Assignment 1

Wireless Technology

Submited to

Dr. Steven Gordon

Prepared to

1. Nutsuda Isarangporn 5122780125
2. Hutchaganit Putiprawan 5122790090
3. Chanapa Leelaphiwat 5122790439
4. Puthanat Tokarnka 5122792674

ITS323 Introduction of Data Communication

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Sirindhorn International Institute of Technology

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Introduction

Now a day, wireless technology is an important for telecommunication that provides the network infrastructure to enable short range or long range wireless communication of data and voice. It comprises of a hardware component and a software component. This project describes about information of ZigBee, Bluetooth, Wireless LAN, and WiMAX. This information all of them related to real-world technologies with the concepts covered in ITS323 introduction of data communication including:

- Protocol Architectures layered stacks, protocols, standards, and standard organizations

- Data Transmission spectrum, frequency, bandwidth, and data rates
- Transmission Media transmit power, receive thresholds, antennas, and distance
- Signal Encoding Techniques analog/digital data/signals
- Errors error detection, error correction, ARQ
- Application
- Usage
- Cost

In addition, we have comparing all of wireless technology for each characteristic that make us know how it differs for each wireless.

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.: ZigBee :.

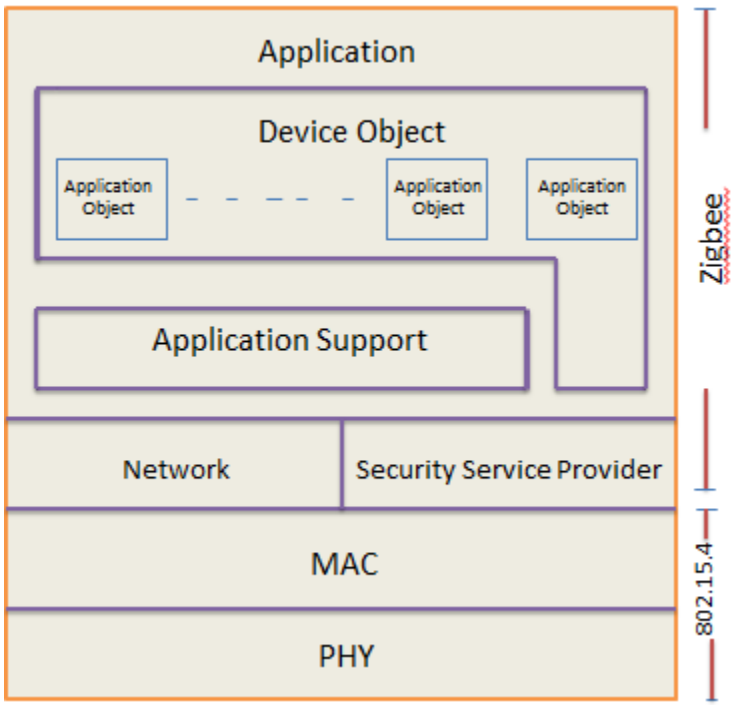
Name of ZigBee is come from the action of bee (Zigzag behavior) that they will communicate with each other about the position distance direction of its food.

ZigBee is fixed by ZigBee Alliance that is A wireless communication which is low data rate , low power , low cost and the main purpose of ZigBee is for create the Wireless Sensor Network that can work indoor outdoor weatherproof and long battery life that can still be for a year.

Protocol Architectures

ZigBee Stack Level

The ZigBee Stack levels provide the ZigBee functional and provide the glue between the applications and the Physical/Data Link level. It consists of stack layers concerned with network structure, routing and security



ZigBee Protocol

The ZigBee protocol is created and permitted by member companies of the ZigBee Alliance. The ZigBee protocol was designed to provide for easy to use wireless data solution characterized by secure, reliable wireless network architectures. The ZigBee protocol is designed to communicate data through resist RF environments that are common in commercial and industrial applications.

