# Wireless Connectivity Technology Selection Guide

Texas Instruments

## Introduction

Selecting the right wireless connectivity technology is a critical design decision from the beginning. This determines the protocol interoperability, distance, robustness and the use-cases for your application. This selection guide will walk you through several key decision requirements starting with the table below as a high-level summary of various wireless connectivity technologies.

| Features & specifications | Bluetooth® Classic | Bluetooth Low Energy | Zigbee | Thread | Wi-Fi | Proprietary Sub-1 GHz / 2.4 GHz |
|---|---|---|---|---|---|---|
| **Range** | Up to 100 m | Up to 200 m or 400 m w LR | Up to 200 m(1) | Up to 200 m | Up to 200 m | Up to 1600 m |
| **Frequency** | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz | 2.4 GHz 5 GHz | Sub-1 GHz 2.4G Hz |
| **PHY throughput** | Up to 3 Mbps | Up to 2 Mbps | Up to 250 kbps | Up to 250 kbps | Up to 72 Mbps | 500 kbps (Sub-1) 2 Mbps (2.4 GHz) |
| **Network type** | Peer-to-peer, Star | Peer-to-peer, Star, Broadcast | Mesh | Mesh | Peer-to-peer, Star | Peer-to-peer, Star, Mesh |
| **Network size** | 8 | 30 | 500+ | 350+ | 250 | 1000+ |
| **Battery type** | Single-AA | Coin-cell | Coin-cell & energy harvesting | Coin-cell | Double-AA | Coin-cell |

*Notes: (LR) Long Range - Requires the use of wireless power amplifiers and proper antenna setup. (1) For a single-hop.*

| Technology | Considerations |
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| **Bluetooth Classic** | **Advantages of Bluetooth Classic:**<br>• **Network type** | Bluetooth Classic is designed for short range applications, and supports network types such as peer-2-peer (P2P) and star network topologies.<br>• **Throughput** | Bluetooth Classic is designed for high data throughput applications such as audio streaming, with data rates of up to 3 Mbps.<br>• **Example application** | Audio streaming through wireless headsets, speakers and sound bars.<br>**Potential disadvantages of Bluetooth Classic:**<br>• **Power consumption** | Bluetooth Classic is not optimized for low power applications.<br>**To get started with your Bluetooth Classic application, visit** www.ti.com/product/CC2564 |

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| **Bluetooth Low Energy** | **Advantages of Bluetooth Low Energy:**<br>• **Network type** | Bluetooth Low Energy is designed for short range applications supporting peer-2-peer (P2P), star and broadcaster roles. Bluetooth Low Energy can be found in applications like health monitors, personal electronics, asset trackers and many more. Bluetooth is an excellent wireless technology medium that quickly establishes a connection and exchange data between two devices like smart car access.<br>• **Power consumption** | Bluetooth Low Energy is designed for ultra-low power wireless communications and is capable of operating for years on a single coin-cell battery. The protocol is designed to be lightweight with the flexibility of tweaking various communication interval parameters like broadcasting at a 1-second interval.<br>• **Throughput** | The Bluetooth 4 Low Energy and newer version standard data rate is 1Mbps, which is sufficient for most types of communication. However, Bluetooth 5 Low Energy now also supports up to 2 Mbps for transferring data quicker.<br>• **Wireless robustness** | Bluetooth Low Energy uses the 2.4 GHz wireless band, which is shared with other wireless technologies such as Wi-Fi, Zigbee, and Thread. To mitigate collisions in this crowded frequency band, Bluetooth uses frequency hopping to find an open channel before communicating.<br>• **Security** | To learn more about security in Bluetooth networks, read: Understanding Security Features of SimpleLink™ Bluetooth® Low Energy CC13x2 and CC26x2 Wireless MCUs<br>• **Example applications** | Wireless keyboards, heart rate monitors, blood pressure monitors, smart car access and many more. Bluetooth Low Energy is the most widely used wireless technology as it is commonly found in every smartphone or tablets.<br>**Potential disadvantages of Bluetooth low energy:**<br>• **Range** | Bluetooth is not designed for applications requiring long-range connections. Bluetooth would require a gateway bridge to connect to an IP network.<br>**To get started with your Bluetooth low energy application, visit** www.ti.com/ble |
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| **Zigbee** | **Advantages of Zigbee:**<br>• **Network type** | Zigbee technology is a mesh based protocol that allows a network to grow as your application needs. It supports self-forming and self-healing mesh. There are four different Zigbee roles; Coordinators, Routers, End Devices and Green Power Devices. Zigbee is primarily found in building and home automation.<br>• **Power consumption** | Zigbee is a low-power wireless communication enabling long battery life in end applications. To achieve this energy consumption, the end device periodically wakes up to send data and reenters low power mode as soon as possible. Zigbee Green Power Devices can even enable battery-less applications like energy harvesting using solar panels.<br>• **Wireless robustness** | Zigbee is a wireless stack based on IEEE 802.15.4 (as the physical and MAC layer). The Zigbee application is capable of selecting a specific channel to communicate on with up to 16-channels. Zigbee is self-healing, and can identify a broken node in the network and reroute as necessary to preserve the network.<br>• **Range** | Typical range of a Zigbee application is up to 200 m line-of-sight with one-hop distance. However, Zigbee can achieve long range through its mesh network capability by daisy-chaining multiple Zigbee routers in the network.<br>• **Security** | To learn more about security in Zigbee networks, read: Understanding Security Features for SimpleLink™ Zigbee CC13x2 and CC26x2 Wireless MCUs<br>• **Target applications** | You can find Zigbee networks in various home automation controls like a wireless light switch, thermostat and many more. Zigbee Certification guarantees interoperability with Zigbee Certified products from other vendors as well.<br>**Potential disadvantages of Zigbee:**<br>• **Network type** | Zigbee does not provide an easy way to connect to the cloud. Connecting to an IP network would require a gateway and address translation layer.<br>• **Throughput** | Zigbee is not designed for high data rate transfer. It is designed to be a low data rate application with a maximum throughput of 250 kbps.<br>**To get started with your Zigbee application, visit** www.ti.com/zigbee |

