**ARC BRIEF**

By ARC Advisory Group

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# Building a Comprehensive Industrial Wireless Future

## Executive Summary

The revolution in wireless networking has huge potential to improve manufacturing. A major part of realizing that potential requires the development of industrial wireless sensor networks (WSN). Efforts to develop wireless sensor network technology suitable for manufacturing have been hampered by the immaturity and rapid development of the technology, and by standardization programs (such as ZigBee) that initially attempted to standardize a far broader scope than was feasible. A specifically industrial approach to defining standards is now being pursued by the ISA SP100 group, but their work at present is forced to disregard the differences between sensor requirements in process vs. discrete manufacturing, and is focused on sensor networks for process automation.

A truly comprehensive approach to industrial wireless networking must eventually address the unique requirements factory automation sensors in discrete manufacturing operations.

Lately an informal collaboration has developed between 3 companies with complementary expertise in discrete manufacturing. These collaborating companies are ABB, an automation leader and a company that has commercialized wireless sensor products targeting factory automation, FESTO, a firm highly regarded for its machine actuator components and solutions, and Millennial Net, a wireless sensor networking company recently acquired by privately held PHC Holdings. These 3 companies plan to build on their existing work and expertise in order to further advance the use of wireless sensor networks in factory automation and discrete manufacturing. As such, their work should prove complementary to that of SP100, and at some point in the future could be included in industry standards addressing discrete manufacturing.

## The Promise of Industrial Wireless

No development since the Internet has greater potential to advance manufacturing than wireless networking. As with earlier revolutions in manufacturing technology, advances in wireless IT and consumer electronics technology are having impact at all levels of manufacturing. The huge demand for wireless products by IT and consumer markets have made a number of powerful wireless technologies available to manufacturers at very low cost. Globalization of the IT and telecom market has also created global standards for many types of wireless networks. Technologies like Wi-Fi, Bluetooth, and GSM have become global standards, while emerging wireless technologies like WiMAX, Wireless USB, and ZigBee also have the potential to become pervasive globally.

Future manufacturing plants will support not one but many wireless technologies at the same time. Wireless networks will provide voice communication, mobile computing, process and factory automation, process sensors and transmitters, building automation, personnel safety, access control, and security. These applications will employ a set of wireless technologies, not just one, just the way wired industrial networks employ Ethernet, fiber optic, and various industrial fieldbus solutions.

There is another important analogy between the wired industrial networks of today and the wireless plants of the future. Industrial networks are often classified by level (see Figure 1). In the wired world of manufacturing there are sensor and fieldbus networks (that capture sensor and actuator information) automation networks (that control and manage production equipment and human interfaces), and enterprise-level networks that provide services for the whole manufacturing firm and its supply chain partners and customers. The same is true for industrial wireless. This discussion will focus on wireless sensor/actuator networks, the lowest level, the most challenging, and potentially the most revolutionary new type of wireless network.

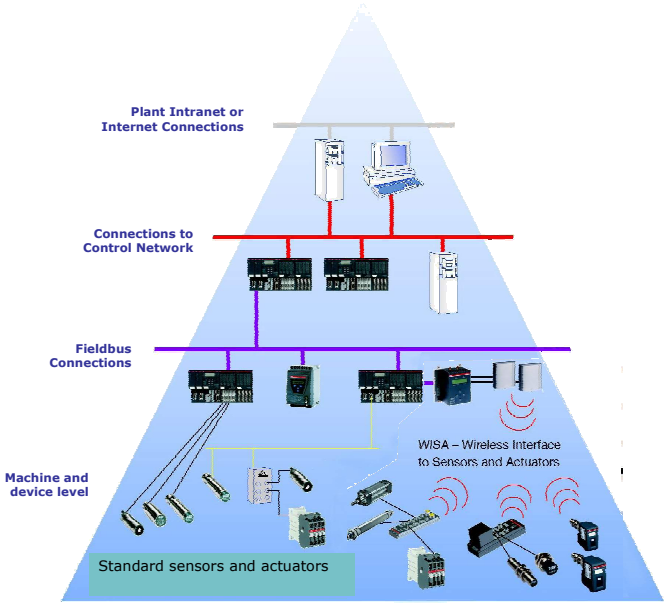


**Figure 1 – Automation Network Functional Hierarchy**

## The Balancing Act of Wireless Sensing

Creating any wireless product for the industrial market requires a balancing act, in order to meet the distinct requirements of manufacturing as opposed to IT and consumer segments. In the case of sensor-level wireless, this challenge is daunting.