ZigBee protocol features

* Support for multiple network topologies such as point-to-point, point-to-multipoint and mesh networks
* Low duty cycle – provides long battery life
* Low latency

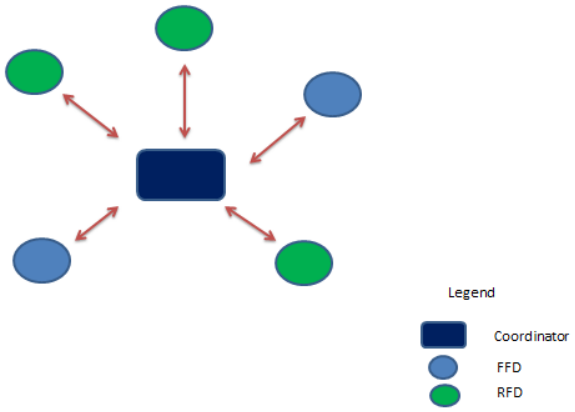
* Direct Sequence Spread Spectrum (DSSS)
* Up to 65,000 nodes per network
* 128-bit AES encryption for secure data connections

Collision avoidance, retries and acknowledgements

NETWORK CONFIGURATIONS

Star Network

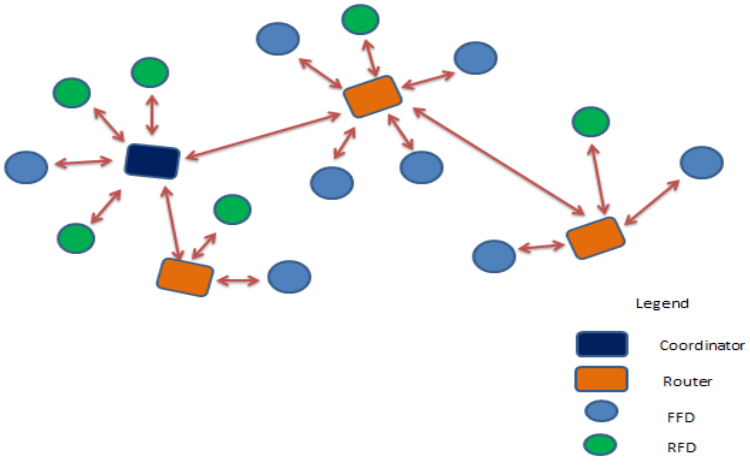
Star Network including 1 coordinator and 1 end device. All of end device will connect to only coordinator. If end device want to send some information to another end device, it should to send to coordinator and coordinator will send to target end device.



Cluster tree

Cluster tree have router increasing from Star Network and end device can contact to router or may contact to coordinator.

Router have 2 action are increasing amount of node that can participation in the network and increasing the physical distance of network that make end device can stay outside the area of radio

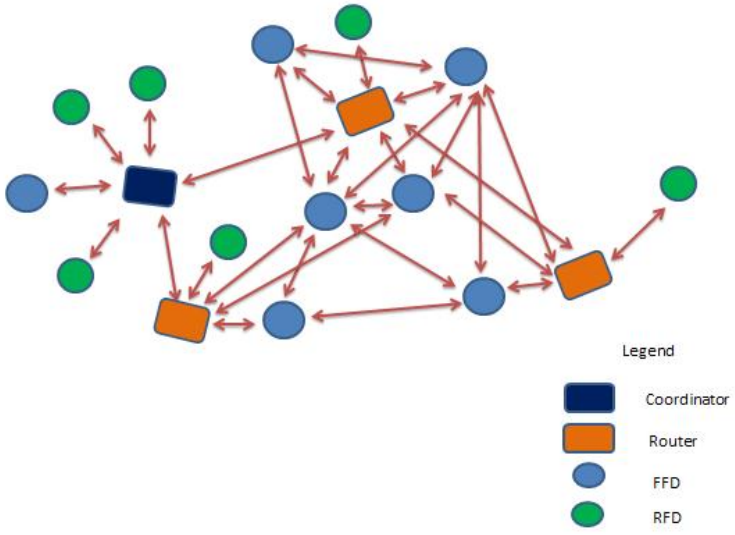


signal of coordinator.

