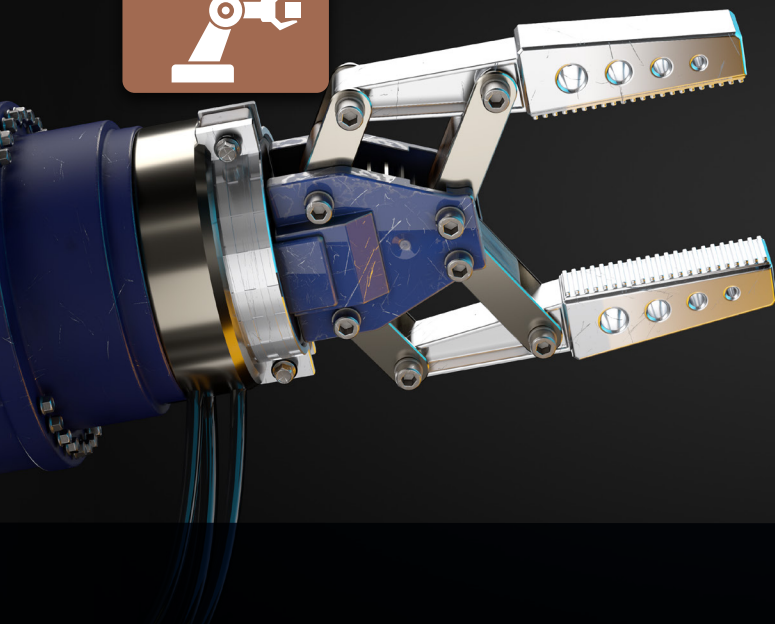




Whitepaper

Industrial



What's next for industrial wireless communications

By Felix Corbett, Director, Supplier Marketing, Europe, TTI Inc.

Executive Summary

Wireless communication is an essential part of modern industrial and commercial products. There are many wireless communication technologies available with differing characteristics. As the IoT market has grown these have been extended, and new standards have emerged, to support the requirements such as low power. This paper attempts to bring some structure to this crowded market, by considering which systems are best suited for personal, local and wide area networks.



Introduction

Wireless networks can be categorized in various ways. For IoT, the most important characteristics are power, range and data rate. Other properties to consider are the network size and topology.

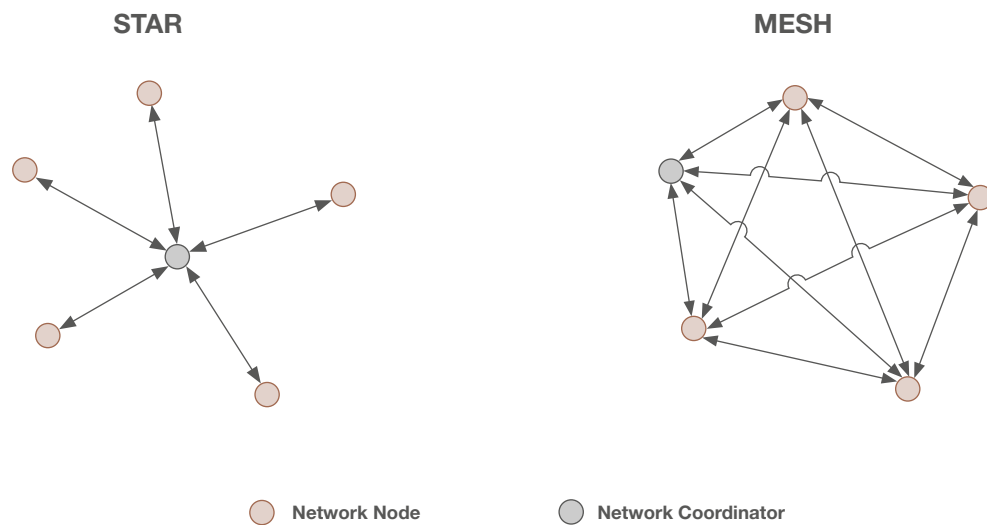
IoT applications have limited power budgets. Power can be reduced if the application only needs to transmit small amounts of data, for example sensors that send infrequent updates of their readings. In this case it can enter a low power mode between messages.

The range and the data rate will be determined by the needs of the application. These are complementary: a low frequency signal can carry less data but can be received over longer distances.

