White Paper

Industrial IoT Devices: *Wireless*HART® and 5G

EMERSON

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This white paper details use cases for *Wireless*HART sensors and 5G backhaul for use in industrial applications.

What is *Wireless*HART?

*Wireless*HART is a secure, multi-vendor, interoperable wireless standard, featuring real-time mesh networking. *Wireless*HART was 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, frequency, temporal, and path diversity to achieve reliable, deterministic data transport using very little power. Unlike the common wireless communication protocols associated with telecommunications infrastructure, such as LTE-M and NB-IoT, *Wireless*HART instruments can achieve 10-year battery life with update periods as short as four to eight seconds. *Wireless*HART also supports low latency downstream communications without sacrificing battery life and works with most existing handheld field devices to support calibration and diagnostics in the field.

What is 5G?

5G is the latest generation of cellular connectivity. The 3rd Generation Partnership Project (3GPP) is the standards organization responsible for the generation and maintenance of mobile telephony standards including 4G/LTE and 5G. The International Telecommunications Union is another international standards organization involved with the development of 5G requirements. They published the document IMT-2020 in 2015, which sets forth general targets for 5G networks, devices, and services. 3GPP generally considers any system or product that uses the "5G New Radio" (5G NR) as "5G".

Encompassed in 5G are wireless protocols NB-IoT and LTE-M. NarrowBand-Internet of Things (NB-IoT) is a standards-based low power wide area (LPWA) technology. This communications standard was designed to let IoT devices operate via carrier networks – either in 200-kHz bands previously occupied by Global System for Mobile Communications (GSM), in guard bands between LTE channels, or independently. LTE-M, like NB-IoT, is also a LPWA technology. The 3rd Generation Partnership Project (3GPP) is the standards organization that introduced LTE-M and NB-IoT in Release 13.

LTE-M deployment can be in a GSM carrier as 1.4-MHz or independently. The current version of the 3GPP 5G standard identifies three types of co-existing systems:

- **eMBB** (enhanced Mobile Broadband) – This is the initial focus of most early 5G systems and devices and can be best characterized as a direct extension of 4G. eMBB provides higher bandwidth and slight improvements in transport latency to support emerging technologies including virtual reality media and UltraHD video. eMBB relies on the use of the 5G New Radio. eMBB supports data rates up to 20 Gbps with up to 10,000 x higher traffic than 4G systems.
- **URLLC** (Ultra Reliable Low Latency Communications) – URLLC provides support for critical systems that require extremely low latency such as self-driving vehicles and machine control. URLLC offers transport latency of less than 1 ms with data rates up to 10 Mbps. Like eMBB, URLLC relies on the use of the 5G New Radio.
- **mMTC** (massive Machine Type Communication) – mMTC supports low data rate machine-to-machine communications with data rates up to 100 kbps. mMTC applications include municipal metering and "Smart Cities" where extremely low data rates (e.g. once per day) and high latency is acceptable. The 5G New Radio does not provide support for mMTC but the latest release of the 3GPP standard includes refinements for existing LTE-M and NB-IoT radios to ensure that they will seamlessly coexist with 5G NR.

Will 5G replace *Wireless*HART in field instrumentation?

There are many use cases for wireless technology in the industrial space including communication with sensors, gateways, and mobile connectivity. With more than 12 years of field experience, *Wireless*HART continues to evolve as the leading wireless protocol for industrial sensor communication. For most industrial sensor applications, 5G cellular will not replace *Wireless*HART in the foreseeable future. However, 5G is a technology that will continue to evolve as a protocol that will allow for more possibilities including faster data backhaul, self-driving cars, and smart cities. Today, cellular technology is already used to backhaul information from industrial wireless gateways and 5G will continue to improve these communications. The 5G mMTC use case is most closely aligned to the type of applications that *Wireless*HART supports. However, *Wireless*HART offers several advantages over proposed mMTC deployments:

Battery life

Wireless battery life is primarily a function of update rate, transmit power, and sensing element requirements. A typical *Wireless*HART radio requires about 9.7 mA for 4 ms to transmit 80 bytes of payload at 8 dBm. When paired with a low power industrial instrument, average system currents of around 120 μA can be achieved. At an eight-second update period, a battery life of approximately 11 years can be achieved (when using a 17 A hr. lithium primary D cell). A typical LTE-M or NB-IoT radio, however, requires around 130 mA to transmit at 8 dBm at the same data rate. This results in a battery life of 2.2 years (5X less than *Wireless*HART) for an equivalent system. Typical *Wireless*HART systems are configurable to update every one to 60 seconds, depending on the application, while LTE-M and NB-IoT are designed for just a few measurements per day. This difference in update rate is what allows LTE-M and NB-IoT systems to market long battery life. While this works well for municipal metering, it is not suitable for critical industrial applications, such as pressure relief valve monitoring. Operating LTE-M or NB-IoT systems at these update periods (less than eight seconds) would result in significantly shorter battery life compared to the equivalently configured *Wireless*HART device due to the current required to run the radio.

Range

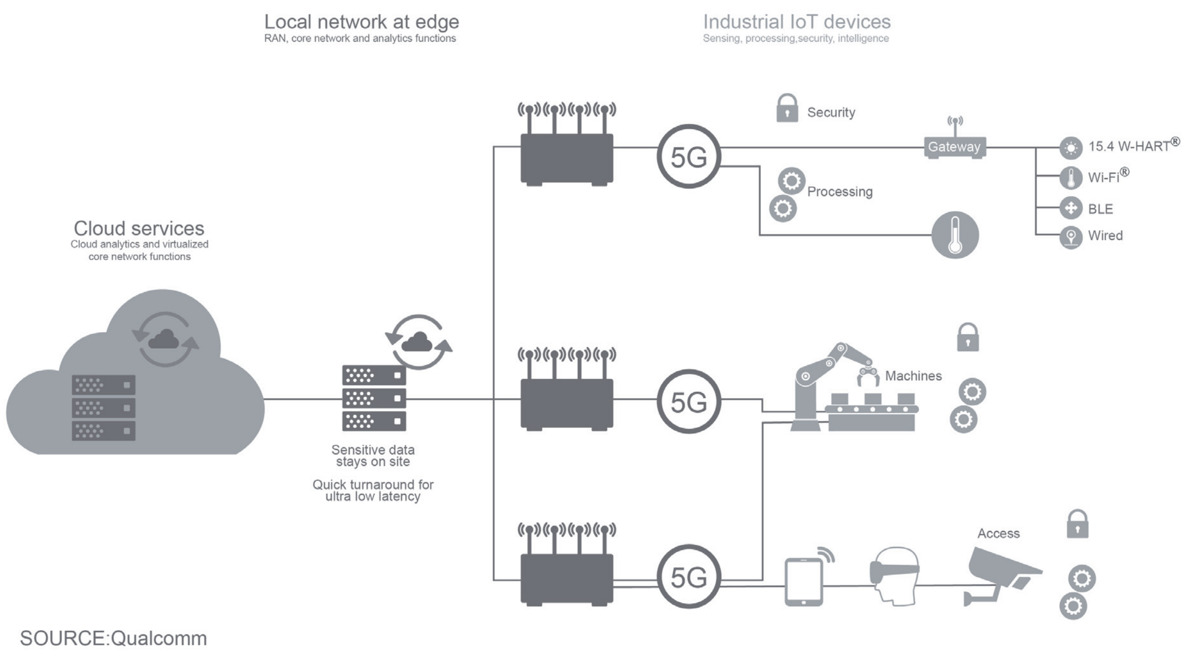
Wireless range is a function of frequency, antenna type, environment, and power. Since LTE-M and NB-IoT systems operate in licensed bands, they are allowed to transmit at higher power levels, which results in greater communication range. Long communication range is often necessary to reach the closest cell tower. This higher transmit power comes at the expense of battery life. For the system described above, increasing transmit power to 23 dBm results in a battery life of 1.5 years. Another consideration is the requirement to obtain a license or to use a cellular provider's network. Both come at a substantial cost-either in obtaining and maintaining the license or in paying the provider on a per-byte basis. *Wireless*HART systems operate in the global 2.4 GHz unlicensed ISM band and are therefore required to transmit at lower power levels (typically around 10 dBm), resulting in shorter line of site range. The *Wireless*HART standard overcomes this limitation through the use of a multi-hop mesh network topology. Using the mesh, *Wireless*HART networks can extend over large physical distances.

