HMS Industrial Networks

Your Partner for Industrial Communication

Wireless technologies for industrial communication

Whitepaper

A guide to the different wireless technologies and when to use them.

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1. Introduction

Wireless communication in tough, demanding applications is nothing new. Wireless has been used for more than 30 years through the use of proprietary radios. However, with the modernization of industrial networks and the emergence of different Ethernet protocols, there has been an increasing demand for standardized wireless technologies.

During the last 10 years, standards like Wireless LAN (IEEE 802.11) and Bluetooth technology (IEEE 802.15.1) have become the dominating wireless technologies. In 2011, Bluetooth low energy technology also entered the scene.

This whitepaper compares the wireless technologies available so you can find the solution that fits your application the best.

Happy reading,
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Why use wireless technology instead of traditional cabling?

- Greater mobility and freedom of movement
- Bypassing long distances and applications where cables are an issue
- Eliminate expensive and maintenance-heavy cabling
- Fast and easy installations and commissioning
- High flexibility when modifying an installation
- Increased personal safety in hazardous areas (for instance, when needing to climb in a crane) by offering a control possibility from further distance than can be the case with a cable
- Easy integration of devices into the network
- Obtain flexible Human Interface Devices (HID)

2. Executive summary: Which wireless technology is the best choice?

One wireless technology cannot offer all the features and strengths that fit the various application requirements. Standardized wireless technologies including WLAN (also commonly referred to as WiFi), Classic Bluetooth and Bluetooth low energy as well as number of proprietary technologies are cater for different requirements. These could either be high data throughput, robustness or low power (the latter especially for battery operated devices).

WLAN is often used for production planning and data acquisition as well as applications where rapid roaming is required. Bluetooth is used for Human Machine Interfaces (HMI), programming, service/maintenance and real-time control tasks.

During the last few years, other technologies like Bluetooth low energy technology have become increasingly used for sensors, actuators and other small devices that need to be interconnected.

	Bluetooth technology	Wireless LAN / WLAN	Bluetooth low energy technology
Data throughput	+/-	++	-
Robustness	++	+/-	++
Range	10-300 m	50-300 m	10-250 m
Local system density	++	-	++
Roaming	+	++	N/A
Large scale network	-	+/-	+
Low latency	+++	+/-	++
Connection set-up speed	-	+/-	++
Power consumption	+	-	+++
Cost	+	-	++

Caption: *The table offers a quick overview of the differences between the wireless technologies.*
+ = Good
++ = Strong
+++ = Very strong
+/- = Average
- = Weak

Summary: If high data throughput is most important – choose WLAN.
If connection robustness/stability or cost efficiency is most important – choose Bluetooth.

3. Bluetooth

3.1 Classic Bluetooth Technology

Bluetooth technology (IEEE 802.15.1) is well-suited for wireless integration of automation devices in serial, fieldbus and Ethernet networks. Bluetooth technology is especially suitable for devices with high demands on small footprint, low power consumption and cost-efficiency.

Bluetooth Technology Facts

- Range of 10 meters up to over 300 meters with a long-range module.
- Cyclic and fast transmission of smaller data packages.
- Data throughput of maximum 780 kbit/s gross (up to ~700 kbit/s net). With Bluetooth v4.0+EDR (Enhanced Data Rate), the data through-put is 2.1 Mbit/s gross (~1.5 Mbit/s net).
- Latency of 5 –10 ms.
- Security features with 128-bit encryption that offers protection against data eavesdropping.
- High system density where several wireless devices can be connected in the same radio environment and operate flawlessly
- Robust features like Adaptive Frequency Hopping (AFH), Forward Error Correction (FEC), narrow frequency channels, and low sensitivity to reflections /multi-pathing.
- High availability in consumer products (phones, tablets, laptops etc).

3.2 Bluetooth Low Energy (Bluetooth Smart)

Bluetooth Low Energy (marketed as Bluetooth Smart) was introduced in 2011 and has been a hot topic ever since. The technology has some important limitations as well as benefits and is quite different from Classic Bluetooth technology:

- Bluetooth low energy technology enables new applications and is ideal for episodic or periodic transfer of small amounts of data.
- In a Bluetooth application where streaming data is used, Classic Bluetooth technology is the preferred choice as it achieves substantially greater throughput than Bluetooth low energy technology.

3.3 Comparison: Classic Bluetooth vs. Bluetooth Low Energy

Power consumption
Since a Bluetooth Low Energy device is in sleep mode most of the time – t he maximum/ peak power consumption is only 15 mA and the average power consumption is of only about 1 uA.

