

Industrial wireless: Bluetooth can be robust, easy to use

Technology Update: Bluetooth offers optimal features to satisfy industrial requirements of robustness, reliability, and seamless, coexistent operation with Wireless LAN networks. In addition to low power consumption, Bluetooth allows for multiple wireless links, offers fast connections, and has easier configuration and setup than many other wireless technologies.

BY ROLF NILSSON FEBRUARY 25, 2013



Bluetooth technology is a robust, easy-to-use wireless solution for industrial wireless applications. Operating in the same 2.4 GHz ISM band as other standard wireless technologies, Bluetooth offers optimal features to satisfy industrial requirements of robustness, reliability, and seamless coexistence and co-located operation with Wireless LAN networks. In addition to low power consumption, Bluetooth allows for multiple wireless links, offers fast connections, and has easier configuration and setup than many other wireless technologies.

Tailored features for industrial applications are available that further fulfill these needs.

Wireless communication technologies have been used in industrial applications for more than 30 years. The adoption of wireless communication is typically a gradual process where the initial requirements include creating wireless device islands connected to an existing infrastructure or wired network. The following are the main advantages of industrial wireless solutions:

- Greater mobility and possibility to move devices and connect to smartphones and tablets freely without constraining cables
- Bypassing long distances and areas where cables cannot physically fit
- Fast and easy installation and commissioning
- High flexibility if there is a need to modify an installation
- Increased personal safety by not having to be physically close to a device during configuration and/or maintenance
- Easy integration of devices into the network

Industrial requirements for wireless technologies include:

- Reliable and robust communication
- Advanced security features
- Similar configuration and operation as the commonly used automation tools
- Real-time and deterministic behavior
- Increased temperature range
- Coexistence with existing wireless technologies (no interference)

What is Bluetooth?

Bluetooth technology has grown to become one of the most widely implemented wireless technologies, with more than 9 billion Bluetooth devices shipped through 2012. Most of these devices are consumer products, but its unique features have also established Bluetooth as a standard for industrial applications with high demands on reliability and robustness.

Bluetooth technology was launched back in 1998 with the aim to replace connecting cables with a cost-effective wireless communication method. Many of the engineers who developed Bluetooth came from an industrial automation background and knew the importance of making Bluetooth technology robust and reliable for industrial applications. Bluetooth is now managed by Bluetooth SIG Inc., which has more than 17,000 member companies that jointly drive the Bluetooth development. To market Bluetooth devices, manufacturers must be members of the SIG and their products must pass the Bluetooth Qualification Program.

Bluetooth versions

Bluetooth operates in the globally unlicensed 2.4 GHz Industrial, Scientific and Medical (ISM) radio band. Now most products adhere to Bluetooth v2.1+EDR, which was adopted by the Bluetooth SIG in 2007. EDR stands for “enhanced data rate” and allows for increased data throughput. Bluetooth v4.0 was adopted by the SIG in 2010; the main feature of v4.0 is Bluetooth low energy, which offers an entirely new protocol stack for rapid buildup of simple links and long battery operation.

Recent discussion pertains to whether one should use Classic Bluetooth or Bluetooth low-energy technology. It is important to note that although Bluetooth low energy has inherited several Classic Bluetooth features, from a technology and implementation perspective it is different, and therefore there are the following implementation options:

- Single-mode: Traditional Classic Bluetooth implementations are single-mode implementations. But with the addition of Bluetooth low energy, there are also single-mode Bluetooth low-energy devices known as Bluetooth Smart devices. Examples of single-mode Bluetooth low-energy devices include accelerometers, and temperature and pressure sensors.

- Dual-mode: These dual-mode devices, also known as Bluetooth Smart Ready devices, include both Bluetooth low-energy and Classic Bluetooth technologies. Examples include smartphones, computers, and industrial platforms.

Bluetooth profiles

Bluetooth has a determined set of “profiles” that in essence are application defined behaviors that Bluetooth devices use to communicate with each other.

Important profiles used in industrial applications of Classic Bluetooth include the following:

- Serial Port Profile (SPP) emulates a complete serial interface with hardware handshaking via Bluetooth. A traditional serial interface (UART, RS232, RS422, or RS485) can be replaced with a wireless point-to-point, point-to-multipoint, or multi-drop connection. SPP is used during data exchange between computers, control systems, and other devices with a serial interface.
- Personal Area Network (PAN) can be used to transmit IPv4 and IPv6 protocols transparently. Supported are both ad-hoc and access point operations. PAN is ideal for Ethernet-compatible devices with small amounts of data. In addition, PAN can also provide local access to the machine and system network during configuration and maintenance.

Bluetooth low-energy technology profiles are different from those used in Classic Bluetooth and are based on the Generic Attribute Profile (GATT). GATT is used for service discovery as well as read/write values on a device.