Coexistence and Noise Immunity

*Wireless*HART 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. *Wireless*HART also uses frequency and temporal diversity to ensure reliable delivery even in congested and noisy environments. LTE-M and NB-IoT systems operate in licensed bands, which eliminates some RF congestion but does not deal with spurious noise present in the environment. These systems use a point-to-point connection between each subscribed node and the base station antenna. If there is no good line of site between these points, the connection can be unreliable. Outside of the industrial environment, these unreliable cellular connections are frustrating but often corrected by moving the mobile device from one side of the building to another. In the industrial space, sensors are typically fixed, and unreliable communications are not acceptable even with changing environmental and structural conditions.

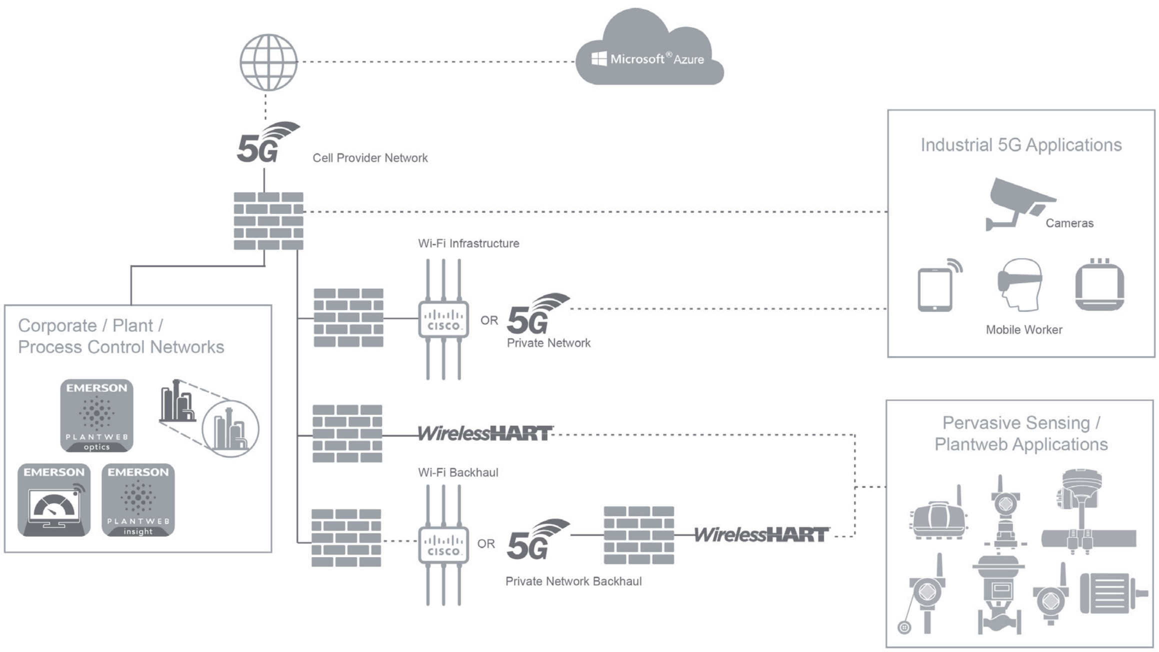
For the reasons mentioned above, 5G cellular sensors will not replace *Wireless*HART sensors for typical industrial process automation communication in the foreseeable future. However, 5G cellular technology will continue to be a great alternative to wireless gateway backhaul with either public or private network solutions. Figure 1 specifically separates the sensor network and associated gateway and demonstrates the use of 5G for backhaul from these systems.

Figure 1. Wireless Edge for the Industrial IoT



In this use case, 5G cellular (either private or public) is used as a data backhaul for *Wireless*HART instrumentation and direct link to field devices. Additional use cases have been provided at the end of this white paper to highlight how to best use 5G for industrial applications. Figure 2 on page 5 illustrates examples of installations enabling industrial wireless applications like mobile worker and wireless sensing instrumentation and analytics.