Connection set-up times
In Bluetooth Low Energy, the actual connection times are of only a few mS and thereby the connection is quickly initiated as the device wakes up.

Robustness
Many features of Classic Bluetooth technology are inherited in Bluetooth low energy technology including Adaptive Frequency Hopping (AFH) as well as part of the Logical Link Control and Adaptation Protocol (L2CAP) interface.

Throughput
Data transfer rates with Classic Bluetooth technology using Enhanced Data Rate (Bluetooth v2.1 + EDR) can exceed 2 Mbps (actual payload), but practical transfer rates for Bluetooth Low Energy technology are below 100 kbps (actual payload of roughly 1/20).

Profile support
Bluetooth Low Energy technology provides no support for the Serial Port Profile (SPP) in the standard Specification v4.0. Many other profiles are not offered for Bluetooth low energy technology because of the differences in the connection models. The Classic Bluetooth scenarios that are not part of Bluetooth Low Energy technology include headset (HSP), audio distribution (A2DP), video distribution (VDP) and file transfer (FTP).

Number of nodes
Just as with Classic Bluetooth technology, Bluetooth Low Energy technology is based on a master connected to a number of slaves. However, in Bluetooth Low Energy, the number of slaves can be a lot more. How many depends on the implementation and available memory.

Advertising
The new “Advertising“ functionality of Bluetooth Low Energy technology makes it possible for a slave to announce that it has something to transmit to other devices that are “scanning.“ “Advertising“ messages can also include an event or a measurement value.

Software structure

In Bluetooth Low Energy technology, all parameters have a state that is accessed using the Attribute Protocol. Attributes are represented as characteristics that describe signal value, presentation format, client configuration, etc.

Comparison chart

	Classic Bluetooth technology	Bluetooth low energy technology
Data payload throughput (net)	2 Mbps	~100 kbps
Robustness	Strong	Strong
Range	300 m	250 m
Local system density	Strong	Strong
Large scale network	Weak	Good
Low latency	Strong	Strong
Connection set-up speed	Weak	Strong
Power consumption	Good	Very strong
Cost	Good	Strong

3.4 “Single-mode” and “Dual-mode” – What does that mean?

Classic Bluetooth implementations are single-mode implementations. But with the addition of Bluetooth Low Energy, there are also single-mode Bluetooth low energy devices. Because the two technologies are fundamentally different, there are two options for low energy implememtations:

- **Single-mode Devices:**
  These devices are stand-alone Bluetooth low energy devices (also known as “Bluetooth Smart” devices) optimized for small battery-operated devices with low cost and low power consumption in focus. A typical single-mode device is for example a heart rate sensor.
- **Dual-mode Devices:**
  These devices (also known as “Bluetooth Smart Ready” devices) include both Bluetooth Low Energy technology and Classic Bluetooth technology. Dual-mode devices will rarely generate power savings since they need to support both technology implementations; the power savings will only be achieved with the single-mode option. A typical dual-mode device is a mobile phone or PC.

In a dual-mode implementation, you can for instance, in parallel, connect a number of Classic Bluetooth single-mode modules (OBS410/411/etc.) as well a number of Bluetooth low energy single-mode modules (OLS426) to a Bluetooth dual-mode module (OBS421). You can also connect Bluetooth dual-mode modules to one another.

4. Wireless LAN (WLAN)

Wireless LAN (IEEE 802.11) is well-suited for monitoring, configuring and data acquisition, but can also be used for time-critical control in the same applications. Furthermore, the built-in roaming functionality is useful in factory automation applications with moving devices.

Wireless LAN Facts

- Range 200 meters (up to 400-500 meters in free line-of-sight) in the 2.4 GHz band and some 50 meters in the 5 GHz band (802.11a) (free line of sight up to 150 meters); however, obstacles and interference could lower the range substantially.
- Data throughput of 11 to 54 Mbit/s gross (~5 to 25 Mbit/s net) for IEEE 802.11b/g and 300 Mbit/s gross (~70 Mbit/s net for IEEE 802.11n).
- Security models like WEP, WPA, WPA2, TPIK and PSK EAP.
- IEEE 802.11a operates on the 5 GHz band and provides the possibility for 19 additional non-overlapping channels in addition to the three non-overlapping channels in the 2.4 GHz band.
- High availability in consumer products.