Unlike Classic Bluetooth, product developers can develop their own profiles and services to add to those from the Bluetooth SIG. For example, connectBlue has developed the following service for cable replacement to fit the needs of industrial applications:

- Low-Energy Serial Port Service is a GATT-based service that offers transparent serial communication and thus is of importance in industrial applications where Bluetooth low energy is used.

Wireless ruggedness

The wireless transmission method used in mission-critical industrial applications must be rugged and reliable. Interference can appear from high-voltage transmissions, welding machines, magnetic fields from electrical motors, etc. Interference can also occur between wireless technologies that operate in the same radio band. If interference occurs it can affect the connection robustness. With several wireless standards operating in the 2.4GHz ISM band Bluetooth has adopted several robust features.

Bluetooth connections, interference

A Classic Bluetooth network is known as a piconet and consists of one master / host and up to seven active slaves / clients. The devices can switch roles, by agreement, and the slave can become the master. When a Classic Bluetooth device is doing service discovery or connection setup, it may disturb other wireless connections in the same ISM band, whereby frequency planning of those technologies is needed.

With Bluetooth low energy, one can have more slaves than in Classic Bluetooth. To use as little power as possible, a Bluetooth low-energy connection is in idle mode most of the time. A Bluetooth low-energy connection consists of one "central" and one "peripheral" device. The "peripheral" contains the data and "advertises" it to inform the environment about its existence. The "central" scans its environment and if an advertisement is detected, it can initiate a connection. Contrary to Classic Bluetooth, during the scan no radio transmission is sent, thus Bluetooth low energy does not interfere with the radio environment.

FH-CDMA

Frequency-hopping code division multiple access (FH-CDMA): In Classic Bluetooth, the 2.4 GHz radio band is divided into 79 hopping channels of 1 MHz each, where a new channel is chosen every 625 μ S. Bluetooth low energy uses frequency-hopping on 40 2-MHz channels at the same hopping rate.

Each communicating device pair has its own frequency-hopping schema, which is determined during the initial connection and chosen to avoid connection conflicts. Frequency-hopping minimizes potential interference issues within a Bluetooth system, with other radio-based systems, and from other interference sources.

AFH

Both Classic Bluetooth and Bluetooth low energy apply the adaptive frequency-hopping (AFH) feature, which detects potential channel interference – for instance, a Wireless LAN IEEE 802.11 b, g, n device transmitting in close proximity. If such interference is found, the channel is automatically blacklisted.

These blacklisted channels are later re-tried to handle temporary interference. AFH prevents Bluetooth from interfering with other nearby wireless technologies, such as Wireless LAN 802.11 b, g.

Wireless coexistence

Wireless coexistence is a major requirement in industrial wireless, and there are several opportunities for good cooperation in the 2.4 GHz ISM band. For instance, Wireless LAN uses 13 overlapping 20-MHz wide channels, two to three non-overlapping channels, and operates with direct-sequence spread spectrum (DSSS) in the 2.4 GHz band. Bluetooth uses 79 1-MHz wide channels and AFH to avoid disturbances. IEEE 802.15.4 has 16 channels; each is 5 MHz wide and operates with DSSS.

With frequency planning, it is possible to allow multiple technologies to operate in the same band. If one wants to use Wireless LAN and 802.15.4 in parallel, there is room for a smaller number of 802.15.4 channels in between the three non-overlapping Wireless LAN channels to get a disturbance-free configuration, and there is also enough room for a high number of Bluetooth channels. It is also possible to choose channels beforehand that are not to be used (blacklisting) to avoid interference with other wireless systems used in the same environment.

The Bluetooth Specification coexistence mechanisms cover most potential interference issues; however, industrial applications need assurance that Bluetooth will not disturb the Wireless LAN communication during Classic Bluetooth service discovery and connection setup when AFH is inactive. (To solve these potential interference issues, connectBlue has developed the connectBlue Low Emission Mode for Bluetooth, which optimally configures how often and how long a Classic Bluetooth product is to conduct inquiry and scanning, paging and page scanning, respectively. This mode minimizes the impact on other wireless systems without losing stability on the Bluetooth link setup.)

Error correction (EC)

Bluetooth supports forward error correction (FEC) and packet retransmission. A faulty wireless connection will lead to an increase in the bit error rate. FEC packets transmit redundant information, which can be used by the receiver to correct faulty packets. FEC reduces the bit error rate by up to the power of three and eliminates the need for repeated packets.

Then an automatic repeat request (ARQ) packet retransmission scheme is applied where each packet is checked for errors. Retransmission is done if packets are lost or not acknowledged. This procedure allows for safe data transmission.

As Bluetooth supports packets both with and without FEC, it is possible to configure the link to select packages with FEC only. The number of retransmissions is also affected by the used packet sizes. In some environments and applications it can be more efficient to force small packets to be used.

Operating modes

One can configure any connectBlue Bluetooth product for different operating modes, for example, optimized for latency or throughput. By selecting the correct mode, the optimal packet sizes and other connection parameters are selected.

