## Table of Contents

### Chapter -6

**2.4-GHz Wireless Communication with Transceivers**

6.1 2.4-GHz Wireless Communication with Transmitters 63  
6.1.1 Wi-Fi Wireless Communication Protocol 63  
6.1.1.2 Wi-Fi Transceiver Module 64  
6.1.1.3 Working Principle of W-Fi 65  
6.1.1.4 Types of WI-FI Technologies 66  
6.1.2 Bluetooth Wireless Communication Protocol 68  
6.1.2.1 Bluetooth Transceiver Module 68  
6.1.2.2 Bluetooth Specifications 69  
6.1.2.3 Advantages of Bluetooth Technology 70  
6.1.2.4 Bluetooth Applications 71  
6.1.3 Zigbee Wireless Communication Protocol 72  
6.1.3.1 Zigbee Architecture 73  
6.1.3.2 Zigbee Operating Modes and Its Topologies 75  
6.1.3.3 Zigbee Topologies 76  
6.1.3.4 Applications of Zigbee Technology 77  
6.1.4 6LowPan Protocol Transceiver Module 78  
6.1.4.1 6LoWPan Working Procedure 79  
6.1.4.2 Difference between Zigbee and 6LowPan protocols 80  
6.1.5 IEEE802.15.4 Protocol 80  
6.1.5.1 IEEE802.15.4 Architecture 81  
6.1.6 Wireless Hart Protocol Transceiver module 83  
6.1.6.1 Wireless Hart Working Procedure 84  
6.1.7 ANT Protocol Transceiver Module 86  
6.1.8 Ultra-low power Transceiver Module 86
2.4-GHz Wireless Communication with Transceivers

6.1 2.4-GHz Wireless Communication with Transmitters
6.1.1 Wi-Fi Wireless Communication Protocol

Introduction of Wi-Fi
Wi-Fi is a popular wireless networking technology. Wi-Fi stands for “wireless fidelity”. The Wi-Fi was invented by NCR corporation AT&T in Netherlands in 1991. By using this technology, we can exchange the information between two or more devices. Wi-Fi has been developed for mobile computing devices, such as laptops, but it is now extensively used for mobile applications and consumer electronics like televisions, DVD players and digital cameras.

There should be two possibilities in communicating with the Wi-Fi connection that may be through access point to the client connection or client-to-client connection. Wi-Fi is a one type of wireless technology. It is commonly called as wireless LAN (Local Area Network). Wi-Fi allows local area networks to operate without cable and wiring. It is making a popular choice for home and business networks. A computer’s wireless adaptor transfers the data into a radio signal and then into antenna for users.
6.1.1.2 Wi-Fi Transceiver Module

Wi-Fi is a high-speed internet connection and network connection without the use of any cables or wires. The wireless network operates three essential elements that are radio signals, antenna and router. The radio waves are keys which make the Wi-Fi networking possible.

The computers and cell phones are ready with Wi-Fi cards. Wi-Fi compatibility is a new creation to communicate within the ground connected with community network. The Wi-Fi consists of a Wide Area Network (WAN) and Personal Area Network (PAN) to communicate with the other devices.

- The Wi-Fi Network transceivers support UART and SPI protocols.
- The Wi-Fi network transceivers have SoC.
- Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying and Quadrature Amplitude Modulation (QAM) techniques are used.
- Wi-Fi developing companies in India are Vie Technology Pvt. Ltd (Chennai), Atlas Comnet Pvt. Ltd (Delhi).
- The operating voltage of Wi-Fi transceivers is between 2.7-3.6V.
6.1.1.3 Working Principle of W-Fi:

