SELF-ORGANIZED WIRELESS NETOWRKS FOR MEASURE IN INDUSTRIAL PLANTS

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SUMMARY

The current document is intended to show the reader a general view about the use of wireless technology for the instrumentation in the industrial processes as a path to reduce the risk and as an improvement of the plant operation once the field operation expands by adding new process instrumentation and machinery that becomes spread around the facility, as it covers a wider geographical area into the plant, and where the conventional way to transfer the information from the field, becomes much more expensive. Many users has chosen the implementation of digital field buses that allows the reduction in the wiring cost as the Foundation^{TM} fieldbus ISA/SP50, IEC-61158-2, the creates channels that can connect up to 16 devices in a single channel, without sacrificing the quality of the signal or the security in the plant. During the development of a project, it is intended to cover all the variables related with the operation and security of the process, however, in many cases, once the plant is in operation, becomes the need of include measuring points that were not consider originally, and this incremental measuring points can mean an important additional investment to the users related to the expansion of the system that not always is the simple addition of the Input/Output module in the control system, and sometimes requires labor, marshaling panels, additional wiring, etc. The cost of prepare an incremental measurement can exceed by far the cost of the field device itself, and here is where a wireless solutions becomes very attractive because the lower total cost, easy to install and easy to start up and commissioning. But sending the signal to the air is just a small part of the equation. The user has to consider other key characteristics such as:

- Security of the information
- Data encryption and other security levels
- Signal power transmission
- Transmission frequency band
- Power supply and power consumption
- Site topography
- System architecture
- Obstacles and obstruction across the transmission path
- Quality of the variable transmitted
- Variable reading frequency
- Compliance with international o local standards

KEY WORDS
Wireless measuring system, Self-Organized Networks, Diagnostics, HART Digital Communication, Field Intelligence

INTRODUCTION

One of the main concerns of the users when considering a wireless network is the distance range between the transmission devices, based on their previous experience for remote wireless measurements required distances up to kilometers using point-to-point topology. The point-to-point topology (including a later variation known as cluster-tree), has the disadvantage of being highly susceptible to obstructions across the line of sight of the between the measuring device and the information system. In some cases, this problem is solved by increasing the transmission power; however, this solution generates another problems such as the reduction of the battery life of the measuring device, and also coexistence issues (interference) with other wireless devices outside of the network that uses the same transmission frequency. It is good to remember that most of the applications in industrial plants, the geographical area is not as relevant as the capability of the system to operate in areas where the obstacles as buildings, tanks, or infrastructure are the common topic to sort, specially in the mining industry where among the plants, the geographic conditions are characterized by wide extensions and rough topography.

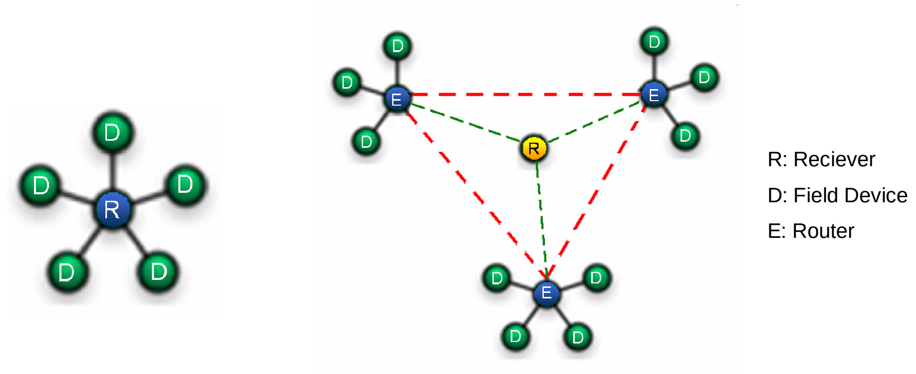


Figure 1: Traditional topology point-to-point (a) and the variation “Cluster Tree” (b).

Right now, there are several technologies for wireless transmission available for the users, and the correct selection of the right technology will have an important impact on the system and plant life cycle and finally the process operation The wireless systems based on analog measurements –that in a second process are converted into wireless signals- does not offer diagnostics capability, because the analog measurement only allows the transmission of one single variable –process variable when we talk about process instrumentation. The best choice for wireless communication systems, are those based in digital systems –that in a second process are converted into wireless communication, because allows the user to count with information such as the process variable, field device diagnostics, radio system diagnostics, alarms, battery status, and any other information that let the user to take a better decision un critical situations. One option available today is the transmission of the HART protocol commands (Highway Addressable Remote Transducer) in a wireless way. HART is a standard industrial protocol that allows the transfer of information of intelligent sensors in an effective way, and also is highly known for the plant personnel. There are about 20 million of field devices installed in several applications world wide that use HART protocol.