The possible size of a network is determined by the signal range, the maximum number of nodes supported by the protocol, and the topology.

Many networks use a star configuration where all nodes communicate with a central hub. This limits the size of the network, unless further infrastructure is used to communicate between multiple hubs. Other technologies use a mesh, where every node can communicate with its neighbors, and messages will be passed on to their ultimate destination.

Figure 1. Network topologies

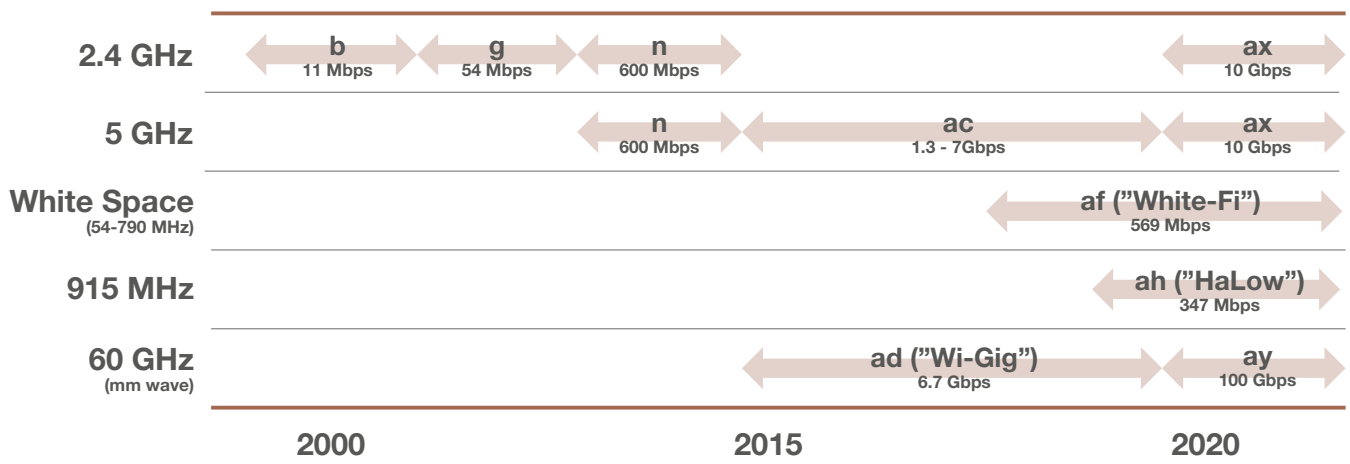


Another factor to consider is the choice between open standards and proprietary solutions. This may affect how many vendors support the protocol.

Wireless Standards

There are two standards that form the basis of several wireless communication protocols. The first is IEEE 802.11, better known as Wi-Fi. This has progressed from its initial 1 Mbps target to gigabit speeds by using techniques such as multiple antennas (MIMO) and directional transmission (beamforming). Some of the latest changes are better suited to the IoT, with reduced power consumption and greater range.

Figure 2. Wi-Fi Timeline



The other standard, IEEE 802.15.4, is the basis of protocols including Zigbee and 6LoWPAN. These extend the standard by defining extra high-level protocol layers. For example, 6LoWPAN defines how to carry IPv6 over 802.15.4 and is, in turn, the basis for other protocols such as Thread.

Network Types

The communication range can be used to group networks into three broad categories:

- Personal area network (PAN): up to 10 meters
- Local area network (LAN): 10s to 100s of meters
- Wide area network (WAN): 100s of meters up to kilometers

Most IoT applications fall into either the PAN or WAN categories. PAN applications have sensors and equipment in close proximity, for example wearables and industrial or home automation. WAN applications are where devices may be separated by large distances, such as smart electricity meters or sensors in remote areas.

A LAN may be used to link smaller networks together or provide an Internet gateway. This area is dominated by Wi-Fi and wired networks.

Personal Area Network (PAN)

This section covers the wireless systems designed for use in a PAN.

Bluetooth is widely used as a wire-replacement communications protocol, often for handheld and mobile devices. The Bluetooth 4.2 specification introduced new features aimed at IoT applications, the most important being Bluetooth Low Energy (BLE). This provides lower power consumption and cost. It should enable button-cell battery operation for months or, even, years.

BLE has a data rate of about 1 Mbps and a range of 100 meters. Bluetooth 5 adds options to double the data rate of BLE or increase the range by up to four times at the same power consumption.