Wi-Fi is a high-speed internet connection and network connection without the use of any cables or wires. The wireless network operates three essential elements that are radio signals, antenna and router. The radio waves are keys which make the Wi-Fi networking possible. The computers and cell phones are ready with Wi-Fi cards. Wi-Fi compatibility is a new creation to communicate within the ground connected with community network. The actual broadcast is connected with in sequence – in fact – it is completed by a way of stereo system surf as well as the worth of wires monitoring to classification prone. The Wi-Fi consists of a Wide Area Network (WAN) and Personal Area Network (PAN) to communicate with the other devices. Wi-Fi allows a person in order to get access to Web any place in the actual provided area. You can now generate a system within resorts, library, schools, colleges, campus, personal institutes, as well as espresso stores on the open public spot to help make your company much more lucrative as well as interactive with its own customers. Wi-Fi is compatible with all devices and capable of surfing and sharing a company’s information without using cable or wires. The radio signals transmitted from antennas and routers are picked up by the Wi-Fi receivers, such as computers and cell phones that are ready with Wi-Fi cards. Whenever a computer receives the signals within the range of 100-150 feet from the router, it connects the device immediately. The range of the Wi-Fi depends upon the environment and on the indoor or outdoor ranges. The Wi-Fi cards read signals and create an internet connection between the user and network. The speed of the device that uses Wi-Fi connection increases as the computer gets closer to the main source; and, the speed decreases as the computer gets further away. Many new laptops, mobile phones have inbuilt Wi-Fi cards and, therefore, you don't have to do anything which is one of the best thing. If it is a free-based type of network connection, the user will be promoted with a login ID and password. The free-base network connections also work well in some areas. The Wi-Fi network connection is creating hot spots in the cities. The hot spots are a connection point of Wi-Fi network. It is a small box that is hardwired into the internet. There are many Wi-Fi hot spots available in public places like restaurants, airports, and hotels offices, universities, etc.
Security:
Security is an important element in the Wi-Fi technology. Security is our personal decision, but if we have a wireless connection, we should pay attention to protect our private details. We may get connected easily to unsecured wireless routers with the Wi-Fi connection. Therefore, the main problem is security because if somebody gets access to your wireless router using the data like downloadable games, downloadable apps, illegal music and movie files and does some illegal activities, then it becomes necessary to provide security to the wireless technologies based devices.

How to Make the Security?
All routers have a web page that you can connect to for configuring the Wi-Fi security. And turn on WEP (Wire Equivalence Privacy) and enter a password and remember this password. Next time when you connect your laptop, the Wi-Fi router will ask you to enter the connection password and you can enter that password.

6.1.1.4 The Types of WI-FI Technologies

802.11a: It supports wireless LAN and provides 1 to 2 Mbps transmission in the 2.4 GHz band frequency using either frequency hopping spread spectrum or direct sequence spread spectrum.

802.11b: It supports wireless LAN and provides fast 11 Mbps transmission in the 2.4 GHz band frequency. This specification uses only DSSS.

802.11ac: It supports wireless WAN and provides fast 1300 Mbps transmission in the 2.4 and 5.0 GHz band frequencies. It is fast accessing and cost effective.

Wi-Fi-802.11g: In 2002 and 2003, this technology supporting newer standard products. It is the best technology of 802.11a and 802.11b. The 802.11 b supports bandwidth up to 54 mbps and it uses a 2.4 GHz frequency for greater range. This technology's cost is more than 802.11b. It is fast accessible with optimum speed.

Wi-Fi-802.11n: The 802.11n is the newest WIFI technology. It was designed to improve on 802.11g. The amount of bandwidth supported by utilizing multiple wireless signals and antennas instead of one. It supports 100 mbps bandwidth and increased signal intensity.
Applications

- Mobile applications
- Business applications
- Home applications
- Computerized application
- Automotive segment
- Browsing internet
- Video conference

Advantages

- Wireless laptop can be moved from one place to another place.
- Wi-Fi network communication devices without wires can reduce the cost of wires.
- Wi-Fi setup and configuration is easy than cabling process.
- It is completely safe and it does not interfere with any network.
- It can be used to connect internet via hot spots.
- Can be used to connect internet wirelessly.

Disadvantages

- Wi-Fi generates radiations which can harm the human health.
- We must disconnect the Wi-Fi connection whenever we are not using the server.
- There are some limits to transfer the data; we are unable to transfer the data for long distance.
- Wi-Fi implementation is very expensive when compared to the wired connection.
6.1.2 Bluetooth Wireless Communication Protocol

Bluetooth wireless technology was named after a Danish Viking and King, Harald Blatand; his last name means “Bluetooth” in English. He is credited with uniting Denmark and Norway, just as Bluetooth wireless technology is credited with uniting two disparate devices.