Figure 2. 5G Industrial Use Case Options

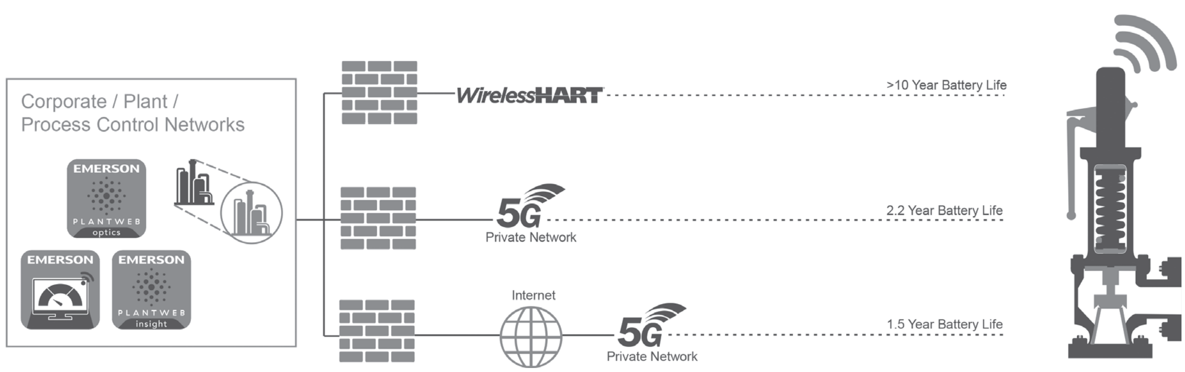


5G and *Wireless*HART Use Cases

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), 60-second update rate, 10-year battery life, and analytics to document releases which are hosted locally within the facility (Figure 3).

Figure 3. Examples (Eight second update rate)



The following table breaks down the battery life, infrastructure, and update rate for these devices.

Instrument protocol	Battery life	Infrastructure	Licensed	Update rate
*Wireless*HART (8dBm)	Greater than 10 Years	1 Gateway	No	60 Seconds
5G Cell Provider (23dBm)	2.0 Years	Cell Provider Gateway	Yes	60 Seconds
5G Private Network (8dBm)	2.9 Years	1 Gateway	Both	60 Seconds

One year later, this same chemical facility was pleased with the data they were receiving from the non-intrusive instrumentation currently monitoring their 40 PRV's at 60-second update rates and wanted better device resolution to improve environmental compliance and reduce emissions. Instead of 60 seconds, they wanted to increase the update rate of these same instruments to eight seconds. The following table summarizes the impact on battery life with this change in update rate.

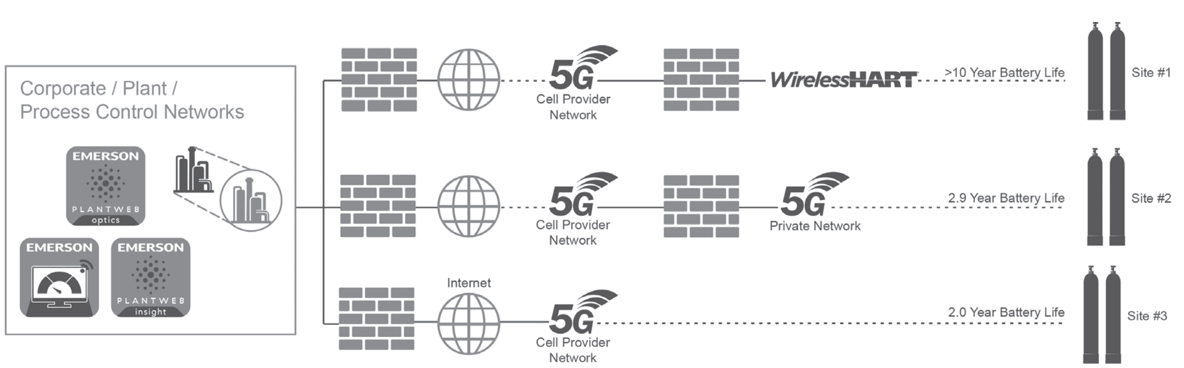
Instrument protocol	Battery life	Infrastructure	Licensed	Update rate
*Wireless*HART (8dBm)	Greater than 10 Years	1 Gateway	No	8 Seconds
5G Cell Provider (23dBm)	1.5 Years	Cell Provider Gateway	Yes	8 Seconds
5G Private Network (8dBm)	2.2 Years	1 Gateway	Both	8 Seconds