Currently, there are many types of wireless networks commercially available, some of them have been adapted to operate with the instrumentation for measuring and control of the industrial processes, each technology is oriented to satisfy particular needs. Because of that, by having one technology that satisfies a particular need, it doesn't mean that will work properly in another application. Some of the technologies available today are available for different markets such as the residential, personal use and industrial are:

- Wi-Fi
- Bluetooth
- ZigBee
- GSM/GPRS

The technologies mentioned are not the only ones available, eventually; the reader will find other technologies currently under development. The intention of this document, is not to describe every single particularity of each of those technologies, this is an invitation to the reader to look for additional documentation about this technologies in order to have a better criteria when selecting one.

Las tecnologías anteriores son enunciativas mas no limitativas, el lector eventualmente podrá encontrar otras tecnologías en desarrollo, así mismo no es la intención de este documento describir las características particulares de cada una de ellas, se invita al lector a documentarse mas sobre estas tecnologías para formar mejor su criterio de selección.

Application Layers of Industrial Wireless Networks

The Institute of Electrical and Electronics Engineers (IEEE) established IEEE-804.15.4 which is the standard that defines the wireless transmission between field devices, such as the instrumentation used in the industrial processes. Some of the more relevant topics of this stardard are:

- Data speed rate of 250 kbps, 40 kbps and 20 kbps
- Frequency transmission band of 2.4 GHz, 915 MHz and 868 MHz.

The IEEE standard defines the characteristics for data transmission for applications in the industrial, personal use and residential market.

Recently, the Instrument Society of America (ISA) created a committee that is looking for the creation is a standard for the development of best practices for the wireless communications. This comitee is known as the SP-100, and expects to have a definitive standard in 2008. At this time, the committee suggests three main groups with six divisions as shown on table 1.

Table 1: *ISA-SP100 Model*

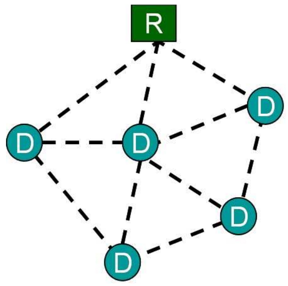
SAFETY	Class 0: Emergency action *(Always critical)*	Importance of message timelines increase
CONTROL	Class 1:Closed Loop Regulatory Control *(Often critical)*	
	Class 2: Closed Loop Supervisory Control *(usually non-critical)*	
	Class 3: Open Loop control *(human in the loop)*	
MONITORING	Class 4: Alerrting *(Short term operational consequence)*	
	Class 5: Logging & downloading/uploading *(No immediate consequence)*	

In a similar way, the HART foundation has developed an industrial standard, that is intended to take advance of the enormous installed based of devices that currently use this digital protocol. It is known as the HART 7.0 or the Wireless HART. For more information, you can review the site http://www.hartcomm2.org/hart_protocol/wireless_hart/wireless_hart_main.html

It is expected that the first wireless devices available commercially will be oriented applications below to Class 2 (including Class 2) as shown on table 1. Probably, the Class 0 applications will require to remain wired as today.

Self Organized Networks

By mixing the microprocessor technology, HART digital communication and the IEEE 802.15.4 for wireless transmission, emerge the revolutionary concept of self organized networks. This architecture is based in intelligent field devices that are organized in a smart mesh topology, with a high reliability, able to measure the process variable, transmit it to a central system, but it is also capable to transmit diagnostics of the field device, diagnostics of the radio system and also, the information of any surrounding neighbor. As a difference with other existing technologies, where the coverage area is a function of the power of the transmission and the area topography, the self-organized networks does not require high power transmission units, nor field surveys to operate in the plant, based on the capability of the network, to surround the obstacles either of the topography as well the plant. Based on the capability to build a digital wireless network, it is possible to recognize the devices that belong to the network. Also, with the use of sophisticated algorithms, the systems determines the frequency channel for transmission with a technique based in a pseudo-random change of the required frequency, which is known as Frequency Hopping Spread Spectrum (or FHSS). The name of pseudo-random is because any device in the network that does not have the algorithm will see those frequency hops as randomly. This technique, along raising the security level of the network, makes the system stronger against electromagnetic or radio interference, which will affect other wireless network system that does not provide this capability. The self organized networks, forms an intelligent mesh between the field devices where the intelligence provided is more needed. The self organized networks do not need routers or radio systems to build the mesh topology. Figure 2 shows the mesh topology used in the self-organized networks.



R: Reciever
D: Field Device

Figure 2: Topology of a typical self-organized network.

The mesh topology is –by definition- redundant as a transmission path, as you can see in figure 2. The topology offers alternative paths for the information transmission in the event that the current link is broken by a failure in the field device, interference or an obstruction such as a new building construction, trucks going to a load terminal, cranes, etc.