The Bluetooth technology emerged from the task undertaken by Ericsson Mobile Communications in 1994 to find alternative to the use of cables for communication between mobile phones and other devices. In 1998, the companies Ericsson, IBM, Nokia and Toshiba formed the Bluetooth Special Interest Group (SIG) which published the 1st version in 1999.

The first version was 1.2 standard with a data rate speed of 1Mbps. The second version was 2.0+EDR with a data rate speed of 3Mbps. The third was 3.0+HS with a speed of about 24 Mbps. The latest version is 4.0.

6.1.2.1 Bluetooth Transceiver Module

Bluetooth technology is a high-speed low powered wireless technology link that is designed to connect phones or other portable equipment together.

It is a specification (IEEE 802.15.1) for the use of low-power radio communications to link phones, computers and other network devices over short distance without wires. Wireless signals transmitted with Bluetooth cover short distances; typically up to 30 feet (10 meters). It is achieved by embedded low-cost transceivers into the devices. It supports on the frequency band of 2.45GHz and can support up to 721 Kbps along with three voice channels.

This frequency band has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM).rd-compatible with 1.0 device. Bluetooth can connect up to “eight devices” simultaneously and each device offers a unique 48-bit address from the IEEE 802 standard with the connections being made point-to-point or multipoint.
• The Bluetooth Network transceivers support SPI protocol.
• The Bluetooth network transceivers have SoC.
• The Bluetooth network transceivers use Gaussian Frequency Shift Keying (GFSK) modulation technique.
• Manufacturing companies of Bluetooth are Mega Byte Technologies (Bangalore), Bitsmind Technologies (Chennai).
• The operating voltage of Bluetooth transceivers is between 2-3.6V.
• A network node consists of PAN RF transceiver for 2.4GHz spectrum.

Bluetooth Network consists of a Personal Area Network. The latest version of the standard Bluetooth is Bluetooth 4.0, which is introduced as a low-energy technology, which means, it operates at low power.

6.1.2.2 Bluetooth Specifications

Core Specifications: It defines the Bluetooth protocol stack and the requirements for testing and qualification of Bluetooth-based products.

The profiles specification: It defines usage models that provide detailed information about how to use the Bluetooth protocol for various types of applications.

The core specification consists of 5 layers:
Radio: Radio specifies the requirements for radio transmission – including frequency, modulation, and power characteristics – for a Bluetooth transceiver.

Baseband Layer: It defines physical and logical channels and link types (voice or data); specifies various packet formats; transmits and receives timing; and, controls channel and the mechanism for frequency hopping (hop selection) and device addressing. It specifies point-to-point or point-to-multipoint links. The length of the packet can range from 68 bits (shortened access code) to a maximum of 3071 bits.

LMP- Link Manager Protocol (LMP): It defines the procedures for link set up and ongoing link management.

Logical Link Control and Adaptation Protocol (L2CAP): It is responsible for adapting upper-layer protocols to the baseband layer.

Service Discovery Protocol (SDP): It allows a Bluetooth device to query other Bluetooth devices for device information, services provided, and the characteristics of those services. The 1st three layers comprise the Bluetooth module, whereas the last two layers make up the host. The interfacing between these two logical groups is called Host-Controller Interface.

6.1.2.4 Advantages of Bluetooth Technology

Bluetooth technology removes the problem of radio interference by using a technique called Speed-Frequency Hopping. This technique utilizes 79 channels of particular frequency band, with each device accessing the channel for only 625 microseconds, i.e., the device must toggle between transmitting and receiving data from one time slot to another. This implies that the transmitters change frequencies 1,600 times every second, meaning that more devices can make full use of a limited slice of the radio spectrum. This ensures that the interference won’t take place as each transmitter will be on different frequencies. The power consumption of the chip (consisting of transceiver) is low, at about 0.3mW, which makes it possible for least utilization of battery life. It guarantees security at bit level. The authentication is controlled using a 128-bit key. It is possible to use Bluetooth for both transferring of data and verbal communication as Bluetooth can support data channels of up to 3 similar voice channels. It overcomes the constraints of line of sight and one-to-one communication as in other mode of wireless communications like infrared.
6.1.2.5 Bluetooth Applications

Cordless Desktop: All or most of the peripheral devices (mouse, keyboard, printer, speakers, etc.) are connected to the PC cordlessly.

