White Paper

Industrial Wireless Sensors:

Use cases for *Wireless*HART® and LoRaWAN™ protocols for use in industrial applications.

EMERSON™

What is *Wireless*HART?

*Wireless*HART is a secure real-time mesh networking wireless communication protocol designed to provide highly reliable, low latency, ultra-low power connectivity for challenging process monitoring and automation applications. The technical requirements for the protocol are defined in IEC 62591.

*Wireless*HART uses field proven IEEE 802.15.4 radio technology, deterministic scheduling, and path diversity to achieve reliable, deterministic data transport using very little power. Unlike other high-power protocols, *Wireless*HART instruments can achieve 10-year battery life with update periods as short as 4 to 8 seconds.

*Wireless*HART also supports low latency downlink communications without sacrificing battery life. *Wireless*HART operates in the unlicensed 2.4GHz band and has a data rate of 250 kbps.

What is LoRa and LoRaWAN?

The LoRa physical layer is based on a non-cellular modulation technique called chirp spread spectrum (CSS) for LoRaWAN which uses the unlicensed spectrum. This LPWAN (Low Power Wide Area Network) based technology is focused on up-link applications. The primary application is transmitting small amounts of data from sensors/devices to gateways infrequently.

The three most often cited attributes of LPWAN are as follows:

- **Low Power:** LoRaWAN transmits small data packages of between 51 and 222 bytes, at between 0.3kbps to 5.5kbps. It takes less power to send small amounts of data, less frequently. A typical update rate for a LoRa Class A sensor is 1 hour or more. This is not unique to sensors utilizing LoRa however, any battery powered wireless device (including *Wireless*HART) which remains off for long periods of time will inherently consume less power.

- **Wide Area (Range):** Device range is a function of 4 factors: frequency, antenna type, transmit power and environment. Unlicensed LoRaWAN frequency bands vary by world area (Table 1), so devices must be designed and manufactured with the end-use location considered.

World Area	Frequency
Europe	867-869MHz
North America	902-928MHz
China	470-510MHz
Korea	920-925MHz
Japan	920-925MHz
India	865-867MHz

Table 1: Sub-GHz Unlicensed Frequency by World Area

These sub-gigahertz frequencies are inherently good at penetrating obstacles typically found outside of an industrial environment (trees and wood structures) and have longer transmission ranges than higher frequency protocols with the same power levels in these environments. However, in the industrial space where steel structures such as furnace walls, tanks, and pipe racks are common all wireless frequencies are impacted which is why network topology becomes so important.

Device range is just one factor in the overall design which directly impacts other key features including battery life, reliability, security, scalability, interoperability and update rate. These features all work together and while it is possible to extend the range of any wireless protocol there will be direct impacts to battery life, reliability and update rate.

- **Low Cost:** LoRaWAN networks and sensors are often marketed as low cost and many end users often associate the LoRaWAN protocol as being low cost based on the network infrastructure needed to get started. This is true for applications like residential utilities monitoring where the environment allows for non-hazardous area sensor approvals and update rates of 1 hour or greater on measurements that only ever increase. However, unlike the residential metering space, measurements in the industrial automation space oscillate and hazardous environments exist.
    - When evaluating the cost of an instrument and network architecture to support an application it is important to consider the 7 industrial automation features (battery life, reliability, security, scalability, interoperability, range and update rate). When a protocol is marketed as low price, consider what is driving that difference in price and how that might impact your measurement today and in 5 or 10 years.

To accommodate different use cases, LoRaWAN features three classes A, B, and C. Most LoRaWAN sensor providers offer Class A devices to maintain long battery life.

- Class A operates as an asynchronous ALHOA system where devices listen for a response after an uplink transmission during two downlink receive windows (at recommended offset times of 1 second and 2 seconds). This operating mode offers the lowest power consumption while sacrificing uplink and downlink reliability. This is currently the most common Class utilized for instruments marketing suitability for industrial process applications.

- Class B devices are designed for applications with added downlink traffic needs, with scheduled uplink and downlink windows. Due to the additional radio traffic, this is at the cost of reduced battery life.

- Class C devices improve overall data reliability by always listening to the channel after a transmission. This significantly increases overall power needs and often requires devices to be wired to a power source.