Sensors used in manufacturing need to be highly reliable. The performance of these sensors often determines the success of the manufacturing operation itself. If the sensors do not perform their mission, production may be lost, sometimes large amounts of valuable production or production time.

Wireless sensors need to be designed specifically to fulfill an industrial mission. A large number of design variables need to be controlled so that the wireless sensor can perform. Some of these variables are:

- **Power supply –** The sensor will need reliable battery power (with its disadvantage of additional service intervals) or some other source of energy.
- **Range –** the sensor network will need to communicate reliably over a specified distance. Some production equipment is compact, and some is very large.
- **Latency –** The time required for a sensor reading to reach the automation system must be bounded if the sensor data is used in a closed-loop control system. The upper limit of this bound depends upon the application. It can range from seconds to just a few milliseconds.
- **Data types –** There are both analog and discrete output sensors, and in addition some "smart" sensors may supply diagnostic information that can also be used to improve the reliability or quality of production.
- **Production cycle –** Some production operations shut down every day, providing a window for maintenance activities. Others have operating cycles that last for several months or even more than a year.
- **Control loop cycle times –** Process automation control loop cycle times are normally in the range of seconds to minutes, while machine control loop cycle times are normally in the range of milliseconds.
- **Scalability –** The number of sensors in a single production unit can vary from a few to several thousand.
- **Immunity to interference –** Radio interference is certain, and the sensor network must be able to perform its mission in the presence of many types of radio interference.
- **Radio signaling –** Wireless sensors can use a variety of signaling and modulation techniques, and the choice of these may limit some other aspects of sensor network performance.

- **Network Protocols** – Sensor networks use a variety of different communication protocols and are not suited for TCP/IP, the most common set of protocols used in wired networks.

Different industrial applications will have very different needs and will choose different solutions, values, or bounds for each of these variables. The solution developer must focus intently on what the manufacturing operation requires. Then the challenge is to choose a set of network properties that will satisfy all the application requirements. The real objectives for any wireless industrial product are determined by the manufacturing operation in which it must perform, not by the technology employed.

## Meeting the Requirements of Factory Automation Applications

While wireless sensing is very broadly applicable and is certainly getting its share of publicity, the number of commercial products that have been introduced is disappointingly low. Even applications where concept and prototype products have been shown publicly have not seen full-scale commercialization of new wireless sensing products. However in some industrial applications products are now beginning to appear. Process field transmitters are one area where major product introductions have occurred. But why has it taken so long, and what happened to non-industrial areas such as building lighting control that were supposed to be in the market 1-2 years ago? To answer this question it helps to review some recent history concerning the development of standards for wireless sensor technology.

Commercial products using wireless sensor networks have been slow in coming to market, even in areas such as building lighting where prototype products have been shown to the public.

### ZigBee

The ZigBee standard, developed by a broad consortium and made public in 2004, was the first major attempt to standardize all types of wireless sensor networks. ZigBee focused originally on networking, network formation, and network management. The idea behind ZigBee was to create a single technology replacing many services provided to wired networks by the TCP/IP suite and the global Internet. Originally, ZigBee was envisioned as a lingua franca for all types of wireless devices from thermostats, to cardiac monitors, to industrial sensors, to light fixtures. At such an early stage of WSN technology, this turned out to be far too broad a scope. Many end users had trouble getting ZigBee to meet their application requirements satisfactorily. This was especially true in industrial applications and when applications were scaled up to normal size. They also encountered significant structural issues when

trying to introduce a disruptive yet immature technology into established business channels.

In response, the ZigBee organization has further refined its underlying technology and has also narrowed its focus. It is now addressing applications like building lighting and has a longer term roadmap that gradually expands its target market. The failure of developers to commercialize many ZigBee products speaks volumes about the difficulties and the risks of trying to standardize on too broad a scale. The large-scale deployment of ZigBee will take far longer than its proponents predicted just a few years ago.