The range increase is achieved by using forward error correction. This uses a number of bits in the data packet for error detection and correction. This reduces the number of data bits transmitted but allows the data to be correctly decoded at greater distances. There are two different error coding schemes: S2 approximately doubles the range but halves the data rate, while S8 provides roughly four times the range but 1/8th data rate.

Originally, Bluetooth was conceived as a peer-to-peer or star configuration. BLE now also supports mesh configurations. This uses flood networking, where every packet received by a node is sent out to all connected nodes (this can be disabled for battery-powered nodes to reduce energy consumption). This enables networks of any size and makes BLE more competitive with existing mesh-based systems such as Zigbee.

BLE modules are available from manufacturers such as ALPS. Typically such wireless modules are available with or without integrated antennas. A wide range of suitable antennas, for internal or external mounting, are available from suppliers such as Ethertronics, an AVX company. Their line-up includes passive ceramic 'chip' and pressed metal types.

Thread is a proprietary IPv6-based, low-power mesh networking technology with AES encryption for security. It has a range of around 100 meters, with a data rate of 250 kbps. The specification is managed by the Thread Group made up of Nest Labs, Samsung, Apple, NXP, ARM and others.

Zigbee is a low-cost wireless mesh network designed for low data rate applications that require long battery life and secure networking. The data rate is fixed at 250 kbps. To pass Zigbee certification devices must have a battery life of at least two years.

The low power means that the transmission distance is limited to less than 100 meters line-of-sight. However, data can be transmitted over longer distances through the mesh-connected network of intermediate devices. It is particularly well suited to intermittent data transmissions from a sensor or input device.

For example, the Honeywell Limitless range includes industrial pressure sensors (Figure 4), limit switches and receiver modules. These enable monitoring and control where wiring or maintenance is not physically possible or is uneconomical.

ANT is a proprietary protocol, conceptually similar to BLE. It is designed for battery-powered sensors, particularly in health and fitness applications. It provides a data rate of up to 20 kbps at a range of 30 meters.

Z-Wave is a proprietary protocol from Sigma Designs. It provides a data rate of up to 100 kbps in a mesh topology. The maximum distance between nodes is about 30 meters but messages can be sent through up to four intermediate devices to their destination. The network size is limited to 232 nodes.

Figure 3. Ethertronics ceramic Wi-Fi / Bluetooth antenna



Figure 4. Honeywell wireless pressure sensor



WirelessHART is based on 802.15.4 and the Highway Addressable Remote Transducer (HART) protocol, providing a range of around 100 meters with a data rate of 250 kbps. It utilizes a time synchronized, self-organizing, and self-healing mesh architecture. It is used for process control, including the measurement of temperature, flow rates and pressure, across multiple industries.

There are other systems which have limited application or have not yet established their place in the market. These include:

- **MiWi** is proprietary protocol from Microchip Technology based on the 802.15.4 standard. It is designed to provide low data rates (250 kbps) and short distance (100 meters) communication in cost constrained networks. MiWi is integrated into some of Microchip's microcontrollers.
- **DECT ULE** is a low energy extension of the DECT protocol widely used by cordless phones. It provides data rates of up to 1 Mbps over a distance of 100 meters.

Local Area Network (LAN)

Wi-Fi is the ubiquitous wireless LAN. It is often used in conjunction with other technologies to link hub nodes or provide access to the Internet for remote monitoring and control.

802.11ax is the successor to the current 802.11ac Wi-Fi standard. It uses the same 2.4 and 5 GHz frequencies and will be backward-compatible with existing Wi-Fi hardware. It will provide much higher data rates (up to 10 Gbps) and advanced power-saving techniques to provide longer battery life for mobile devices.

Wide Area Network (WAN)

The specifications for a low-power wireless WAN are typically:

- Low data rate: 100 bps to 1 Mbps
- Long range: up to 10 km
- Low power: as much as 10 years of battery life

802.11ah (HaLow) is a Wi-Fi standard intended for low data rate, long-range sensors and controllers. It uses the unlicensed 900 MHz frequency, which penetrates obstructions better than higher frequency networks, and will support mesh networking.

This allows a single access point to provide much longer range and support large numbers of remote IoT nodes, hence reducing deployment costs. The maximum data rate is just under 350 Mbps. It can be powered down between communications, further saving energy in the case of infrequent data transmission.