4.1 The difference between 2.4GHz and 5GHz Wireless LAN

As the use of wireless technologies is increasing in the 2.4GHz band, interference problems can occur. To make sure that the wireless solution is robust, companies are starting to use the 2.4GHz band for office and IT communication and then use the 5GHz band for the manufacturing and M2M communication.

The Wireless LAN IEEE 802.11b/g radios utilize the 2.4GHz frequency band (2.412 – 2.472GHz) and the IEEE 802.11a radio utilizes the 5GHz frequency band (5.180 – 5.825GHz). IEEE 802.11n radios can operate in either frequency band. There are the following worldwide implementation attributes:

- The 2.4GHz ISM band provides 13 overlapping channels spread equally over the frequencies plus a 14th channel used in Japan with the center frequency 2.484GHz. This leaves available only three non-overlapping channels in the 2.4GHz band.
- The 5GHz ISM band is divided up into sub-bands called U-NII bands (Unlicensed National Information Infrastructure) and are usually named U-NII-1, U-NII-2, U-NII-2e, and U-NII-3 where U-NII-3 is not freely available worldwide. In total, this gives 23 non-overlapping channels where four of these have limitations based on location*.

Channel	U-NII Band	Frequency (MHz)	United States 40/20 MHz	Europe 40/20 MHz
36	1	5180	Yes	Yes
38	1	5190	No	No
40	1	5200	Yes	Yes
42	1	5210	No	No
44	1	5220	Yes	Yes
46	1	5230	No	No
48	1	5240	Yes	Yes
52	2	5260	Yes	Yes
56	2	5280	Yes	Yes
60	2	5300	Yes	Yes
64	2	5320	Yes	Yes
100	2e	5500	Yes	Yes
104	2e	5520	Yes	Yes
108	2e	5540	Yes	Yes
112	2e	5560	Yes	Yes
116	2e	5580	Yes	Yes
120	2e	5600*	No	Yes
124	2e	5620*	No	Yes
128	2e	5640*	No	Yes
132	2e	5660*	No	Yes
136	2e	5680	Yes	Yes
140	2e	5700	Yes	No
149	3	5745	Yes	No
153	3	5765	Yes	No
157	3	5785	Yes	No
161	3	5805	Yes	No
165	3	5825	Yes	No

Table of U-NII bands in the 5GHz frequency band. (ref. www.wikipedia.com)
**) For FCC channels 120 – 132, use is restricted near airports due to the interference risk of the Terminal Doppler Weather Radar (TDWR). (ref. FCC KDB 443999). Canada requires a restriction on the channels 120 – 128.*

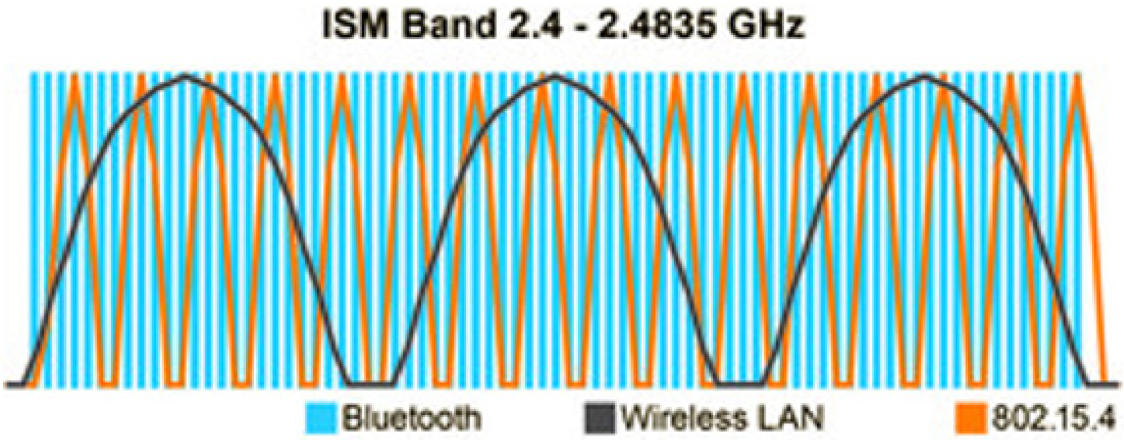
5. Wireless Coexistence

As more than one wireless technology is often used in parallel, there could potentially be disturbances resulting in higher latency or even data losses. These potential side effects cannot be accepted in mission-critical industrial and medical applications. Therefore, it is important to optimize coexistence of various wireless technologies in order to get a disturbance-free operation.