LoRa Class A	LoRa Class B	LoRa Class C
Battery Powered	Low Latency	Lowest Latency
Bidirectional communications	Bidirectional with scheduled receive slots	Bidirectional communications
Unicast messages	Unicast and Multicast messages	Unicast and Multicast messages
Small payloads, long intervals	Small payloads, long intervals, Periodic beacon from gateway	Small payloads
End-device initiates communication (uplink)	Extra receive window (ping slot)	Server can initiate transmission at any time
Server communicates with end-device (downlink) during predetermined response windows	Server can initiate transmission at fixed intervals	End-device is constantly receiving

Table 2: LoRa Class A, B, and C Features

Will LoRaWAN Replace *Wireless*HART in Field Instrumentation?

For most process monitoring applications, LoRaWAN will not replace *Wireless*HART. *Wireless*HART offers several advantages for industrial monitoring applications over the LoRaWAN protocol:

Criteria		*Wireless*HART®	ISA100	Cellular (5G/4G)	LoRa	Proprietary
Design	Original use case	Designed for the industrial automation space	Designed for the industrial automation space	Designed for cell and web communication with large scale implementation	Designed for automated meter reading (AMR), not instrumentation (single point distributed)	Typically sub 1 GHz
	Applications	Critical asset monitoring, Safety, Non-critical control	Critical asset monitoring, Safety, Non-critical control	Cell phones, Public networks, Remote monitoring	Low rate, Wireless remote monitoring	Niche industry specific
Industrial Automation Features	Battery life	↑	→	→	↓	↓
	Reliability	↑	↓	↓	↓	↓
	Security	↑	↑	↑	↓	↓
	Scalability	↑	↑	→	→	↓
	Interoperability	↑	↓	↑	↓	↓
	Range	→	→	↑	↑	↑
	Update rate	↑	↑	→	↓	↓

Table 3: Protocol Comparison for the Industrial Automation Space

- **Update Rate:** The LoRaWAN protocol was originally designed to support low data rate, low update rate (>1 hour) applications like "smart cities" which monitor residential gas, electric and water usage a few times per day. By collecting this information once an hour vs once per month, for example, utilities providers can run analytics to determine if there is a water leak by looking for continuous water usage every hour of every day.

Since these measurements only ever increase, a slower, less reliable measurement is tolerable for this application. In the case of industrial process monitoring, however, measurements oscillate and a more robust industrial protocol such as *Wireless*HART offers the flexibility to update as fast at every second if required. This flexibility supports more demanding monitoring and analytics while preserving battery life.

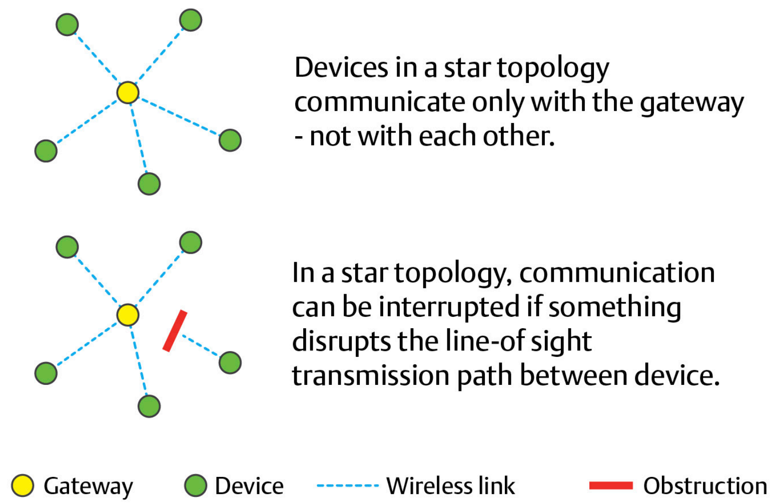
- When considering wireless instrumentation for the industrial automation space (which *Wireless*HART was designed for) it is important to understand the impact changes to specific features will have on the overall system, and for future use cases.

- Consider Environmental reporting, today the government may require a facility to report data on a daily or hourly basis. If this changes to 30 seconds, will your existing instrumentation and network be able to support this new requirement. Many end users require a 10-year battery life for these instruments which suggests they will be used for at least 10 years – what will your update rate requirements be for that instrument in 5 or 10 years?

- **Bandwidth and Data Rate:** Bandwidth and data rate are important because the bandwidth determines the ability in which data can be sent and received. An example application is corrosion monitoring, where measurements require in-depth analysis and uses algorithms to predict the wall thickness. This requires the waveform to be transferred to perform advanced analytics – the (raw) waveform holds a lot of information and is essential to understanding the corrosion rates. *Wireless*HART offers the flexibility to support very infrequent scalar values or waveforms depending on the needs of the application. While not all applications will require large bandwidths, utilizing a protocol that provides flexibility in bandwidth will future-proof the infrastructure investment.