This facility is benefiting from eight second non-intrusive monitoring of their PRV's through real-time monitoring utilizing *Wireless*HART instrumentation. At an eight second update rate, the facility can expect battery life of 10 years with *Wireless*HART and has extra capacity with their existing gateway to add 60 additional instruments. In this case, 5G instrumentation battery life, even at 60 second update rate, is not feasible for this application.

Power Plant Use Case

A combined cycle power plant is interested in performing real-time monitoring of all compressed gas bottles used for the continuous emissions monitoring system (CEMS) at three of its power plants each located in a different state.

Figure 4. Examples (60 Second Update Rate)



Each facility maintains two compressed gas bottles (2000psi) that are currently monitored with mechanical pressure gauges and are checked twice a day with a manual walk down. These mechanical gauges will be replaced with wireless pressure gauges that will all be monitored from the central corporate office.

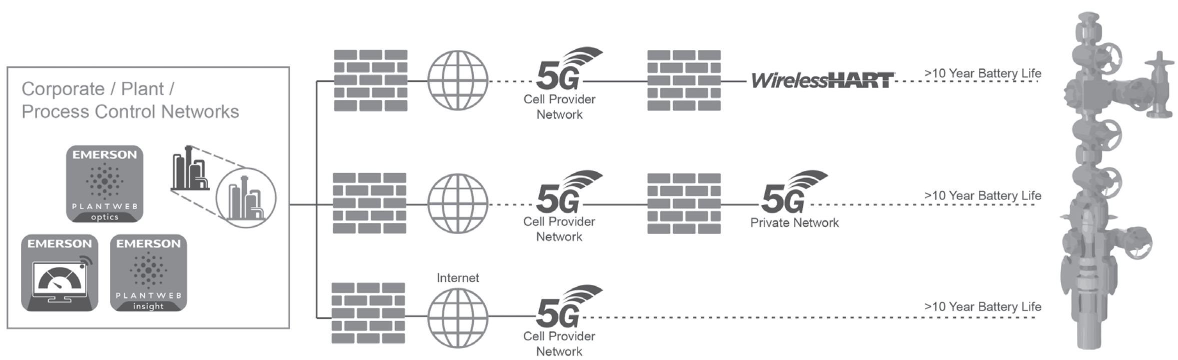
Instrument protocol	Battery life	Infrastructure	Licensed	Update rate
*Wireless*HART (8dBm)	Greater than 10 Years	(3) *Wireless*HART Gateways (3) 5G Cellular Backhaul	No	60 Seconds
5G Cell Provider (23 dBm)	2.0 Years	Cell Provider Gateway	Yes	60 Seconds
5G Private Network (8dBm)	2.9 Years	(3) 5G Private Gateways (3) 5G Cellular Backhaul	Both	60 Seconds

This power plant is benefiting from real-time remote monitoring of two compressed gas bottles per power plant for a total of six bottles. Mechanical gauges have been replaced by wireless pressure gauges, reducing a manual round and modernizing purchasing of replacement bottles across all three of their facilities. In this case, 5G instrumentation battery life is not adequate to support this application. However, 5G backhaul is an appropriate use for the technology to centralize data from each of the three sites to their corporate office.

Upstream Oil and Gas Use Case

A global upstream oil and gas producer is interested in wireless toxic gas monitoring at 40 existing well sites across a large territory where most wells are several miles from each other (Figure 5), one hour (60 minute) update rate.

