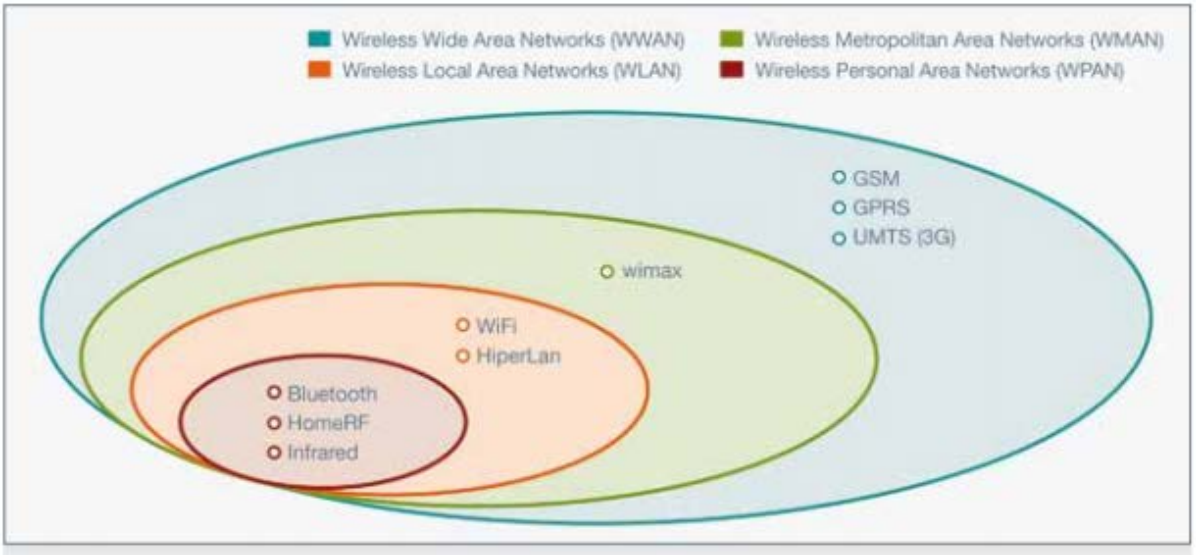
# Getting Started: Wireless Technologies

Wireless communication is one of the most desired modes of communication (connectivity) between two or more devices. In this technology, the data communication is performed and delivered over the air via electromagnetic waves, such as radio frequencies, infrared and satellite, rather than over cables and wires.

Wireless communications operate over particular frequencies in the electromagnetic spectrum from 3 Hz to 3000 GHz (3 THz), called radio waves. It includes a diverse variety of computing and communications applications ranging from third-generation/fourth-generation (3G/4G) cellular devices, broadband access, indoor WiFi networks, vehicle-to-vehicle (V2V) systems to embedded sensor and radio frequency identification (RFID) applications, microwave, aeronautical, maritime and other commercial and private radio services.

Due to the dynamic requirement of wireless requirement different methods and standards of wireless communication have been developed across the world, based on various commercially driven requirements like specific application and transmission range. These technologies can roughly be classified into four individual categories; Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN), Wireless Wide Area Network (WWAN). As implicated by their names, the properties of these solutions in terms of range and data rate are optimized for personal, local, metropolitan, or worldwide coverage and use.




The reach of a Wireless PAN is typically a few meters. WPAN's can be used for communication among the personal devices themselves (intrapersonal communication), or for connecting to a higher level network and the Internet. A Wireless LAN links the two or more computers without using wires, WLAN utilizes spread-spectrum technology based on radio waves to enable communication between devices IEEE 802.11, the Wi-Fi standard, denotes a set of Wireless LAN/WLAN standards. The Wireless MAN is the name trademarked by the IEEE 802.16 Working Group on Broadband Wireless Access Standards for its wireless metropolitan area network standard (commercially known as WiMAX), which defines broadband Internet access from fixed or mobile devices via antennas. The Wireless WAN is a computer network covering a broad geographical area, WAN's are used to connect Local Area Networks (LAN's or WLAN's) together, so that users and computers in one location can communicate with users and computers in other

locations, WAN's also refer to Mobile Data Communications, such as GSM, GPRS and 3G. The largest and most well-known example of a WAN is the Internet.

Here are the main Wireless Technology Standard and applications:

- **NFC (Point-to-point)** – Near Field Communication: Offers a low-speed connection with a simple setup that can be used to bootstrap more capable wireless connections. NFC devices are used in contactless payment systems, social networking like sharing contacts, photos, videos or files.