Mesh Network

Mesh Network is similar to Cluster tree but difference that FFD of Mesh Network can sent data between each other directly. For the advantage, it can decrease the message latency and increasing the reliability to the system.

A key component of the ZigBee protocol is the ability to support mesh networking. In a mesh network, nodes are connected with other nodes so that multiple pathways connect each node. Mesh networks are decentralized in nature, each node is capable of self-discovery on the network. Also, as nodes leave the network, the mesh topology allows the nodes to reconfigure route paths based on the new network structure. The characteristic of mesh topology and ad-hoc routing provide greater stability in changing conditions or failure at single nodes.



Standard/standard organisation

ZigBee is a basic of a technology standard that based on IEEE 802.15.4 standard. This standard is created mainly sensor network and control. Within the organization of IEEE (Institute of Electrical and the Electronics Engineer) and for about "802" is a group which deals with the network technology and operation. Apart from the IEEE standard, the

Zigbee standard has been built for addressing the sensory network control and remote monitoring applications. The standard is created by Zigbee Alliance, which is an organization consisting of various industry and company leaders which strived to enable control devices using the standard.

Data Transmission

ZigBee is designated range of frequency by standard for 3 ranges. The frequency need in the unlicensed 2.4 GHz

For worldwide that has 16 channels and the Data rate is 250kbps (0.24 Mbps) each channel need bandwidth about 5 MHz

For America and some of Pacific Rim need 902-928 MHz have 10 channels and Data rate is about 40 kbps.

Some countries in Europe need 868 MHz have only 1 channel and Data rate is 20Kbps.

For spectrum is about 2.4 GHz. They are using direct-sequence spread spectrum.

Transmission Media

Type of ZigBee antenna that will be suitable can vary greatly depending on the intended use of the device but in the commonly used in the 2.4 GHz and the transmit power is -4 to +20dBm

- For 2.4 GHz, the minimum receiver sensitivity is -85 dBm.
- For 900 MHz, it is about -92 MHz.

These are specified by the 802.15.4 standard. The Alteration about 10 dBm is large effecting to system. The minimum output power also is specified by the 802.15.4 standard. It needs to have -3dBm or 0.5mW

In nowadays, there are usually use about 0dBm or 3dBm. The range of Zigbee is depends on receive power and transmit power.

For the distance, the normal Zigbee is between 10 and 75 meters and ZigBee pro can up to 1500 meters.

Signal Encoding Techniques

Zigbee implement IEEE 802.15.4 in lower layer. The higher layer is controlled by ZigBee alliance.

Coordinator have to create the communication that connected to network between End device and Router or Coordinator and Coordinator also Coordinator and Router. Router can act as an intermediate router, passing on data from other devices. The end device using for receive the signal from Sensor at destination and use the low power.

Routers is send and receive data on the path of network, monitor signal of incoming connection such as active channel then authorize that connection to send and receive with other. The action of router happens on coordinator. Coordinator has to communicate and link connection between end device and router, coordinator and coordinator or coordinator and router. Every device on network is managed by coordinator to not have any conflict address and routing path. If there is unused channel, coordinator can start network on it. Digital radio has been send into data frame.

Error

When the ACK frame is transmitted to the receiver when the receiver got the data, the receiver does not sent the data back so it have to wait for data back from the receiver but if no data back it will does not know it has an error or not so, no error of transmitted and considered it as complete frame transmission (cannot find the error correction + ARQ).