Figure 5. Example (One Hour Update Rate)



This upstream oil and gas producer is benefiting from implementing wireless instrumentation at their existing well sites to improve safety and environmental compliance. Through the benefits of extended range provided by a high-power licensed cell provider service, this producer is able to minimize well site equipment costs. This application works for 5G instrumentation because of the long update rate (one hour).

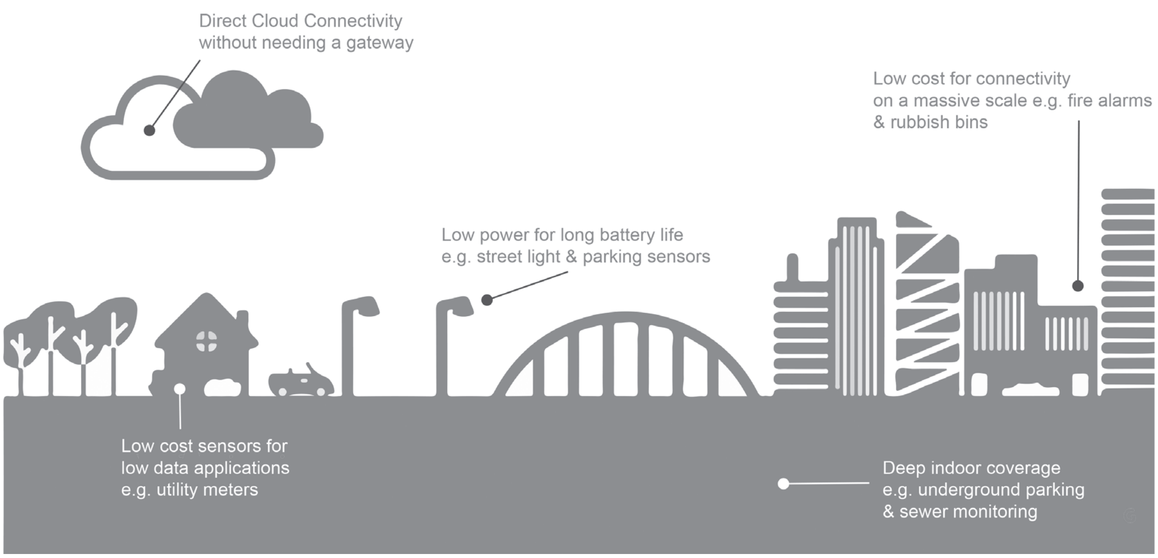
Instrument Protocol	Battery Life	Infrastructure	Licensed	Update Rate
*Wireless*HART (8dBm)	10 Years	1 Gateway per Pad	No	1 Hour
5G Cell Provider (23 dBm)	10 Years	Cell Provider Gateway	Yes	1 Hour
5G Private Network (8dBm)	10 Years	1 Gateway per Pad	Both	1 Hour

If this customer ever wanted to improve their data resolution and accelerate the update rate, they would run into battery life problems like the previous chemical and power plant examples. As an example, let's assume that this same oil and gas producer wants to add an instrument to this network to begin collecting well casing pressure every 8 seconds. In this case, if this producer tried to again utilize 5G Cell Provider instrumentation, they would be limited to 1.5 year battery life versus 10 years with *Wireless*HART.

Practical Uses for 5G

Due to NB-IoT and LTE-M's low power properties, both protocols are useful when small amounts of data need to be sent long distances at very infrequent rates (once per hour). Suitable applications for this technology include smart metering (such as parking, electricity, gas, and water), intruder and fire alarms, and smart city infrastructures (such as street lamps and smart bins). See Figure 6.