Ultimate Headset: It can be used to allow one headset to be used with myriad devices, including telephones, portable computers, stereos, etc.

Automatic Synchronization: This usage model makes use of the hidden computing paradigm, which focuses on applications in which devices automatically carry out certain tasks on behalf of the user without user intervention or awareness.

Multimedia Transfer: Exchange of multimedia data like songs, videos, pictures can be performed between devices using Bluetooth.
6.1.3 Zigbee Wireless Communication Protocol

Zigbee modules are the wireless communication modules that are built based on Zigbee standard. They utilize the IEEE 802.15.4 protocol. Zigbee standards are standards with a range between Bluetooth and WIFI. They are basically RF modules. Wireless technology can be challenging without the right combination of expertise and resources. The Zigbee is an arrangement of modular products that make deploying wireless technology easy and cost-effective. The module can communicate up to 100 feet indoors or 300 feet outdoors.

It can be used as a serial replacement or you can put it into a command mode and configure it for a variety of broadcast and mesh-networking options. The Zigbee modules provide wireless connectivity to devices.

- The Zigbee Network transceivers support UART and SPI protocol.
- The Zigbee network transceivers have SoC.
- The Zigbee network transceivers use binary phase shift keying (bpsk) modulation technique.
- The operating voltage of Zigbee transceivers is 1.8v--3.8V.
- A Network node consists of 802.15.4 RF transceiver.
6.1.3.1 Zigbee Architecture
Zigbee system structure consists of three different types of devices such as Zigbee coordinator, Router and End device. Every Zigbee network must consist of at least one coordinator which acts as a root and bridge of the network. The coordinator is responsible for handling and storing the information while performing receiving and transmitting data operations. Zigbee routers act as intermediary devices that permit data to pass to and fro through them to other devices. End devices have limited functionality to communicate with the parent nodes such that the battery power is saved as shown in the figure. The number of routers, coordinators and end devices depends on the type of network such as star, tree and mesh networks.

Zigbee System Structure

Zigbee protocol architecture consists of a stack of various layers wherein IEEE 802.15.4 is defined by the physical and MAC layers while this protocol is completed by accumulating Zigbee's own network and application layers.
Zigbee Protocol Architecture

Physical Layer: This layer does modulation and demodulation operations up on transmitting and receiving signals respectively. This layer’s frequency, data rate and number of channels are given below.

<table>
<thead>
<tr>
<th>BAND</th>
<th>COVERAGE</th>
<th>DATA RATE</th>
<th>CHANNEL NUMBERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 GHz</td>
<td>ISM</td>
<td>250 kbps</td>
<td>11-26</td>
</tr>
<tr>
<td>868 MHz</td>
<td>Europe</td>
<td>20 kbps</td>
<td>0</td>
</tr>
<tr>
<td>915 MHz</td>
<td>ISM</td>
<td>40 kbps</td>
<td>1-10</td>
</tr>
</tbody>
</table>

Physical Layer of Zigbee Protocol

MAC Layer: This layer is responsible for reliable transmission of data by accessing different networks with the carrier sense multiple access collision avoidance (CSMA). This also transmits the beacon frames for synchronizing communication.

Network Layer: This layer takes care of all network-related operations such as network setup, end device connection and disconnection to network, routing, device configurations, etc.
**Application Support Sub-Layer:** This layer enables the services necessary for Zigbee device object and application objects to interface with the network layers for data managing services. This layer is responsible for matching two devices according to their services and needs.

**Application Framework:** It provides two types of data services as key value pair and generic message services. Generic message is a developer defined structure, whereas the key value pair is used for getting attributes within the application objects. ZDO provides an interface between the application objects and APS layer in Zigbee devices. It is responsible for detecting, initiating and binding other devices to the network.

**6.1.3.2 Zigbee Operating Modes and Its Topologies**

Zigbee's two-way data is transferred in two modes: Non-beacon mode and Beacon mode. In a beacon mode, the coordinators and routers continuously monitor active state of the incoming data and, hence, more power is consumed. In this mode, the routers and coordinators do not sleep because at any time any node can wake up and communicate. However, it requires more power supply and its overall power consumption is low because most of the devices are in an inactive state for over long periods in the network.