- **RFID (WPAN - IEEE 802.15)** – Radio Frequency Identification (RFID) is a contactless technology uses radio waves to read and capture information stored on a tag attached to an object electronically without any human action, it's a dedicated short range communication.

- **Bluetooth (WPAN - IEEE 802.15.1)** - Bluetooth uses WPAN technology for exchanging data over short distances wirelessly. It is used is mobile phones, headsets, headphones, MP3 players, computers, boom boxes, laptops, computer mice, GPS units, and car stereos.

- **Zigbee (WPAN - IEEE 802.15.4)** - It is a low-power, low data rate, and close proximity wireless ad-hoc network. It implements high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, sensors, medical device data collection, and other low-power low-bandwidth needs.

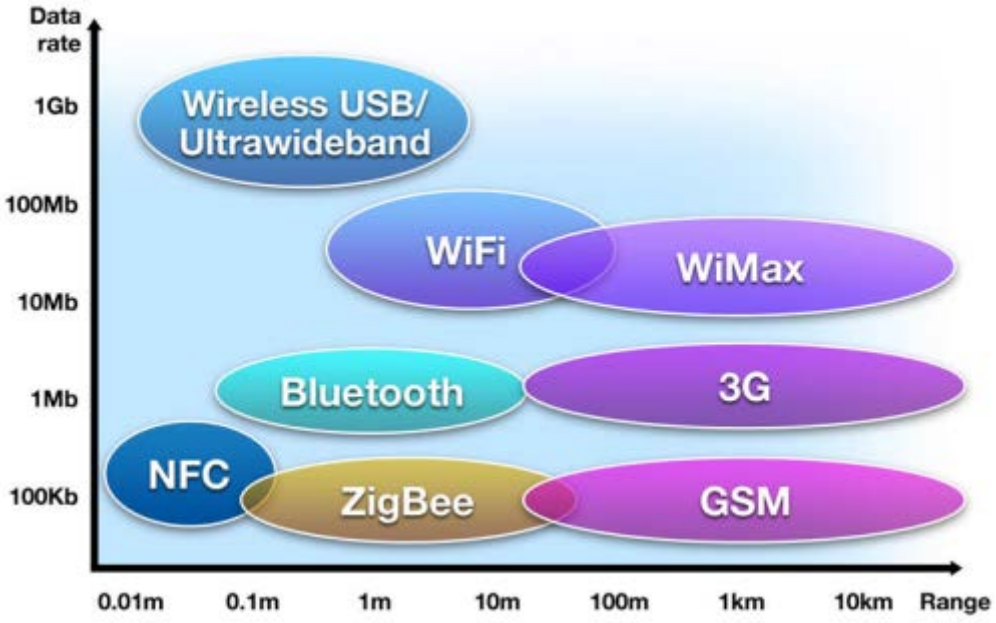
- **Z-Wave (WPAN)** - Z-Wave is a wireless radio frequency technology that lets smart devices talk to and connect with one another. Household products, like lights, door locks, and thermostats are made smart when Z-Wave connectivity is added. The devices can be easily accessed and controlled remotely on your Smartphone. Mainly used in the home or building automation applications.

- **WiFi (WLAN – IEEE 802.11)** - Wi-Fi enables a user to get access to the internet anywhere in the given location like Hotels, Libraries, colleges, universities, campus, private institutes, and coffee shops and even on a public place. Wi-Fi allows connecting several devices, like computers, phones, printer etc, at once anywhere in the house or building.

- **LoRa (LPWAN)** - LoRa is a LoRaWAN protocol, open standard for secure connectivity. It's a long-range, low-power, low-bit rate, standard intended for battery operated devices for M2M and Internet of Things networking. It the most prevailing technology choice for building IoT networks worldwide.

- **Sigfox (LPWAN)** - Similar to LoRa but not open. A wireless network designed to connect low-energy devices over the ultra-narrow band, in particular for battery powered IoT applications.

- **Cellular (WWAN - IEEE 802.16)** - A wireless technology used by mobile phones, it re-uses radio frequency to enable complex two-way communication. It uses several small cells located over a wide geographical are interconnected through a central exchange to form a WWAN.




# Wireless Standards Overview:

**Near Field Communication (NFC):**

Near Field Communication (NFC) is a new, short-range wireless connectivity technology that evolved from a combination of existing contactless identification and interconnection technologies. It uses magnetic field induction to enable communication between electronic devices in close proximity. Based on RFID technology, NFC provides a medium for the identification protocols that validate secure data transfer. NFC enables users to perform intuitive, safe, contactless transactions, access digital content and connect electronic devices simply by touching or bringing devices into close proximity.