All of today’s most used wireless technologies operate in the 2.4 GHz band and they address potential disturbances in different ways:

- **Wireless LAN / WLAN**, also commonly referred to as Wi-Fi, has three non-overlapping channels with a bandwidth of 22 MHz and is using Direct-Sequence Spread Spectrum (DSSS). DSSS makes sure that the transmitted signal takes up more bandwidth than the information signal that is being modulated and thereby the wireless communication link becomes less vulnerable to disturbances.
- **Classic Bluetooth technology** has 79 channels with a bandwidth of 1 MHz and combines this with Adaptive Frequency Hopping (AFH) in order to avoid interferences. AFH monitors the bit-rate and when disturbances (such as when another wireless technology occupies the link) are found, Bluetooth technology stops to use the channels that are occupied. The channel is monitored in the background and as soon as the occupied channel is free, it can be used again.
- **Bluetooth low energy technology** also uses AFH; but Bluetooth low energy technology only uses 40 2 MHz wide channels.

5.1 Enhanced WLAN Coexistence Possibilities



WLAN, Bluetooth and IEEE 802.15.4 work in the same 2.4 GHz frequency band.

As you see in the illustration above, the 2.4 GHz frequency band is very crowded. Besides WLAN, Bluetooth, IEEE 802.15.4/ ZigBee/Wireless HART, several proprietary technologies operate in the 2.4GHz band. WLAN is well-established throughout offices on to the production planning; and therefore, in order to get disturbance-free communication, one first has to secure that WLAN is not disturbed.

5.2 Different ways to avoid disturbance:

Implement 5GHz WLAN
The WLAN IEEE 802.11 b, g radios utilize the 2.4GHz frequency band and the IEEE 802.11a radio utilizes the 5GHz frequency band. IEEE 802.11n radios can operate in either frequency band. In order to get disturbance-free WLAN communication links, it is thus possible to use the 5 GHz band instead of the 2.4 GHz band. However, even though the 5 GHz band is increasing in popularity in industrial and medical applications, there is a large installed base of IEEE 802.11 b, g networks that requires a good coexistence solution.

Hardware Solutions
In order to secure disturbance-free communication for WLAN in the 2.4GHs band, it is possible to use special antenna solutions (like leakage cables); however, these solutions are typical expensive installations.

Frequency Planning
It is also possible to beforehand choose channels that are not to be used (frequency planning) in order to avoid interference with other wireless systems used in the same environment.

For instance, in cases where WLAN and IEEE 802.15.4 are used in parallel, coexistence can be implemented by making room for some IEEE 802.15.4 channels in-between the three WLAN channels. By doing so, it is possible for WLAN and IEEE 802.15.4 to work reliably in parallel. When using Bluetooth, the same feature is possible by using channel blacklisting.

Adaptive Frequency Hopping (AFH)
Both Classic Bluetooth and Bluetooth low energy apply the Adaptive Frequency Hopping (AFH) feature which detects potential channel interference; for instance, a WLAN 802.11 b, g, n device transmitting in close proximity. If such interference is found the channel is automatically blacklisted. In order to handle temporary interference, an implemented scheme re-tries the blacklisted channels and if the interference has ceased the channel can be used. AFH prevents Bluetooth from interfering with other nearby wireless technologies.

Low Emission Mode®
Classic Bluetooth is built to be robust mainly thanks to AFH. But when performing device discovery or establishing a device connection, the Bluetooth activities can disturb a WLAN network.

In order to make sure that Classic Bluetooth operates smoothly in parallel with other wireless technologies, there is an extended Bluetooth coexistence feature which is named “Low Emission Mode®.” This is developed by u-Blox and is available in the Anybus Wireless Bridge from HMS.

With the Low Emission Mode, coexistence is solved during device discovery and connection set-up without jeopardizing the Bluetooth Specification or interoperability between various Bluetooth enabled products.

6. Conclusion: Which technology should you choose?

As we have seen, there is no one-for-all technology for industrial wireless communication. On a general note, we can say that if if high data throughput is most important – choose WLAN. If connection robustness/stability or cost efficiency is most important – choose Bluetooth. However, there are a lot of gray zones here and sometimes, you want a bit of both.

Choose a solution that supports many wireless technologies
Since your requirements may change as your networking infrastructure changes, it is wise to choose a wireless solution which can support the different technologies on the market. This way you can easily update your wireless infrastructure as your prerequisites change. The Anybus Wireless Bridge from HMS Industrial Networks is an example of a solution supporting the different wireless technologies on the market.