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| **Thread** | **Advantages of Thread:**<br>• **Network Type** | Thread is designed for the connected home using mesh to an IP-based network. It is designed primarily for building automation to control lighting, thermostats and other product. Thread self-heals and self-forms, meaning that it automatically promotes or demotes nodes to ensure there is no single-point of failure in the network. In addition, Thread works with any IPv6 gateway thus making it easy to commission new devices to the network.<br>• **Power consumption** | Thread is designed to operate in low-power sensing applications, and connecting your sensors to the IPv6 network. Thread End Devices can sleep for an extended period of time, thus extending battery life.<br>• **Range** | Thread range is typically up to 200 m line-of-sight for a single-hop. Thread is a mesh network capable of up to 32-hops to extend range.<br>• **Security** | Inter-device communication is secured by default using AES-128. Commissioning uses standard DTLS with ECJ-PAKE.<br>• **Target Applications** | You can find Thread networks being used in various home automation devices like light bulbs, electronic locks and many more. Thread is also designed to be controlled through any Thread certified devices. It can easily integrate with any existing application framework.<br>**Potential disadvantages of Thread:**<br>• **Throughput** | IPv6-based networks have the possibility for high-overhead, so the 250 kbps throughput of Thread may be less adequate for existing IPv6 deployments.<br>• **Application agnostic** | Thread does not prescribe an interoperable application framework; while Thread certifies network interoperability, application framework interoperability is not guaranteed.<br>**To get started with your Thread application, visit** www.ti.com/thread |
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| **Wi-Fi** | **Advantages of Wi-Fi:**<br>• **Network Type** | Wi-Fi is generally a star connection but also supports mesh-capability.<br>• **Wireless Robustness** | Wi-Fi operates in both 2.4 GHz and 5 GHz frequency spectrums which are open wireless spectrums across the globe. And, Wi-Fi uses several frequency channels to avoid collisions.<br>• **Security** | Wi-Fi has an active ecosystem that constantly evolve its security to keep it up to date and robust against hackers. Wi-Fi data can be encrypted before being transmitted by using WPA encryption. Wi-Fi also has multiple layer of security because of its native IP like TLS. To learn more about security in Wi-Fi networks, read: Understanding security features for SimpleLink Wi-Fi CC32xx MCUs<br>• **Throughput** | Wi-Fi is designed to support high-data rates. As new standards have been defined, it now supports over Gbps through multiple-input and multiple-output or MIMO implementation.<br>• **Power Consumption** | Wi-Fi is also the most power efficient per bits of data transfer. The protocol is also flexible to allow very low average power in continuously connected to the network for battery applications.<br>• **Target Applications** | It is commonly used in consumer, industrial and enterprise applications. Wi-Fi could be found in laptops, smartphones, thermostat controllers and many more applications that needs to connect to the internet. Wi-Fi is of the most widely used wireless communication standards for high throughput communication between devices to the Internet.<br>**Potential disadvantages of Wi-Fi:**<br>• **Power consumption** | Wi-Fi peak power consumption is higher thus requiring a larger battery like AA sized battery.<br>• **Range** | Wi-Fi is designed for a localized network. And at 5 GHz, the frequency spectrum quickly gets attenuated or blocked from going through walls.<br>**To get started with your Wi-Fi application, visit** www.ti.com/wifi |