NFC operates in a frequency range cantered on 13.56 MHz and offers a data transmission rate of up to 424 kbit/s within a distance of approximately 10 centimetres. Modulation schemes are amplitude on/off keying (OOK) with different modulation depth (100 % or 10 %) and BPSK. NFC uses an inductive coupling similar to the transformer principle, the magnetic near-field of two conductor coils is used to couple the polling device (initiator) and listening device (target).

Communications between NFC-capable devices can be active-active (peer-to-peer) as well as active-passive; NFC therefore represents a link to the RFID world. It is backwards compatible with the widely used Smart Card infrastructure. NFC lets you interact securely with the world around you with a simple touch. NFC is available in hundreds of millions of Smartphone's, tablets, and other consumer electronics. NFC enabled mobile devices will allow consumers to store and access all kinds of personal data at home or on the move. Simply by bringing two NFC-enabled devices close together, they automatically initiate network communications without requiring the user to configure the setup. NFC is intended to be used as an access key to contents and for services such as cashless payment, ticketing and access control.

**Radio Frequency Identification (RFID):**

RFID (Radio Frequency Identification) can be defined as Automatic identification technology which uses radio-frequency electromagnetic fields to identify objects carrying tags when they come close to a reader. RFID technology is a simple method of exchanging data between two entities namely a reader/ writer and a tag. This communication allows information about the tag or the element carrying the tag to be determined and in this way it enables processes to be managed more easily.

The use of RFID technology has become widespread within many areas of industry. RFID provides an ideal technology for tracking assets and identifying them by using a simple low cost antenna attached to the target. It is used for identification of everything from shop tagging to vehicle tracking and many more applications.

Similar to how a radio must be tuned to different frequencies to hear different channels, RFID tags and readers have to be tuned to the same frequency in order to communicate. RFID uses several radio frequencies and many types of tag exist with different communication methods and power supply sources. RFID tags generally feature an electronic chip with an antenna in order to pass information onto the interrogator (also known as a base station or more generally, reader). The assembly is called an inlay and is then packaged to be able to withstand the conditions in which it will operate. This finished product is known as a tag, label or transponder.

RFID is considered as a non specific short range device. It can use frequency bands without a license. Its range differs from 1–12 meters with speed of 640 kbps. RFID has to be compliant with local regulations (ETSI, FCC etc.) most countries have assigned 125 to 134 kHz of the spectrum for low-frequency RFID systems; 13.56 MHz is generally used around the world for high-frequency RFID systems. UHF RFID systems use 433, and 860-960 MHz and 2.45 / 5.8 GHz are super high frequencies.

**Bluetooth:**

Bluetooth is a standard for wireless communications based on a radio system designed for short-range connectivity for portable personal devices. It defines a whole communication stack that allows devices to find each other and advertise the services they offer. Bluetooth is extensively used in WPAN technology. IEEE 802.15.1 standard specifies the operation and architecture of Bluetooth devices, but the operation is concerned only for physical layer and medium access control (MAC) layer. The protocol layers and applications are standardized by Bluetooth SIG. The channels are accessed using an FHSS technique, with a signal rate of 1 Mb/s, using Gaussian shaped frequency shift keying (GFSK) modulation.
Bluetooth devices use the 2.4 GHz band, which is licence free Industrial, Scientific and Medical (ISM) frequency band for its radio signals and enables communications to be established between devices up to a maximum distance of around 100 metres. Bluetooth's main strength is its ability to simultaneously handle both data and voice transmissions, allowing such innovative solutions as a mobile hands-free headset for voice calls, print to fax capability, and automatically synchronizing PDA, laptop, and cell phone address book applications.

The two most prevalent implementations of the specification are Bluetooth Basic Rate/Enhanced Data Rate (BR/EDR), which was adopted as version 2.0/2.1, and Bluetooth with low energy (LE), which was adopted as version 4.0/4.1/4.2/5.0. Bluetooth BR/EDR establishes a relatively short-range, continuous wireless connection, with EDR data rate of 2-3 Mbit/s respectively which makes it ideal for use cases such as streaming audio. BLE allows for short bursts of long-range radio connection, making it ideal for Internet of Things applications that don't require continuous connection but depend on long battery life.