Application

Sensor networks

Typical application areas

- **Home Entertainment and Control**
  - Smart lighting
  - Temperature control,

- Safety and security
- Movies and music

- **Home Awareness**
  - Water sensors
  - Power sensors
  - Energy monitoring
  - Smoke and fire detectors
  - Smart appliances and access sensors
- **Mobile Services**
  - m-payment
  - m-monitoring and control
  - m-security and access control
  - m-healthcare and tele-assist
- **Commercial Building**
  - Energy monitoring
  - HVAC
  - Lighting
  - Access control

- **Industrial Plant**
  - Process control
  - Asset management
  - Environmental management
  - Energy management
  - Industrial device control
  - Machine-to-machine (M2M) communication

Device types

There are three different types of ZigBee devices:

- **ZigBee coordinator (ZC)**

The most capable device, Coordinator have to create the communication that connected to network between End device and Router or Coordinator and Coordinator also Coordinator and Router. Define address for the device that inside the network for make it not duplicate. Manage the Routing way

- **ZigBee Router (ZR)**

As well as running an application function, a router can act as an intermediate router, passing on data from other devices.

- **ZigBee End Device (ZED)**

The end device, that use for receiving the signal from Sensor at destination and use the low power.

Usage

The benefit of ZigBee is that it is designed for situations that need to communicate small amounts of data while using less energy to transmit that data. The Zigbee is its ability to be configured in so-called mesh networks with wireless nodes that are capable for many years' battery lives. In a mesh topology, each node is in direct communication with its immediate neighbor: if a node fail, messages are automatic redirected a sort of miniature Internet. ZigBee also support more efficient star topologies in which central access points talk to the nodes.

ZigBee is actually the network protocol, security, and application layer for one type of network that can run on radios according to the 802.15 standard of the Institute of Electrical and Electronics Engineers Inc. (IEEE), an umbrella that also covers Bluetooth and other types of wireless personal area networks (WPANs). The physical layers for ZigBee transmitters are described in IEEE 802.15.4 and were approved last year.

The Zigbee protocol was designed to be optimal for the control and sensor application space. It is less complex than Bluetooth, has superior power management (Just 2 AA battery can make ZigBee module still for last over years), supports many more nodes per network, has lower latency, permit devices join the network more quickly.

But in Thailand, Zigbee is not the most popular of wireless network like the other country because in other country ZigBee is already well known. But in Thailand the chip cost of ZigBee is the same price with Bluetooth chip so, they know too much about Bluetooth but don't know too much about ZigBee then they will pay for something that you already know but in the future , the cost may be decreasing because nowadays ZigBee is now popular Industry logistic etc.

Advantage/Disadvantage

Advantages

The main advantage of ZigBee is its ability to be configured in so-called mesh networks with wireless nodes that are capable for many years battery lives. In a mesh topology, each node is in direct communication with its immediate neighbor: if a node fail, messages are automatic redirected a sort of miniature Internet. ZigBee also support more efficient star topologies in which central access points talk to the nodes.

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Disadvantage

In the whole network only one node can transmit data to the bus at anyone moment and all other nodes must be in receiving status. If there are two or more nodes transmitting data to the bus at the same time, all transmission fails

A special communication cable is needed. The maximum communication distance depends on communication cable type.

Cost

ZigBee is a cheap wireless technology of the future. It is a technology of the next generation and for the third world. Batteries for the ZigBee can be maintained for a long time. It will connect all kinds of wireless devices

at home, office and the business place also. For the cost, ZigBee use the lowest cost than the other wireless network and the price is starting at $3 cost.

.: Bluetooth :.

Bluetooth is a wireless protocol for exchanging data over short distances for creating personal area networks. The IEEE 802.15.1 has derived a Wireless Personal Area Network standard based on the Bluetooth. It was developed by Ericsson. Bluetooth is widely used in much type of devices like Personal Digital Assistant (PDAs), computer peripherals (for example mice, keyboards, joysticks, cameras, printers, LAN access points etc.), cell phones, audio peripherals and other many more applications. The radio technology used in Bluetooth is Frequency Hopping Spread Spectrum (FHSS) which send the data in the form of chunks over entire 79 channels. It reduces the interference the Bluetooth technology utilizes Adaptive Frequency Hopping (AFH) mechanism. Frequency hopping works within the available spectrum to take advantage of the available frequency. This frequency hopping provides more efficient transmission within the spectrum, providing users with greater performance even if they