The field devices in a smart mesh self-organized type, has the ability to communicate with the surrounding devices (neighbors) only if the devices has the access code verified by the receiver of information system, allowing to determine the best way to access the information system, in other words, the path to deliver the information from the field device to the information system, can change dynamically, in case of failure of one of the devices in the path, because the presence of an obstruction (that can be permanent or intermittent): the self-organized network has the capability –as it names states- to organized itself once two or more devices are energized and commissioned by the user. The figure 3 shows the communication path of a smart mesh with self-organizing capability

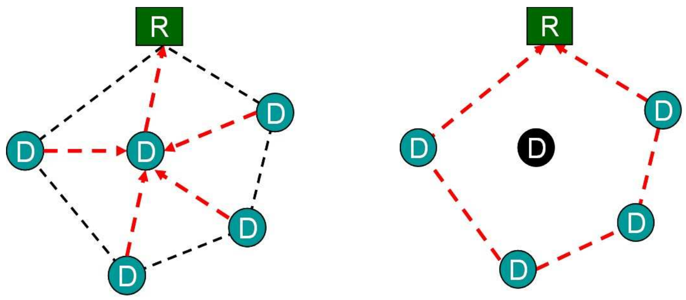


Figure 3.1.a Figure 3.1.b

Figure 3.1.a Communication path consider as more efficient by the system.
Figure 3.1.b Alternative communication path when the parent device fails

Figure 3: Communication path of a self-organized mesh.

The self-organized mesh does not require a high power or long range transducers, because use the network itself to transmit the information from the field device to the information system. This way helps to reduce the energy requirements, repeater units and the use of special antennas.

It is important to differentiate between a conventional mesh and a self-organized mesh. The conventional mesh does not have the capability of re-build the path between the devices in an automatic way, and typically requires a pre-configuration in the field. In those cases where there is a certain capability to re-establish the links, this capability is typically limited, impacting negatively the reliability of the network.

Measuring Devices

A self-organized network is integrated by filed devices, intelligent sensors that measures pressure, differential pressure (and based on this, any other inferred measurement such as level and flow), and temperature (either with thermocouple or RTD), switches (pressure, temperature, level), corrosion and vibration. Once the technology evolutes, many other measuring variables will become available. Since at this time, the suggested application for wireless devices are oriented for monitoring purposes, it doesn't mean that a low performance and low reliability sensors should be installed, even that accuracy is not a key decision point –as in security or control systems-, reliability, repeatability and stability, are key factors to consider in a decision for the devices that will form a wireless network.

Asset Administration

Another factor to be consider by the user when selecting and designing a wireless network is the use of software systems that enables the asset optimization, on-line, by maximizing the use of the diagnostics available in the field devices, based in the HART digital communication, as mentioned in the previous section, specially when the devices are located in inaccessible areas where the periodic inspection becomes difficult to handle. In this case, the use an asset management system (AMS) becomes an important factor for the success of a project based in a wireless network.

Benefits

The benefits of the wireless self-organized networks are evident by just eliminating the wiring related to the installation, common wiring practices and others. However, there are public tools available to generate more realistic estimations.

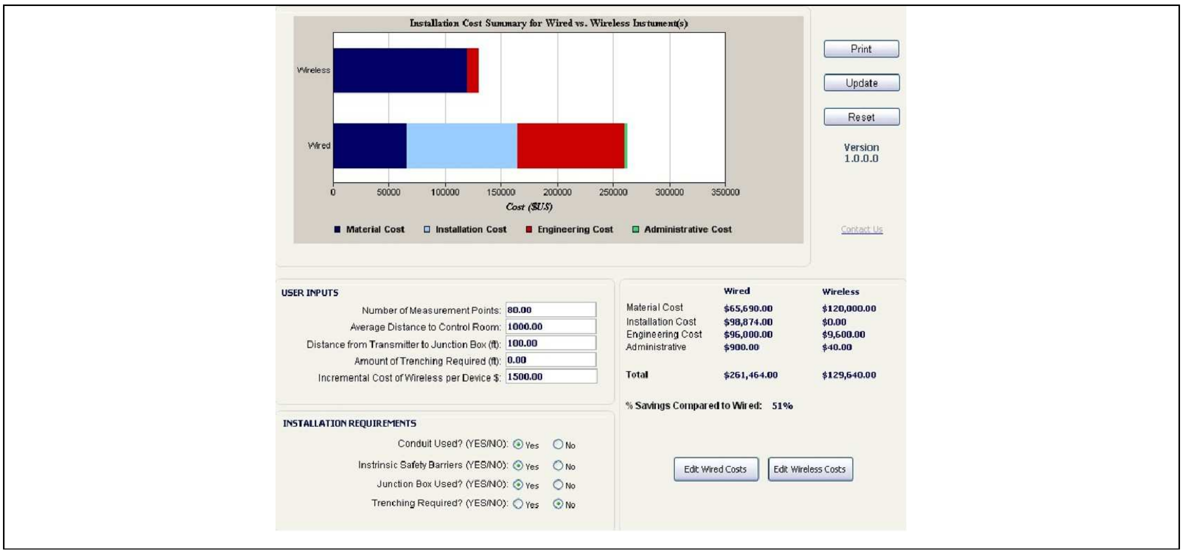


Figure 4: Cost savings when using a self-organized network.

