time, they bring computing power to places and things that were previously cost prohibitive or simply physically impossible.

There are a lot of terms floating around for wireless sensor networks, but the term that best captures the essence of what the technology is trying to achieve is the “Internet of Things.” Much like the individual PCs and servers connected via the Internet into a worldwide computing network, wireless sensor networks turn objects in the physical world into an integrated, digital network that opens up a realm of new possibilities.

While the technology is interesting, the reason for the excitement and high expectations for wireless sensor networks is its long list of potential applications. Many of these new and emerging applications are extraordinary in the way they represent a fundamentally new way for companies to do business and for people to interact with the world around them (see “A Closer Look at Applications” on p. 10).
A Service Broker Does This...

With its breadth of potential applications, wireless sensor and control networks are clearly one of the most important emerging technologies in the wireless field. Yet, why are there not more real-world deployments of wireless sensor networks? Why is the technology still stuck in the test lab or proof-of-concept stage, rather than graduating more quickly from pilot project to formal deployments?

Obstacles to deployment

In the past, the answer to these questions may have been that organizations were waiting for the hardware to mature, but with tremendous progress by hardware companies like Ember and Crossbow, products are quite robust. Another answer might be that organizations are waiting for standards, but there has been substantial progress here as well by organizations such as the ZigBee Alliance (ZigBee), IETF (IPv6 low-pan) and HART (Wireless HART). The problem, it seems, is not on the hardware or standards side of the equation; it’s on the software side.

There are two key deployment challenges that are standing in the way of getting wireless sensor network technology out of the lab:

- The “Slow Programming” Obstacle—Programming the software that manages wireless sensor networks is so complex and laborious that it can take months of work by specialized programmers just to deploy the simplest application.
- The “Adding Control” Obstacle—Incorporating reliable control mechanisms into these networks (rather than just passive sensing nodes) is a complicated process due to the lack of software for supporting that kind of functionality.

Addressing these challenges will remove two of the final hurdles to much broader deployment of wireless sensor and control networks.

Addressing the challenges

Simplifying the programming process for software that orchestrates wireless sensor networks is a critical step for enabling its broader deployment. The programming process currently takes months for even basic large-scale deployments since the industry predominantly offers a packet interface only. This laborious process requires specialized programming teams who focus primarily on getting meaningful packets to interact back and forth, rather than on higher-level enterprise functions that enable the network to achieve its overall mission. The resulting costs and difficulties are often too imposing for most organizations to move forward with their first major deployments.

The complexity of this programming process must be reduced in order to allow organizations to put deployment plans into action. Reducing the programming time to weeks or days, rather than months, is a key need. Making the programming process accessible to Java/.NET enterprise programmers is one solution as it will allow companies to use their existing programming resources to deploy wireless sensor networks.

Another critical step for enabling...
broader deployment is to add reliable control capabilities that currently do not exist in most networks. Wireless sensor networks are reasonably good at providing bulk environmental data that can speed human decision-making, but they are incomplete without the ability to act on that information and control their physical surroundings. Basic wireless sensor networks are simple, passive systems. They relay data from sensor to computing systems so that organizations can understand the world, but they lack the key control capabilities that allow organizations to directly act on that information.

This obstacle is particularly significant for commercial applications of wireless sensor networks, which require both sensing and control capabilities in order to fully realize the application’s potential. That control capability may, for example, adjust a water valve, calibrate a mechanical component, lock or unlock a remote access point, or even activate a security/defense mechanism. Unfortunately, programming these kinds of control capabilities into wireless sensor network software is agonizingly complex with current network protocol stacks.

A software-based solution

These problems can be solved using a service broker, which has characteristics that make it an ideal solution for overcoming the obstacles outlined above (Figure 1). A service broker is a distributed layer of software that orchestrates many of the normal activities of a wireless sensor and control network. It allows organizations to focus their programming efforts on the application business logic.

A service broker democratizes wireless sensor networks from a programming perspective by providing a familiar development platform that a typical Java/.NET enterprise programmer can use to build and manage wireless sensor networks. This allows organizations to move forward with deployments using existing programming resources rather than requiring specialized programmers with hard-to-find skills.