There are very few products available yet. Just one company, the Korean startup Newracom, has announced a microcontroller with integrated HaLow.

LoRa (Long-Range) is a proprietary LPWAN now owned by Semtech. It uses unlicensed sub-gigahertz radio frequency bands. It provides very long range transmission (over 10 km in rural areas) at very low power consumption. The data rate is around 50 kbps.

LoRa refers to the physical layer and LoRaWAN to the upper communication and management layers. The protocol is designed for low-cost, long-range connectivity for IoT devices in remote and offshore locations. Data is transmitted asynchronously by devices and received by one or more gateway nodes, which forward it to a centralized server.

Symphony Link is a proprietary protocol based on the LoRa physical layer. It adds features such as quality of service (QoS) guarantees, variable data rate and over-the-air firmware upgrades.

Sigfox uses proprietary ultra-narrowband (UNB) technology on a star or cellular topology. It has a low data rate of 100 bits per second that, combined with a lightweight protocol, enables very low power consumption. The range is up to 10 km.

Mobile IoT refers to two related standards based on the 4G cellular network. These are Long-Term Evolution for Machines (LTE-M) and Narrowband-Internet of Things (NB-IoT). These use secure operator-managed networks in the licensed phone spectrum. They are designed for IoT applications that are low cost, use low data rates, require long battery lives and often operate in remote and hard to reach locations. This offers potential world-wide coverage: the ultimate wide area network. Because they use the cellular network, there will be a recurring access cost. However, as they use relatively little network capacity, carriers will be able to offer lower cost service plans.

LTE-M technology is a version of LTE (4G) for IoT. It is compatible with the existing LTE network and so devices can connect directly to the cellular network, without a gateway. It provides data rates of about 1 Mbps. It is suitable for applications such as smart metering, in which only small amounts of data are transmitted.

NB-IoT uses the simpler single-carrier frequency division multiple access (SC-FDMA), to reduce cost and complexity. This limits the data rate to about 200 kbps.

Other Specialized Applications

There are some new Wi-Fi variants targeted at very high bandwidth applications.

802.11ad (Wi-Gig) is a multi-gigabit protocol designed for wireless connection of high-bandwidth signals such as high-definition video. It can support data rates up to 6 Gbps but is limited to line of sight communication over a few meters.

802.11ay will offer higher speeds up to 40 Gbps and improved range of up to 300 meters.

Conclusion

There are a large number of wireless communication solutions available for IoT, depending on the needs of the application. All provide low power, leaving the main deciding factor as the choice between the range required and the data rates. These characteristics are summarized in Table 1.

	Typical Data Rate	Approximate Range	Network Type
ANT	20 kbps	30 m	
BLE	1 Mbps	100 – 600 m	
DECT-ULE	1 Mbps	100 m	
MiWi	250 kbps	100 m	
Thread	250 kbps	100 m	PAN
WirelessHART	250 kbps	100 m	
Z-wave	100 kbps	30 m	
Zigbee	250 kbps	100 m	
802.11ax	1 – 10 Gbps	300 m	LAN
802.11ah	350 kbps	1 km	
802.11af	560 Mbps	1 km	
LoRa	50 kbps	10 km	
LTE-M	1 Mbps	1 km	WAN
NB-IoT	200 kbps	1 km	
Sigfox	100 bps	10 km	
Symphony Link	50 kbps	10 km	
802.11ad	7 Gbps	10 m	
802.11ay	40 Gbps	300 m	Other

Table 1. Wireless communications technologies



About TTI

TTI, Inc. is the world's leading authorized distributor specialist offering passive, connector, electromechanical, discrete, power supplies and sensor components. TTI's extensive product line and supply chain solutions have made the company the distributor of choice for industrial, defense, aerospace and consumer electronic manufacturers worldwide.

TTI's extensive product line includes: resistors, capacitors, connectors, discretes, potentiometers, trimmers, magnetic and circuit protection components, wire and cable, wire management, identification products, application tools, power supplies, sensors and electromechanical devices. These products are distributed from a broad line of leading manufacturers. TTI strives to be the industry's preferred information source by offering the latest IP&E technology and market information through the online MarketEye Research Center. MarketEye includes articles, technical seminars, RoHS, seminars, industry research reports and much more.

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