As a rough estimation, for 80 incremental measuring points, with an average distance of 1000 ft between the measuring points and the information system, the estimated costs savings are about **51%** compared with a wired system when using a intrinsically safety configuration. The cost calculator tool (for public use) can be found in the internet web site: http://www.emersonprocess.com/rosemount/smartwireless/index.html.

Applications

The applications for the mining industry are many, and depend on the process type. Below you will find some typical applications for the wireless technology:

Monitoring of Differential Pressure in Coalescent Filters in Extraction Plants with Solvents

In the hydrometallurgical process of the copper, the final stage is named Electro Recovery where copper cathode is obtained by the electrolysis of solutions rich in dissolved copper. For the correct process of the growth and formation at the cathode surface, there are several variables to consider, for example the concentration of organic elements that for the non-conductive properties interferes with the correct formation of the cathode surface. Because of this effect, the organic elements must be removed of the system before the “electro winning” process, by the use of filters that guaranties the maximum level of purity along the appropriate flow rate for the next stage. This separation is performed by the coalescent filter where the additive traces are removed by the use of consecutive filtering mesh element that, with the specific configuration and geometry allows the coalescence of the organic element, also by the presence of an additional stage of filtering beds of sand (anthracite + Garnet Sand)

The maintenance of the filters includes the cleaning that is performed by the injection of water in counter-flow. The volume of water used in each counter-flow wash is typically of 19 m3/m2. This washing cleaning procedure is performed every 12 or 24 hours with a typical duration of 10 minutes.

In order to optimize the water consumption, that for some mining plants becomes a limited resource, it is suggested the use of a wireless differential pressure transmitter to determine by the increase of the differential pressure value through the filter, the real need of the counter-flow wash, and then optimize the water consumption.

It is recommended the use of self-organized wireless technology, because the cost savings in time and money compared with a wired system, based on the complex that the Extraction Plant with Solvents may become specially with the limitation on having dead times and shutdowns, involved in wiring a new measurement variable and also, by the impact in the other sub-process of the plant due to the close relation of each stage in the copper process. The areas where these devices are typically installed are susceptible to obstructions due to heavy truck or machinery transit, which justify the use of self-organized mesh wireless networks, in order to guarantee the reliable transmission of the pressure measurement. Finally, this particular process does not require a continuous transmission of the measured variable, and a typical transmission frequency can be every 3 hours, and once the process reach the set value, the counter-flow wash is activated.

Figure 5: Coalescent Filters.

High Level Alarm Monitoring on Tank Farming Applications.

It's very common and often that when trying to adapt a tank for crude oil storage to the new regulations according to API21 sometimes wiring sensors and or installing new field instruments it might be quite a challenge. This might be either due to not having enough modules for I/O on the existing DCS or the elevated costs for wiring and trenching this new signals.

Wireless is a great alternative for this type of applications as it can comply with two requirements by installing a high level alarm either electrical or mechanic together with a Discrete Input Wireless transmitter that will re transmit the state of the relay to the wireless network.

As per the comments of several end user and customers this application is excellent from many perspectives:

- Connections saving
- Mounting of the device
- Connectivity to the host

- Data integration
- Alarm Status

CONCLUSION

The emerging of the wireless technology for the industrial process is generating a positive impact in the cost savings for wiring, specially in applications where the current monitoring systems does not allow an expansion, or in those temporal installations where an expansion in measuring points is needed as long as the system or plant expands as well, as in the Leaching Process.

The self-organized mesh networks offer a higher reliability than the point-to-point topologies, and even better thank the conventional mesh topology. The reliability of the architecture used is a key factor in industrial monitoring applications.

Currently, there are many trends for industrial standard; however it is important to keep in mind that in early 2007 there was no industrial standard for the wireless technology. As a result, part of the current installed based is based on proprietary systems that does not allow interoperability between the devices. With the development of the HART 7.0 or Wireless HART industrial standard and the further SP 100 guidelines, the users will be able to take advance of the use of many instrumentation vendors in a single wireless network, in the short future.

Emerson offers a solution that allows the users to reach a high reliability in the transmission of the information with the self-organized wireless network, adding a great value to the mining industry.