## HART Wireless

If ZigBee tried to do too much, that would certainly not cause any problem for the wireless working group of the HART Communication Foundation. The HART wireless group is now working to specify a wireless implementation of HART for the new generations of wireless field devices. HART is a well-established 20-year-old protocol that is available on millions of analog field devices. HART modulates the 4-20 mA DC current signal put out by these field devices with a low-level sine-wave, without affecting the average DC signal.

In wired HART, the device transmits the measured value using the 4-20mA analog signal and the HART information using a modulated 2200 Hz signal. In a wireless implementation of HART, the only access to the device is through the wireless signal using the HART protocol. This means that the wireless sensor network must be highly reliable so that measurement information is always available. Wireless HART devices would also have to form networks of a certain size so that network management is simplified. Finally these devices will need to perform well in areas where Wi-Fi networks are also deployed. So defining a successful wireless HART solution depends in part upon the other types of wireless networks that are operating near the HART devices. A broader approach, one that looks at all types of wireless devices in a plant, is needed. That is the task now being worked on by the ISA's SP100 working group.

## SP100

Since its creation, the SP100 group has worked diligently to manage the large task it has been assigned. The group recognized that industrial applications had a very broad range of requirements and so different technologies would fit in different parts of this vast application space. One of the first pieces of work that the group developed was a classification scheme for industrial ap-

plications (see Figure 2). All of the group's work is done in the context of these classes of applications. In addition, the SP100 group has employed the OSI 7-layer communication model as a 2nd classification to define which communication "layers" are addressed by their work. This comes at a cost of some complexity, and the group cannot further subdivide the application

| Category | Class | Application | Description |
|---|---|---|---|
| **Safety** | 0 | Emergency action | *(always critical )* |
| **Control** | 1 | Closed loop regulatory control | *(often critical )* |
| | 2 | Closed loop supervisory control | *(usually non -critical )* |
| | 3 | Open loop control | *(human in the loop )* |
| **Monitoring** | 4 | Alerting | *Short -term operational consequence (e.g., event -based maintenance )* |
| | 5 | Logging and downloading /uploading | *No immediate operational consequence (e.g., history collection , sequence -of-events, preventive maintenance )* |

Importance of message timeliness increases

**Figure 2 – ISA SP100 Classification of Wireless Automation Applications**

space without having far too many classifications to manage. As a result, the distinctions between process and discrete manufacturing cannot be addressed by this group at present.

The SP100 group is being managed very much like the IEEE 802 committees, and has focused on the sensor network layer because there is broad agreement among the committee about higher level wireless networks. So while the group has managed to avoid mission creep, they have chosen not to focus on the substantial differences between process and discrete manufacturing and the resulting differences in the sensor-level devices used by these applications.

## The Unique Requirements of Discrete Manufacturing

Most actual manufacturing operations exhibit some characteristics of both continuous and discrete. However these 2 types have very different characteristics that determine the way they are operated and the way they are automated. For example an automotive assembly operation must start and stop every day, while some chemical manufacturing operations must run night and day for several years without stopping. The table nearby (Figure 3) shows some of the different characteristics of continuous and discrete manufacturing and automation. Note that for many of these application requirements, the two types of manufacturing differ by orders of magnitude.

The discrete manufacturing world has not seen the same level of frenzy for developing wireless industrial products. Ethernet is a very common network in such automation systems, so the use of industrial Wi-Fi products is growing rapidly. Some wireless bridges for discrete fieldbus technologies (such as DeviceNet) have been introduced. But at the industrial sensor/actuator level, the only major product introduction has been the WISA product intro-

| Process Attribute | Continuous Manufacturing Plant | Discrete Manufacturing Cell |
|---|---|---|
| Sensor types | Predominately Analog | Predominantly Discrete |
| Sensor count per unit | 1000 | 100 |
| Unit Physical Size | 1000 Meter | 10 Meter |
| Units per Plant | 10s | 100s |
| Production Cycle Length | 100 Days | 1 Day |
| Unit Startup Time | Hours | Minutes |
| Control Loop Time | .1-1000 Sec | .001-.5 Sec |
| Field Device Cost | $1000 | $100 |
| Installation Cost/device cost | 10 X | 4 X |
| Automation Technology | DCS | PAC/PLC |
| Commonly Used Device Networks | HART, Foundation Fieldbus, Profibus-PA, Ethernet | Profibus-DP, DeviceNet, Interbus, AS-i, Ethernet |

**Figure 3 – Characteristics of Continuous and Discrete Manufacturing Operations**

duced by ABB (WISA stands for Wireless Interface for Sensors and Actuators).