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| **Proprietary 2.4 GHz** | **Advantages of proprietary 2.4 GHz:**<br>• **Network Type** | A proprietary 2.4 GHz network allows you the flexibility to tailor your wireless application layer protocol with the flexibility of designing peer-to-peer, mesh or star network configuration. 2.4 GHz operates on a license free band around the world which means you can deploy your application at a lower cost.<br>• **Power consumption** | Proprietary solutions allow the best potential power optimization, as you are not limited in how you can customize the timing and duration of data transfer.<br>• **Throughput** | There could be higher effective data transfer rate than most wireless standards, as you could optimize the communication overhead that is typically associated with wireless protocols.<br>• **Target Applications** | Great for custom wireless protocol applications and interoperability with legacy 2.4 GHz wireless protocol application.<br>**Potential disadvantages of proprietary 2.4 GHz:**<br>• **Standards** | Proprietary 2.4 GHz is chosen to enable custom protocols that do differ from existing standards. You would have to define the application layer protocol when communicating between different peers. Proprietary 2.4 GHz protocols would not be interoperable with devices using any other wireless standard.<br>• **Range** | 2.4 GHz networks do not generally offer the longest range (see Proprietary Sub-1 GHz for long range proprietary networks). However, there are options to select wireless devices with Power Amplifiers (PA) to extend your application range by pairing them with proper external antennas. |
| **Proprietary Sub-1 GHz with 15.4 Stack** | **Advantages of proprietary Sub-1 GHz:**<br>• **Network Type** | A proprietary Sub-1 GHz network allows you the flexibility to tailor your wireless application layer protocol with the flexibility of designing peer-to-peer, mesh, or star network configurations.<br>• **Wireless Robustness** | Sub-1 GHz is also typically less crowded than the 2.4 GHz band, thus offering much more robust wireless communication. However, the Sub-1 GHz spectrum band (typically 300 MHz to 900 MHz) varies by geographical region and the licensing of frequency band needs to be taken into considering when designing products for worldwide deployments. Some countries have specific frequency band within Sub-1 GHz that license free. For example, 915 MHz is a license free band in United States but not worldwide.<br>• **Power consumption** | Proprietary solutions allow the best potential power optimization, as you are not limited in how you can customize the timing and duration of data transfer.<br>• **Range** | Sub-1 GHz frequency band can travel significantly longer distances due to its longer carrier wave, allowing it to penetrate through walls. However, the longer the distance, the lower the data rate may need to be as data losses come into play. Additionally, there are options of using Power Amplifiers (PA) to extend your application range by pairing them with proper external antennas.<br>• **Target Applications** | Great for applications that require long range communication like metering, smoke detectors or temperature sensors for buildings and industrial applications.<br>**Potential disadvantages of proprietary Sub-1 GHz:**<br>• **Standards** | There is currently no widely accepted wireless standard in the Sub-1 GHz frequency band. In a proprietary network, you would have to define the application layer protocol when communicating between different peers.<br>• **Throughput** | Sub-1 GHz data throughputs could range from 5 kbps to 500 kbps, thus effectively lower than higher frequency data transfer like 2.4 GHz. The lower the frequency, the lower the data bandwidth that one could transfer because of the frequency bandwidth.<br>**To get started with your Proprietary Sub-1 GHz application, visit** www.ti.com/sub1ghz |

Choosing a wireless connectivity technology for your application use case can be challenging and this guide provides the initial specs that should be considered. That's why TI offers devices that support all of the above protocols and makes it easy to reuse and re-purpose application code as your requirements change. To get started on your next wireless connectivity project, visit www.ti.com/simplelink to learn more on each specific wireless technology.

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