In a beacon mode, when there is no data communication from the end devices, then the routers and coordinators enter into sleep state. Periodically this coordinator wakes up and transmits the beacons to the routers in the network. These beacon networks work for time slots, which means, they operate when the communication needed results in lower duty cycles and longer battery usage. These beacon and non-beacon modes of Zigbee can manage periodic (sensors data), intermittent (Light switches) and repetitive-data types.
6.1.3.3 Zigbee Topologies

Zigbee supports several network topologies; however, the most commonly used configurations are star, mesh and cluster-tree topologies. Any topology consists of one or more coordinators. In a star topology, the network consists of one coordinator which is responsible for initiating and managing the devices over the network. All the other devices are called end devices that directly communicate with the coordinator. This is used in industries where all the end point devices are needed to communicate with the central controller, and this topology is simple and easy to deploy.

In mesh and tree topologies, the Zigbee network is extended with several routers wherein the coordinator is responsible for starting them. These structures allow any device to communicate with any other adjacent node for providing redundancy to the data. If any node fails, the information is routed automatically to other device by these topologies. As the redundancy is the main factor in industries, hence mesh topology is mostly used. In a cluster-tree network, each cluster consists of a coordinator with leaf nodes, and these coordinators are connected to the parent coordinator that initiates the entire network.

Due to the advantages of Zigbee technology like low-cost and low-power operating modes and its topologies, this short-range communication technology is best suited for several applications compared to other proprietary communications, such as Bluetooth, Wi-Fi, etc. Some of these comparisons such as the range of Zigbee, standards, etc., are given below.
6.1.3.4 Applications of Zigbee Technology

**Industrial Automation:** In manufacturing and production industries, a communication link continually monitors various parameters and critical equipment. Hence, Zigbee considerably reduces this communication cost as well as optimizes the control process for greater reliability.

**Home Automation:** Zigbee is perfectly suited for controlling home appliances remotely as a lighting system control, appliance control, heating and cooling system control, safety equipment operations and control unit, surveillance unit, and so on.

**Smart Metering:** Zigbee remote operations in smart metering include energy consumption response, pricing support, security over power theft, etc.

**Smart Grid monitoring:** Zigbee operations in this smart grid involve remote temperature monitoring, fault locating, reactive-power management, and so on.

This is all about a brief description of Zigbee technology’s architecture, operations modes, configurations and applications. We hope that we have given you enough content on this title, for you to understand it better. We are pioneers in developing Zigbee-based projects. For further help and technical assistance, you can contact us.

---

### Comparison table of Zigbee

<table>
<thead>
<tr>
<th>Physical Layer Standard</th>
<th>ZigBee</th>
<th>Sub-Ghz</th>
<th>Wi-Fi</th>
<th>Bluetooth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>802.15.4</td>
<td>Proprietary / 802.11</td>
<td>802.11</td>
<td>802.15.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application Focus</th>
<th>Monitoring &amp; control</th>
<th>Monitoring &amp; control</th>
<th>Web, email, video</th>
<th>Cable replacement</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Battery Life (days)</th>
<th>100 - 1,000+</th>
<th>1,000+</th>
<th>0.5-5</th>
<th>1 - 7</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Network Size</th>
<th>100s to 1,000s</th>
<th>10s to 100s</th>
<th>32</th>
<th>7</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Bandwidth (Kbits/s)</th>
<th>20 - 250</th>
<th>0.5 - 1,000</th>
<th>11,000+</th>
<th>720</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Range (meters)</th>
<th>100 - 100+</th>
<th>1 - 7,000+</th>
<th>1 - 30+</th>
<th>1 - 10+</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Network Architecture</th>
<th>Mesh</th>
<th>Point-to-point, low cost</th>
<th>Star</th>
<th>Star</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Optimized For</th>
<th>Reliability, low power, low cost, scalability</th>
<th>Long range, low power, low cost</th>
<th>Speed</th>
<th>Low cost, convenience</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Silicon Labs Products</th>
<th>Ember ZigBee Em5x Series</th>
<th>EZRadio, EZRadioPRO Si10xx wireless MCUs</th>
<th>N/A</th>
<th>N/A</th>
</tr>
</thead>
</table>

---

77
6.1.4 6LowPan Protocol Transceiver Module

6 Low Pan is an internet-based wireless-node-sensor network, which sends and receives data directly from a wireless network without requiring other conversions. It is an advanced wireless network of Zigbee.