In an effort to further develop solutions that can specifically address discrete manufacturing, ABB is now working in an informal collaboration with FESTO of Germany and Millennial Net of the United States. Swiss-based ABB is one of the world's largest automation companies. FESTO is a large privately-held automation company that is well known for its actuator products that are used in many types of production machinery. Millennial Net is a wireless sensor network company that was recently acquired by privately held PHC Holdings. This collaboration brings together ABB's experience in developing wireless sensor products for discrete manufacturing, FESTO's leadership in machine actuation, and Millennial Net's deep knowledge of low-power sensor networks.

### WISA and MeshScape

ABB's development of WISA is a case study in adapting standard wireless networks to very demanding industrial applications. The target was to develop wireless replacements for common sensors like inductive proximity sensors. In these applications, the sensors are located on a single machine in a fairly dense configuration, but must be read rapidly and reliably. Because there can be more than 100 sensors on a single machine, ABB rejected battery power as an option for powering the sensors – it would decrease overall reliability or increase maintenance to have that many batteries on each machine.

WISA uses IEEE standard radios of the same type used in Bluetooth devices, but without any of the Bluetooth networking. Bluetooth networks can only extend to 8 devices, whereas ABB needed a network scalable to well over 100 devices that could be polled in a few milliseconds. In place of the Bluetooth network stack, ABB developed a protocol that used a duplex Time Division Multiple Access (TDMA) technique and also used the frequency hopping characteristic of the Bluetooth radios. This was combined with an innovative wireless power supply for the sensors that employs a rotating magnetic field created around the machine by 2 sets of coils. The result is a set of hundreds of sensors that operate without batteries and can be read in milliseconds.

WISA alone is not a complete solution for wireless factory automation. Analog machine sensors and larger sensor networks will require a different type of networking. This is where Millennial Net's MeshScape solution comes into play. MeshScape uses a hybrid approach to sensor networking that enables large and adaptive networks to form but still operate at the very low power levels that enable battery-powered devices to have long life, though MeshScape networks will have far longer latency than WISA. The greater scalability comes from using localized network routing, formation, and synchronization and an Ethernet-like CSMA rule for medium access that allows large networks to respond faster than is possible under TDMA rules. In many ways the design choices taken by MeshScape are quite different than WISA, because the target applications are much different than the simpler sensors served by WISA.

ABB, FESTO, and Millennial Net, the 3 companies that are now engaging in this wireless sensor collaboration, have very different and complementary expertise.

While ABB and Millennial Net each have distinct wireless sensor networking expertise, FESTO's core competence is in its actuation products, for which the firm is highly regarded. At present all FESTO's products use wired networks, but with so much expertise and experience in these products, FESTO can

contribute application expertise and deep insight into the target market, customer needs, and use-cases.

The collaboration between these 3 firms remains informal and no written agreement is in place. The stated purpose of their joint work is to:

- Further define the requirements and applications of wireless sensors in factory automation
- Improve the existing technologies in factory automation wireless sensor networks
- Harmonize their work with other ongoing developments in industrial wireless sensor networks
- Provide a common voice to standards bodies such as SP100 to help ensure that the needs of factory automation are being addressed in the standardization efforts

## Recommendations

- Suppliers of sensors and sensor networks to factory automation applications should consider participation in future work of the ABB/FESTO/Millennial Net collaborative.

- The collaborative should report its results and progress regularly and publicly to discrete manufacturing industry groups, and to various SP100 teams.

- End users of future products, especially machine builders, should become familiar with this work now in order to prepare their products to take advantage of developments in this area.

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