**Zigbee:**

ZigBee is a wireless networking standard that is aimed at remote control and sensor applications which is suitable for operation in harsh radio environments and in isolated locations. It is an established set of specifications for wireless personal area networking (WPAN). ZigBee is one of the global standards of communication protocol formulated by the relevant task force under the IEEE 802.15 working group which defines the physical and MAC layers. The main applications for 802.15.4 are aimed at control and monitoring applications where relatively low levels of data throughput are needed with range of 10–100 meters, and with the possibility of remote, battery powered sensors, low power consumption is a key requirement. Sensors, lighting controls, security and many more applications come under this technology.

The system is specified to operate in one of the three licenses free bands at 2.4 GHz, 915 MHz and 868 MHz. At 2.4 GHz the maximum data rate is 250 kbps. For 915 MHz the standard supports a maximum data rate of 40 kbps, while at 868 MHz can support data transfer at up to 20 kbps. There are three different network topologies that are supported by ZigBee, namely the star, mesh and cluster tree or hybrid networks. There are numerous advantages to the zigbee protocol, including its reliability, scalability and ability to self-heal its mesh network.

ZigBee PRO is a version of ZigBee that carries greater capabilities like routing techniques, Network hops, Max number of devices, Network security. By adopting ZigBee PRO as an enhanced version, it is possible to provide the additional capabilities of some applications, while retaining a simpler, low cost stack and retaining the lower power consumption for those applications that do not require the additional capabilities.

**Z-Wave:**

Z-Wave is an international standard for wireless home automation. Home automation allows to interconnect all functions dealing with electricity such as light, heating, cooking, cooling, security etc with each other and to apply automation of these functions. It is widely used for M2M and smart devices in the IoT, home automation, and security markets. It communicates using wireless technology designed specifically for remote control applications which operates in the sub-gigahertz frequency range, around 900MHz. This band competes with some cordless telephones and other consumer electronics devices, but avoids interference with Wi-Fi and other systems. It offers the right balance of bandwidth, range, power consumption, cost, and product-level interoperability across multiple manufacturers, making it the best overall choice for the vast majority of smart device applications.

Z-Wave is a low powered mesh networking technology where each node or device on the network is capable of sending and receiving control commands through walls or floors and use intermediate nodes to route around household obstacles or radio dead spots that might occur. Zwave utilizes GFSK modulation and Manchester channel encoding. Each Z-Wave module can act as an RF repeater and commands can route through a maximum of four devices. This gives the system a maximum range of 400 ft and routing is managed automatically.

Each Z-Wave network is identified by a Network ID and each device is further identified by a Node ID. The Network ID is the common identification of all nodes belonging to one logical Z-Wave network. Network ID has a length of 4 bytes and is assigned to each device by the primary controller when the device is added into the network. Nodes with different Network ID's cannot communicate with each other. The Node ID is the address of the device / node existing within network. The Node ID has a length of 1 byte.

**WiFi:**

Wi-Fi is the name of a popular wireless networking technology for wireless local area networking that uses radio waves to provide wireless high-speed Internet and network connections based on the IEEE 802.11 standards. Wi-Fi is a trademark of the Wi-Fi Alliance, which restricts the use of the term Wi-Fi certified to products that successfully complete interoperability certification testing. Wireless Fidelity is a generic term that refers to the IEEE 802.11 communications standard for WLANs.

The two basic components of a Wi-Fi network are a computer device outfitted with a low-power radio and another radio-equipped gadget known as an access point, which is wired to the Internet or a local network. The two communicate with each other over a free slice of the radio spectrum reserved for consumer use and inhabited by microwave ovens and cordless phones. WiFi network topology can be Access point (Infrastructure Mode), Peer-to-peer-based (Ad-hoc Mode), or Point-to-multipoint bridge type of topology.

A WiFi network can be easily set up in a home or office and allow all users to share files, printers and a single internet connection, the network can be expanded by adding WiFi radio cards to new devices. Wi-Fi provides freedom to physically move around your home or business and still stay connected to the Internet or local network. Public WiFi “hotspots” are rapidly becoming common in coffee shops, hotels convention centers, airport, libraries and community areas. A WiFi network allows guest and travellers to connect to a public access point and obtain high speed internet access.

Benefits of WiFi are they replace wired Ethernet, extended access, cost reductions, and mobility. The absence of wires and cables extends access to places where wires and cables cannot go, and they bring down the cost.