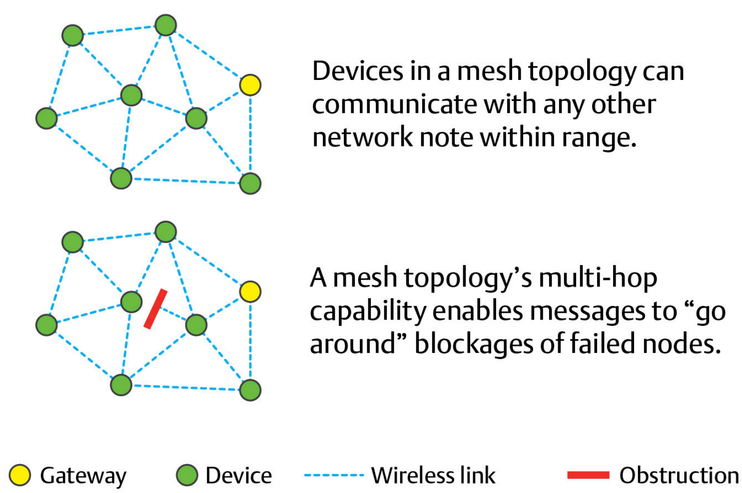
- **Data Reliability:** LoRaWAN uses a star topology in which every device communicates directly to the LoRaWAN gateway. If the signal between the device and the gateway is blocked, there is no alternative path for the signal to take.

Star Topology Modeling



*Wireless*HART is a scheduled protocol that employs several methods to efficiently and reliably transport data through the network. In the *Wireless*HART mesh network, data is sent over diverse paths. If one path fails, the system automatically resends the data using another to maintain industry leading data reliability.

Mesh Topology Modeling



When considering use of the LoRaWAN protocol for industrial applications, data reliability impacts should be reviewed based on the device class being installed and the application environment.

- **On-Demand Downlink:** *Wireless*HART includes provision for deterministic, on-demand downlink which is useful for asset management. This is especially true for widely deployed networks like plantwide asset monitoring to support digital transformation initiatives. With *Wireless*HART you can manage the field nodes efficiently over the air instead of visiting each node. This even extends to full over the air configuration for devices that support such functions. Consider how your facility plans to support the following instrument functions once installed plantwide:

    - Field device configuration
    - Field device diagnostics and health monitoring
    - High resolution spectrum delivery (often done with poll-response)
    - Maintaining security of the network (e.g. changing keys when current keys have been compromised)

Doing most of these becomes very difficult if you must visit every field device to perform the function locally.

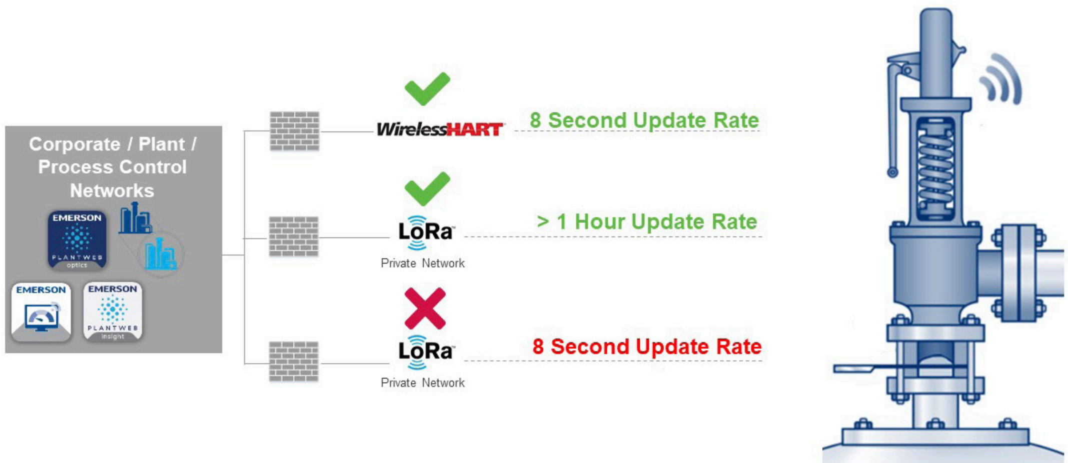
- **Scalability:** *Wireless*HART is an open protocol with numerous major industrial automation suppliers launching new instrumentation every year to support global cross industry process measurement needs. *Wireless*HART networks can be extended to support hundreds of field nodes per gateway. Long range is also possible using the *Wireless*HART protocol if networks are properly deployed (environment, towers, antenna gain, etc.). This can be done without sacrificing deterministic downlink and multi-hop, self-organizing mesh functionality. This scalability allows for use of the exact same instruments that are used for other typical industrial applications which provides a broad portfolio of industrial quality instruments and leverages existing tools and trainings.