Figure 6. NB-IoT Use Cases

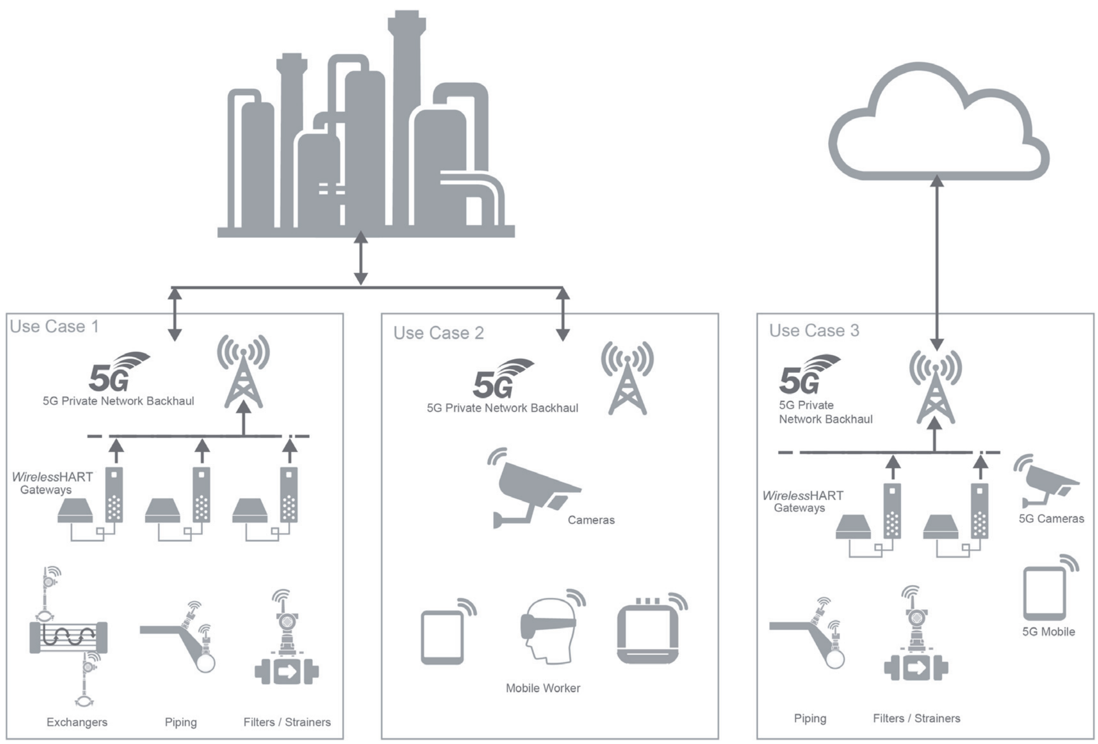


Similar to the upstream Oil and Gas Case, LTE-M and NB-IoT are also suitable for applications where surrounding conditions call for lower frequency narrowband signals that have long range. Application examples include soil pH monitoring in remote areas or weather stations in inhospitable areas.

Finally, when local power is available, cellular backhaul has proven to be a complement to the *Wireless*HART gateway enabling long range transmission of *Wireless*HART data to the cloud or a private network. Today, numerous *Wireless*HART gateways are connected to cellular modems enabling remote predictive maintenance of critical plant assets. Figure 7 illustrates three industrial use cases for 5G.

- **Use Case 1**: Private Network backhaul of *Wireless*HART instrumentation
- **Use Case 2:** Private Network support for 5G equipment such as cameras, phones, and tablets
- **Use Case 3:** Cell Provider Network backhaul of data to the cloud

Figure 7. 5G Industrial Use Cases



Conclusion

*Wireless*HART was specifically designed and optimized for industrial wireless sensor communications. As detailed in this white paper, 5G cellular instrumentation will not replace *Wireless*HART instrumentation for typical industrial process automation applications in the foreseeable future. In fact, the outlook for HART and *Wireless*HART sensors remains strong as I/O densities continue to increase with the size and complexity of new and existing facilities. However, like 4G applications today, 5G offers significant opportunities for backhaul solutions either to the cloud or private networks.

Unlike LTE-M and NB-IoT, *Wireless*HART instruments can achieve 10 year battery life with update periods as short as four to eight seconds. *Wireless*HART also supports low latency downstream communications without sacrificing battery life and works with most existing handheld field devices to support calibration and diagnostics in the field.

In today's industrial environment, there is no single wireless protocol that efficiently solves all applications. It is our assessment along with leaders in cellular communication that; in looking forward coexistence of both cellular and industrial protocols such as *Wireless*HART will work together to transform the global industrial future.

For more information on Industrial Wireless Technology, see Emerson.com/wireless-networks.

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