**LoRa:**

LoRa is a wireless technology that has been developed to enable low data rate communications to be made over long distances by sensors and actuators for M2M and Internet of Things applications. It uses unlicensed radio spectrum in the Industrial, Scientific and Medical (ISM) bands to enable low power, wide area communication between remote sensors and gateways connected to the network. It uses spread-spectrum technology with a wider band. Its frequency-modulated chirp utilizes coding gain for increased receiver sensitivity.

LoRaWAN is an open-source LPWAN infrastructure protocol specification built on top of the LoRa technology developed by the LoRa Alliance that allows other companies to create their own IoT networks based on its technology specifications. This standards-based approach to build a LPWAN allows for quick set up of public or private IoT networks anywhere using hardware and software that is bi-directionally secure, interoperable and mobile, provides accurate localization and works the way you expect.

A LoRa network can be arranged to provide coverage similar to that of a cellular network. Indeed many LoRa operators are cellular network operators who will be able to use existing masts to mount LoRa antennas. In some instances the LoRa antennas may be combined with cellular antennas as the frequencies may be close and combining antennas will provide significant cost advantages. The key features of LoRa is it covers long range of 15-20 Kms, it can connect to millions of nodes and its battery life long lasts for more than 10 years. Applications for LoRa wireless technology includes smart

metering, inventory tracking, vending machine, data and monitoring, automotive industry, utility applications where data reporting and control may be needed

**Sigfox:**

SIGFOX provides a cellular style network operator that provides a tailor-made solution for low-throughput Internet of Things and M2M applications. It connects remote devices using Ultra Narrow Band (UNB) technology and operates in the unlicensed bands (ISM). It uses a standard radio transmission method called binary phase-shift keying (BPSK).
There are a number of applications that need this form of low cost wireless communications technology. It requires an inexpensive endpoint radio and a more sophisticated base station to manage the network. It is mainly targeted for low data rate applications. It requires substantially less antennas compare to traditional cellular networks such as GSM/CDMA. SIGFOX has tailored a lightweight protocol to handle small messages. Less data to send means less energy consumption, hence longer battery life.
Using the Ultra Narrow Band modulation, Sigfox operate in the 200 kHz of the publicly available and unlicensed band to exchange radio messages over the air (868 to 869 MHz and 902 to 928 MHz depending on regions). Each message is 100 Hz wide and transferred at 100 or 600 bits per second a data rate, depending on the region. Hence, long distances can be achieved while being very robust against the noise. The transmission is unsynchronized between the device and the network. The device broadcasts each message 3 times on 3 different frequencies (frequency hopping). The base stations monitor the spectrum and look for UNB signals to demodulate.
The density of the cells in the SIGFOX network is based on an average range of about 30-50km in rural areas and in urban areas where there are usually more obstructions and noise is greater the range may be reduced to between 3 and 10km. Distances can be much higher for outdoor nodes where SIGFOX states line of sight messages could travel over 1000km.

**Cellular:**

The advancement of mobile networks is enumerated by generations. Many users communicate across a single frequency band through mobile phones. Cellular and cordless phones are two examples of devices which make use of wireless signals. Typically, cell phones have a larger range of networks to provide coverage. But, Cordless phones have a limited range. Similar to GPS devices, some phones make use of signals from satellites to communicate.
WWAN is a long-range communication using cellular network data anywhere and also with the utilization of internet. WWANs establish connection over large areas, like cities or countries, via multiple satellite systems or antenna sites looked after by an Internet Service Provider (ISP). These systems are referred to as 2G systems. These networks require high cost to deployment since they cover a large geographical area. WWANs include mobile telecommunication cellular networks such as Long Term Evolution (LTE), GSM, CDMA 2000, cellular digital packet data (CDPD) and Mobitex to transfer data.

Universal Mobile Telecommunication System (UMTS) is a system of third generation (3G) of mobile services, which establish voice communications and high-speed data connectivity, including access to the Internet, mobile data applications, and multimedia content. High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) belong to 3.5 and 3.75 generation of mobile systems respectively. HSDPA possessing bitrates of 2Mbit/s for downlink and 384kbit/s for uplink direction and HSUPA allows sending data at a bit rate of 1.45Mbit/s for the uplink direction.

Fourth generation (4G) of mobile telecommunication technology provides mobile broadband internet access to wireless modems, Smartphone's and also to other mobile

systems. International Mobile Telecommunications Advanced (IMT-Advanced) specifications are used for 4G standards. Theoretical downlink speed is between 100Mbit/s to 1Gbits/s for mobile and fixed transmission and uplink speed is 60Mbit/s.