It is an advanced wireless network of Zigbee. The 6LowPAN protocol is a high-level wireless communication protocol. The 6LowPan device can transmit data over a long distance by helping data pass through intermediate devices and allowing it to cover more distance than the mesh network. The 6LowPan is used in applications that require only low data rate, long battery life and secure networking.

- The 6LoWPan Network transceivers support UART, SPI or USB protocol.
- The 6LoWPan network transceivers have SoC.
- The 6LoWPan network transceivers use binary phase shift keying (bpsk) modulation technique.
- The operating voltage of 6LowPan transceivers is 1.3-42V.
- A network node consists of 802.15.4 RF transceiver.
6.1.4.1 6LoWPAN's Working Procedure

6LoWPAN is a name of IPv6 over Low power Wireless network. There are two types of devices in 6LoWPan network: Nodes and routers. A router is responsible for establishing, maintaining, and controlling a 6LoWPan network.

The 6LoWPan devices have public IPv6 addresses so several applications can directly communicate with the end devices by their addresses and easily find out the whole wireless sensor network topology. It is very fast accessible and cheap compared with the Xbee protocol.

6.1.4.2 Difference between Zigbee and 6LowPAN Protocols

<table>
<thead>
<tr>
<th>Zigbee Protocol</th>
<th>6LowPan Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Zigbee devices cannot directly communicate with devices on the internet. It needs additional mechanism.</td>
<td>1. The 6LowPan devices can directly communicate with the internet.</td>
</tr>
<tr>
<td>2. ZigBee network is managed by a coordinator which must perform application-layer protocol translations and send data to servers.</td>
<td>2. The servers can collect data directly from end devices without waiting the coordinators to handle the request.</td>
</tr>
<tr>
<td>3. The coordinators in the Zigbee network completely unavailable to communicate with the internet.</td>
<td>3. No need to coordinators directly communicate with their IP address.</td>
</tr>
<tr>
<td>4. Data transmission is very slow.</td>
<td>4. Data transmission is very fast.</td>
</tr>
<tr>
<td>5. The Zigbee network layer uses IEEE 802.15.4 Address.</td>
<td>5. It uses IPv6 internet protocol. It supports 2 power 128 IP address are more than sufficient.</td>
</tr>
</tbody>
</table>
6.1.5 IEEE802.15.4 Protocol

- The IEEE802 is a one standard committee that develops and maintains wired and wireless communication networks standards. For example 802.3 is wired Ethernet, 802.11 for wireless LAN and Wi-Fi.
- The 802.15 group of standards specifies a variety of personal area networks for different applications. For 802.15.1 is a Bluetooth, and 802.15.3 is a high-data-rate category for ultra-wideband technologies.
- The 802.15.4 is a new version of network protocol that supports wireless personal area networks (WAN).
- The 802.15.4 maximum transmission distance is 10m. It can be used with Zigbee, Bluetooth and WI Media technologies and other internet protocols.
- The basic framework conceives a 10-meter communications range with a transfer rate of 250 kbit/s.
- IEEE 802.15.4 specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs).
- The feature of the 802.15.4 protocol that contributes mostly to long battery life is the extremely low duty cycle.
- IEEE 802.15.4 offers three operational frequency bands: 2.4 GHz, 915 MHz, and 868 MHz. There is a single channel between 868 and 868.6 MHz, 10 channels between 902 and 928 MHz, and 16 channels between 2.4 and 2.4835 Ghz.
IEEE802 Protocol

6.1.5.1 IEEE802.15.4 Architecture

OSI Communication (Open System Interconnection)

Most networking systems, both wired and wireless, use the OSI communications model. Most systems also use at least the first four layers, but many do not use all seven layers.