LoRaWAN and *Wireless*HART Use Cases

Chemical Facility Use Case

A chemical facility is interested in monitoring 40 pressure relief valves (PRV) across their facility using non-intrusive instrumentation in a hazardous environment (CL I DIV 1), 1-hour update rate, 10-year battery life and analytics to document releases which is hosted locally within the facility (Figure 1). With these very basic project requirements a transmitter using either the *Wireless*HART or LoRa protocol would achieve these minimum design requirements. However, it is unlikely that 1-hour update rates will be acceptable for most PRV monitoring applications.

Figure 1. Chemical Plant Use Case Examples



More realistically, this chemical facility would expect the ability to increase the update rate of these instruments to 8 seconds or less for their most critical PRV's. In this case, if the end user selected *Wireless*HART devices they would simply change the device update rate through the gateway eliminating the need to reconfigure every device locally. Additionally, if the end user had selected LoRa devices they would be unable to achieve this update rate and would have to replace the existing LoRaWAN devices with *Wireless*HART or decide to not take advantage of these higher-level analytics.

Steam Trap Monitoring Application Use Case

A manufacturing facility uses a significant amount of steam for process heating. An annual manual audit determined that the total energy usage of the plant could be reduced by more than 10% if failed steam traps that leaked excessive amounts of steam where replaced in a timely manner. To facilitate this, acoustic/temperature sensors were utilized to continuously monitor the critical steam traps for leakage ("blow-through") or blockage (potential water-hammer and reduced process heating).

*Wireless*HART sensors were installed on the critical steam traps which resulted in lower energy use and improved steam quality. After installing the steam trap monitoring application, operations found needs to monitor other assets such as pumps, tanks, and heat exchangers. The end-user was able to easily add many different types of wireless sensors (pressure, level, temperature, and vibration) to the existing *Wireless*HART network with varying update rates depending on the application.

In this example, an instrument utilizing the LoRaWAN protocol could also be used to monitor acoustic and temperature data from steam traps typically at an update rate of 1 hour or more. With this LoRaWAN network infrastructure in place this end user would only ever be able to add similar slow update, low data rate applications to this network. As digital transformation initiative progressed through this site and high value measurements like vibration wave forms and non-critical wireless control opportunities were identified this end user would need to install a second wireless network with a protocol like *Wireless*HART to begin leveraging these measurements for operational improvement. If this end user had selected *Wireless*HART for their initial steam trap application, they would be able to fully leverage one network for all their wireless process monitoring needs.

Smart Cities Use Case

A large municipality wants to digitalize their operations to provide flood sensors, water leakage detection, smart metering (such as parking, electricity, gas, and water), smart city infrastructures such as street lamps and smart waste management (waste bin fill level, waste bin location), smart bus schedule signs, locating available parking spots, fire hydrant use monitoring, and bike sharing services.

All the applications outlined above exercise the core properties of LPWAN technology discussed in this paper- Low power, low bandwidth applications that can be utilized in a wide non-industrial environment. This is another example of applying a technology to support applications for which it was designed.

Conclusion

*Wireless*HART was specifically designed and optimized for industrial wireless sensor communications. LoRaWAN was designed for wide area, low bandwidth, long interval reporting. Both aim to achieve a 10-year instrument battery life which has become the industry standard for most applications. This suggests that end users expect these instruments to support their measurement needs for at least 10 years. So, thinking long term is critical to ensuring the selected protocol meets these needs today and in 10 years.

As we have detailed in this Whitepaper, LoRaWAN sensors will not replace *Wireless*HART instrumentation for typical industrial process automation applications, just as *Wireless*HART will not replace LoRaWAN for smart city applications.

In today's industrial environment there is no single wireless protocol that efficiently solves all applications. It is our assessment that end users who review the 7 features of industrial wireless applications will find that the best wireless protocol for the application is the one in which it was designed for.

For additional information on Emerson's industrial wireless technology, visit
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