are using other technologies along with Bluetooth technology. The maximum range for Bluetooth radio is 10m but it can be extended up by using amplifiers to 100m by using amplifiers. The data rate achieved is 1 Mb/s The Bluetooth standard work on ISM band on 2.4 GHz frequency range, which is available globally unlicensed. The asynchronous channel can support maximal 723.2 kbps and asymmetric or 433.9 kbps symmetric. The Bluetooth for connection have two characters

1. **Asynchronous Connectionless (ACL)**

Use for general data communication and support the connection for both symmetric and asymmetric. Multi-slot packet use ACL can have a maximum data rate for only direction is 723 Kbps and 57.6 kbps for other direction. The master will control bandwidth to provide slave that use and also ACL support for broadcast message.

2. **Synchronous Connection Oriented (SCO)**

Use for audio data communication and support the connection for symmetric, circuit switch, and point-to-point connection. The connection for symmetric has data transmission is 64 kbps and can be connected to three channels simultaneously.

Protocol Architecture

Bluetooth communication occurs between a master radio and a slave radio. Bluetooth radios are symmetric in that the same device may operate as a master and also the slave. Each radio has a 48 bit unique device address (BD_ADDR) that is fixed. Two or more radio devices together form ad-hoc networks called piconets. All units within a piconet share the same channel. Each piconet has one master device and one or more slaves. There may be up to seven active slaves at a time within a piconet. Therefore, each active device within a piconet is identifiable by a 3 bit active device address. Inactive slaves in unconnected modes may continue to reside within the piconet. A master is the only one that may initiate a Bluetooth communication link. However, once a link is established, the slave may request a master/slave switch to become the master. Slaves are

not allowed to talk to each other directly. All communication occurs within the slave and the master. Slaves within a piconet must also synchronize their internal clocks and frequency hops with that of the master. Each piconet uses a different frequency hopping sequence. Radio devices used Time Division Multiplexing (TDM). A master device in a piconet transmits on even numbered slots and the slaves may transmit on odd numbered slots. Multiple piconets with overlapping coverage areas form a scatternet. Each piconet may have only one master, but slaves may participate in different piconets on a time-division multiplex basis. A device may be a master in one piconet and a slave in another or a slave in more than one piconet.