Service brokers are considered by some to be a piece of “middleware.” However, middleware is not an ideal descriptor for wireless sensor networks as it ignores many important facets needed in this distributed software layer. Middleware implies software that runs on a big server, in a big server farm, and that receives and sends messages. It provides a fairly simple pass-through or store-and-forward method of message transport. In contrast, service broker software is distributed software, from the tiniest of “nodes” to the largest servers. It works in concert to achieve a goal and performs automated decision-making on behalf of the programmer (Figure 2). A service broker can manage network management and control, health and status of the individual devices on the network, protocol translation, end-to-end transactional integrity, security profiles, issuing control commands, and the ability to stack one instance of software on another instance to achieve an even more distributed profile; all key responsibilities of the software that orchestrates sensor networks. Instead of middleware, it’s a necessary component of system software—software that exists in almost all new, emerging broad scale computing platforms.

Some of the important capabilities of service broker software in a wireless sensor and control network are:

- reduces deployment times from months to weeks. Eliminates the costly “build from scratch” programming process that is preventing broader implementations of sensor networks.
- Uses a run-time development platform to easily expand and extend applications to growing networks or new ones.
- Provides programmers with a development platform that they are comfortable with and productive with, thereby bridging the gap between wireless sensor network hardware and enterprise programmers who want to quickly deploy applications.
- Supports the addition of control capabilities to wireless sensor network to achieve true “sensor
and control” functionality.

- Enables the creation of both physical and logical network models, allowing multiple applications and commerce models to overlay a single physical device.
- Supports a mixed environment of hardware platforms, to enable interoperability in a heterogeneous environment and protect users from standards wars and/or proprietary concerns.

To date, the market has consisted of hardware infrastructure companies focused on building low-power network reliability, semiconductors, networking protocols, routing algorithms, packet transmission and error recovery—all the elements that make the next stage of the market’s development possible. The next wave of advancements will be in the area of deployment software, with service broker software being a key ingredient for enabling organizations to take the next steps toward major real-world deployments and to begin using that infrastructure in a robust manner.

**WSNs in action**

What does the future hold for wireless sensor and control network deployments? What will these deployments look like? Some industry observers believe that the next two years will be marked by a period of significant growth in the adoption of wireless sensor network technology and that the technology may soon make the leap from the whiteboard to deployment. One example that provides a powerful illustration of the capabilities of wireless sensor and control networks is what will soon be possible in the field of cargo ship transport.

Consider an average ocean-going cargo container in the sea cargo port (Figure 3). As a cargo ship arrives in a U.S. port and is processed, several constituencies must interact with the container. This includes the U.S. Department of Homeland Security, U.S. Customs, the Port Authority, the shipping company, and the user whose goods are being transported. Each of these constituencies requires information about the container and its contents, and has a variety of questions like:

- **Where is the container?**
- **Has it been dropped or violently handled, thereby damaging the contents?**
- **Is it carrying illicit or unwanted cargo?**
- **Has it been opened or tampered with anywhere in transit? Have the contents been stolen?**
- **Who has interacted with the container or cargo since its original departure point?**
- **Has the temperature, humidity and pressure of the cargo remained constant or has it gone into extremes, thereby damaging the contents? If so, when and where?**
- **Has it been authorized by Customs and the U.S. Department of Homeland Security for further processing? Has it been quarantined?**
- **What is its final destination and who will handle it after being cleared through customs?**

Each constituency wants to interact with that cargo container, but without the capabilities of a wireless sensor network that uses service broker software, each group would need to build a single-purpose, highly specialized form of interaction with the container. With service broker software acting as the conduit and facilitator, those multiple constituencies can all add sensors and controls to the local network within the cargo container. These network additions integrate business logic that processes different access methods at different times in the cargo’s journey.

Both the Department of Homeland Security and Customs can query the device for information about its contents, its journey and its state, as well as issue commands to open for inspection. They can further issue authorization commands to allow the shipping company to open the cargo (if authorized by the end user) or simply authorization commands to allow access to various pieces of data, or commands for additional constituents. None of this would be possible without wireless sensor and control network technology and it would be impossible to orchestrate without general-purpose, extensible service broker software.

Wireless sensor network technology may very well be the next great frontier in computing. Networking physical objects that have previously lacked computing and reporting capabilities is a compelling concept that is as big, if not bigger, than the idea that drove the development of the World Wide Web. Fortunately, the final obstacles to broader deployment of the technology are now being addressed with service broker software.

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