RSSI

Received signal strength indicator (RSSI)-based power control is mandatory for high-power radios (20 dBm) and optional for low-power radios (0 dBm). RSSI ensures that excessive power is not used during the node communication. RSSI also has a positive effect on potential interference issues since several independent Bluetooth networks that are in close proximity will less likely interfere with each other if they use this power control feature.

Power classes, range

Classic Bluetooth supports different output power classes. The highest power class, "Class 1," can transmit legally permissible transmission power of up to 100 mW or 20 dBm, which makes possible a range of more than 1000 m.

The transmission power is automatically reduced to the level required for a good wireless connection. This reduction prevents unnecessary emission and reduces possible interference with other systems. Combined with a high level of input sensitivity at the receiver and good antennas, which should be mandatory in all industrial Bluetooth products, the system can receive at even very weak signals.

Bluetooth low energy is limited to a maximum of 10 dBm, but since it has relaxed radio parameters, Bluetooth low energy can still achieve a good transmission range of 75 m or more.

Data security

The Bluetooth connection is well protected against tapping and external intervention. The frequency-hopping method, with its pseudo-random hopping sequence, makes it virtually impossible to access Bluetooth. In addition, the hardware has an authentication and encryption function (128 bit). Bluetooth modules can be made invisible to other Bluetooth devices, which mean that hackers are unaware of the device. Connections can only be established between devices that are paired in advance.

Industrial wireless choices

In recent years, the standardized Wireless LAN / WLAN / IEEE802.11, ZigBee / IEEE 802.15.4, and Classic Bluetooth / Bluetooth low energy / IEEE802.15.1 have become the dominating technologies for industrial applications. Though not one wireless technology can satisfy all needs in an industrial application, they each have unique capabilities. The best choice depends on the main requirement where one needs to prioritize between high data throughput, robustness, or low power (the latter especially for battery-operated devices).

- Wireless LAN is the preferred choice for production planning, data acquisition, and network interaction. Also, the built-in roaming functionality is useful in factory automation applications with moving devices. The greatest strength with Wireless LAN is its throughput and network connectivity; however, to get a disturbance-free transmission, careful frequency planning or expensive installations with, for instance, leakage cables as antennas can be needed. In many industrial applications Wireless LAN usage is moving towards the 5 GHz band (the 802.11 a standard) to avoid

interference with other radios operating in the 2.4 GHz band (802.11 b, g, n).

- Classic Bluetooth is used for human machine interfaces (HMI), programming, service/maintenance, and real-time control tasks in various industrial environments, such as automotive manufacturing, energy plants, and warehouses. Use cases include wireless I/O and replacement of Profinet, Modbus TCP, and Ethernet IP cables. Classic Bluetooth can easily be configured, is the most widely adopted wireless standard in mobile devices, and has unrivaled robustness. Bluetooth allows for high system density; for example, many radio links can be installed in the same radio environment without disturbance or performance decrease. Operation is flawless as Bluetooth maneuvers with narrow 1 MHz channels and changes 1600 times every second. AFH removes potential interference with other wireless technologies for interference-free coexistence.
- Bluetooth low energy is increasingly used in metering, sensors, actuators, and other small devices that need to be interconnected. Bluetooth low energy has inherited robust features from Classic Bluetooth and is particularly beneficial for applications with low data rates at episodic or periodic intervals. With Bluetooth low energy being rapidly integrated into mobile iOS and Android devices, tailored “apps” can become powerful and cost-efficient tools for industrial applications. An “app” can be designed to gather certain data, or to perform specific tasks such as to act as an HMI. Bluetooth low energy includes all of the Classic Bluetooth coexistence methods.
- IEEE 802.15.4 is available in a number of standards as well as part of proprietary wireless protocols and includes ZigBee, WirelessHART, and ISA SP-100. The technologies are mostly used in energy monitoring, and process and building automation. The mesh network functionality makes them capable of covering wide areas when there are no requirements on low latency. However, interference can occur in environments with high radio density and

noise.

About connectBlue

connectBlue provides robust industrial and medical wireless solutions, designed and tested for the most demanding applications and environments. Based on Classic Bluetooth technology, Bluetooth low-energy technology, Wireless LAN (WLAN), and IEEE 802.15.4 / ZigBee, connectBlue provides ready-to-use products and modules and custom-designed solutions. Its head office is in Sweden and local offices are in Germany and USA. connectBlue has developed tailored features for use of Bluetooth in industrial applications.

About the author: Rolf Nilsson is the CEO and founder of connectBlue, with more than 30 years of thorough insight and know-how from industrial automation and communication. Before founding connectBlue, Rolf was the president of Eurotherm Scandinavia, and before that he was in leading positions at Alfa Laval Automation/ABB Automation Products. Edited by Mark T. Hoske, content manager, CFE Media, *Control Engineering*, mhoske@cfemedia.com.

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