<table>
<thead>
<tr>
<th>Name</th>
<th>Subcommittee</th>
<th>Maximum distances</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMAN (wireless metropolitan area network)</td>
<td>IEEE 802.16</td>
<td>Kilometers</td>
<td>WiMAX</td>
</tr>
<tr>
<td>WLAN (wireless local area network)</td>
<td>IEEE 802.11</td>
<td>Hundreds of meters</td>
<td>Wi-Fi</td>
</tr>
<tr>
<td>WPAN (wireless personal area network)</td>
<td>IEEE 802.15</td>
<td>Tens of meters</td>
<td>ZigBee, Bluetooth, WiMedia</td>
</tr>
</tbody>
</table>
The 802.15.4 standard defines the Physical Layer (PHY) and Media Access Control (MAC) layer of the Open Systems Interconnection (OSI) model of the network operation. The PHY defines frequency, power, modulation, and other wireless conditions of the link. The MAC defines the format of the data handling. The remaining layers define other measures for handling the data and related protocol enhancements including the final application.

The 802.15.4 standard uses only the first two layers plus the logical link control (LLC) and service specific convergence sub-layer (SSCS) additions to communicate with all upper layers as defined by the additional standards.
6.1.6 Wireless Hart Protocol Transceiver Module

The wireless Hart is a wireless sensor networking technology based on Highway Addressable Remote Transducer protocol (HART). Before the release of wireless Hart technology, many industries had been using Zigbee and Bluetooth technologies but these technologies were unable to meet the exacting requirement of industrial control. Wireless HART is a wireless mesh network communications protocol for process automation applications. It adds wireless capabilities to the HART Protocol while maintaining compatibility with the existing HART devices, commands, and tools.

- The WirelessHart Network transceivers support UART and SPI protocol.
- The WirelessHart network transceivers have SoC.
- The WirelessHart network transceivers use quadrature phase shift keying (QPSK and DSSS) and supports modulation technique.
- The operating voltage of Wireless HART transceivers is 3.6V.
- A network node consists of 802.15.4 RF transceiver.
- The transmission distance is about 1 to 250m.

6.1.6.1 Wireless Hart Working Procedure

Each Wireless HART network includes three main elements:

- **Wireless field devices** are connected to a process or plant equipment. This device could be a device with WirelessHART built in or an existing installed HART-enabled device with a WirelessHART adapter attached to it.

- **Gateways** enable communication between the devices and host applications connected to a high-speed backbone or other existing plant-communications network.

**A Network Manager** is responsible for configuring the network, scheduling communications between devices, managing message routes, and monitoring network health. The Network Manager can be integrated into the gateway, host application, or process automation controller.
Each device in the mesh network can serve as a router for the messages from other devices. In other words, a device doesn't have to communicate directly to a gateway, but just forwards its message to the next closest device. This extends the range of the network and provides redundant communication routes to increase reliability.

6.1.7 ANT Protocol Transceiver Module

ANT is a proprietary open access multi-cast wireless sensor network technology. Each ANT channel consists of one or more transmitting nodes and one or more receiving nodes, depending on the network topology. Any node can transmit or receive, so the channels are bidirectional.

ANT accommodates three types of messaging: broadcast, acknowledged, and burst. Broadcast is a one-way communication from one node to another (or many). The receiving node(s) transmit no acknowledgment, but the receiving node may still send messages back to the transmitting node.

This technique is suited for sensor applications and is the most economical method of operation.

Acknowledged messaging confirms receipt of data packets. The transmitter is informed of success or failure, although there are no retransmissions. This technique is suited to control applications.
• The ANT Network transceivers support UART and SPI protocol.
• The ANT network transceivers have SoC.
• The ANT transceivers use Gaussian Frequency Shift Keying (GFSK) modulation technique.
• The operating voltage of Wireless HART transceivers is 2-3.6V.
• A network node consists of 802.15.4 RF transceiver.
• The transmission distance is about 50 to 100m.
6.1.8 Ultra-low-power Transceiver Module

Ultra-low-power technology is a high-speed low-powered wireless technology, which establishes communication from router to computers. All nodes are routers; they can transmit and receive the data from an accelerometer device to the computers.

- The Ultra-low-power transceivers support UART and SPI protocol.
- The Ultra-low-power transceivers have SoC.
- The Ultra-low-power transceivers use and support On-Off keying (OOK) modulation technique.
- The operating voltage of Wireless HART transceivers is 2.1-3.6V.
- A network node consists of 802.15.4 RF transceiver.
- The transmission distance is 20m.