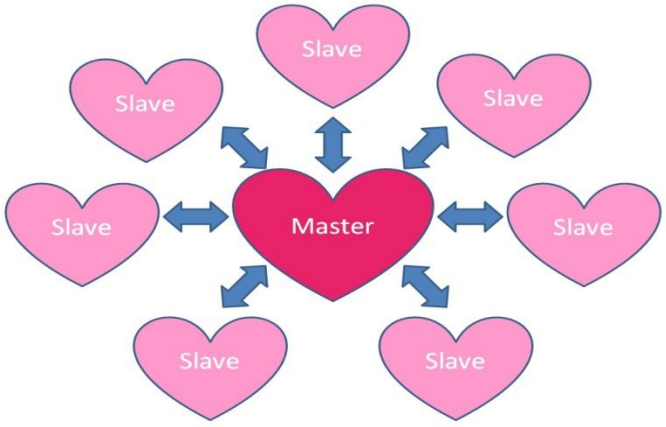


Figure.1: Piconet in Bluetooth

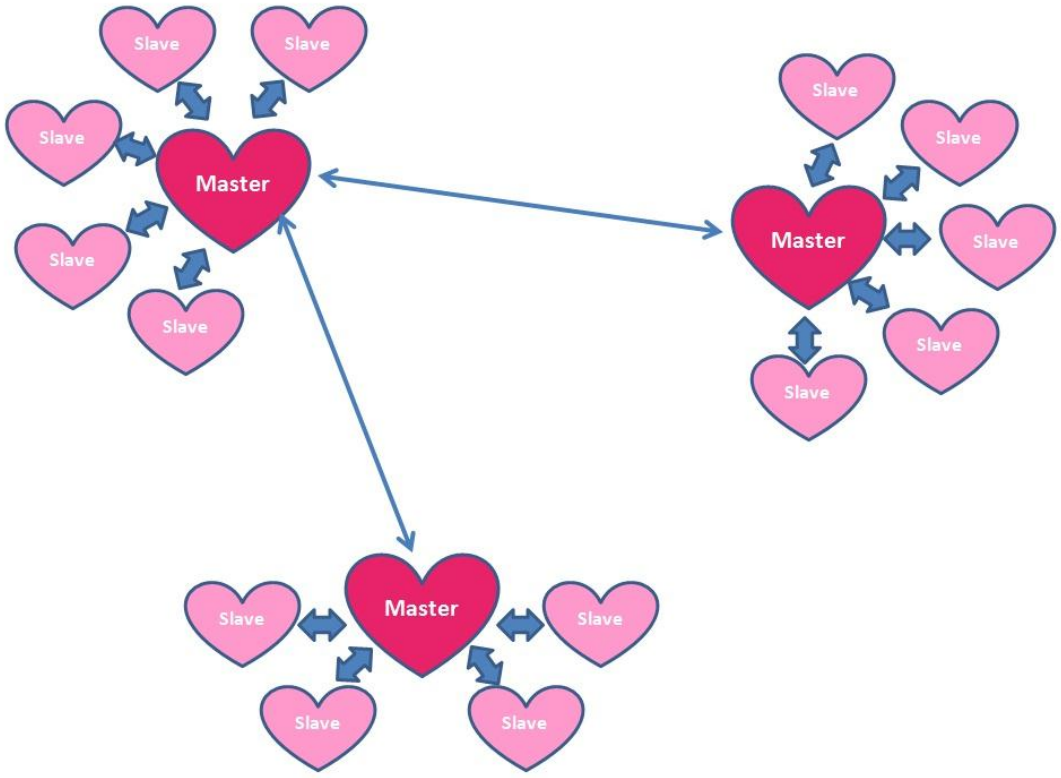


Figure.2: Scatternet formation

Protocol stacks

Bluetooth stack is composition of software or firmware that has capability to access work of device Bluetooth for using control of devices. The following component including:

1. Base-band Layer

Baseband layer also called baseband packet. It is a physical layer protocol in the Bluetooth protocol stack. The Baseband in the Bluetooth manages physical channels and links apart from other services like error correction, data whitening, hop selection and Bluetooth security. The Baseband layer is on a top of the Bluetooth radio layer in the Bluetooth

stack. The baseband protocol is implemented as a Link Controller that works with the link manager for carrying out link level routines like link connection and power control. The baseband also manages asynchronous and synchronous links, handles packets and does paging and inquiry to access and inquire Bluetooth devices in the area.

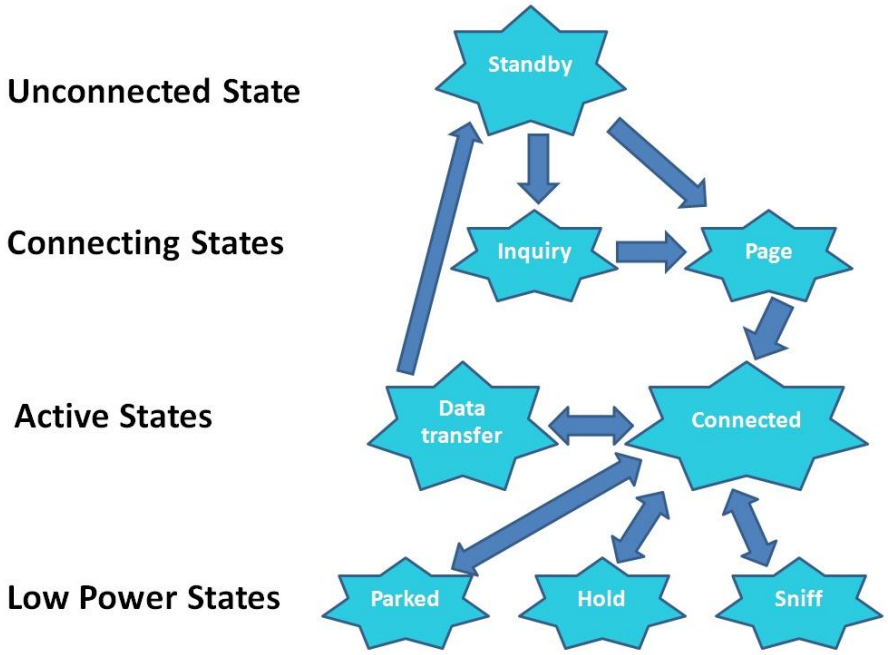


Figure.3: The Baseband State Machine.

2. **Link Manager Protocol**

Used for control of the radio link between two devices. Implement on the controller. This includes the set-up and control of logical transports and logical links and for control of physical links. The Link Manager Protocol is used to communicate between the Link Managers (LM) on the two devices which are connected by the ACL logical transport.

3. **HCI (Host Controller Interface)**

This layer is the HCI provides an interface to the baseband controller and link manager, and access to configuration parameters. This interface

provides a uniform method of accessing the Bluetooth baseband capabilities.

4. **L2CAP (Logical Link Control and Adaptation Protocol)**

L2CAP supports higher level protocol multiplexing, packet segmentation and reassembly, and the conveying of quality of service information. It permits higher level protocols and applications to transmit and receive upper layer data packets up to 64 kilobytes in length. L2CAP also permits per-channel flow control and retransmission via the Flow Control and Retransmission Modes. The L2CAP layer provides logical channels, named L2CAP channels, which are mapped to L2CAP logical links supported by an ACL logical transport.

5. **RFCOMM**

The RFCOMM protocol emulates the serial cable line settings and status of an RS-232 serial port and it is used for provide serial data transfer. The RFCOMM connects to the lower layers of the Bluetooth protocol stack through the L2CAP layer.

6. **SDP (Service Discovery Protocol)**

SDP provides for applications to discover that services are available and to determine the characteristics of those available services.

7. **TCS Binary (Telephony Control-Binary)**

The bit-oriented protocol that defines the call control signal for establish of voice and data calls between Bluetooth devices. In addition, TCS BIN defines mobility management procedure for handling groups of Bluetooth TCS devices.

8. **BNEP (Bluetooth Network Encapsulation Protocol)**

BNEP is used for transfer another protocol stack of data via an L2CAP channel. Its main purpose is the transmission of IP packets in the Personal

Area Networking Profile. BNEP performs a similar function to SNAP in Wireless LAN.

9. **AVCTP (Audio/Visual Control Transport Protocol)**

Used by the remote control profile to transfer AV/C commands over an L2CAP channel. The music control buttons on a stereo headset use this protocol to control the music player.

10. **AVDTP (Audio/Visual Data Transport Protocol)**

Used by the advanced audio distribution profile to stream music to stereo headsets over an L2CAP channel. It intended to be used by video distribution profile.

11. **Adopted protocols**

Point-to-Point Protocol (PPP) is the internet standard protocol for transport IP datagram over a point-to-point link.

TCP/IP/UDP is the foundation Protocols for TCP/IP protocol suite.
Object Exchange Protocol (OBEX) is the session-layer protocol for the exchange of objects, providing a model for object and operation representation.

Wireless Application Environment/Wireless Application Protocol (WAE/WAP) is the WAE, it specifies an application framework for wireless devices and WAP is an open standard to provide mobile users access to telephony and information services.

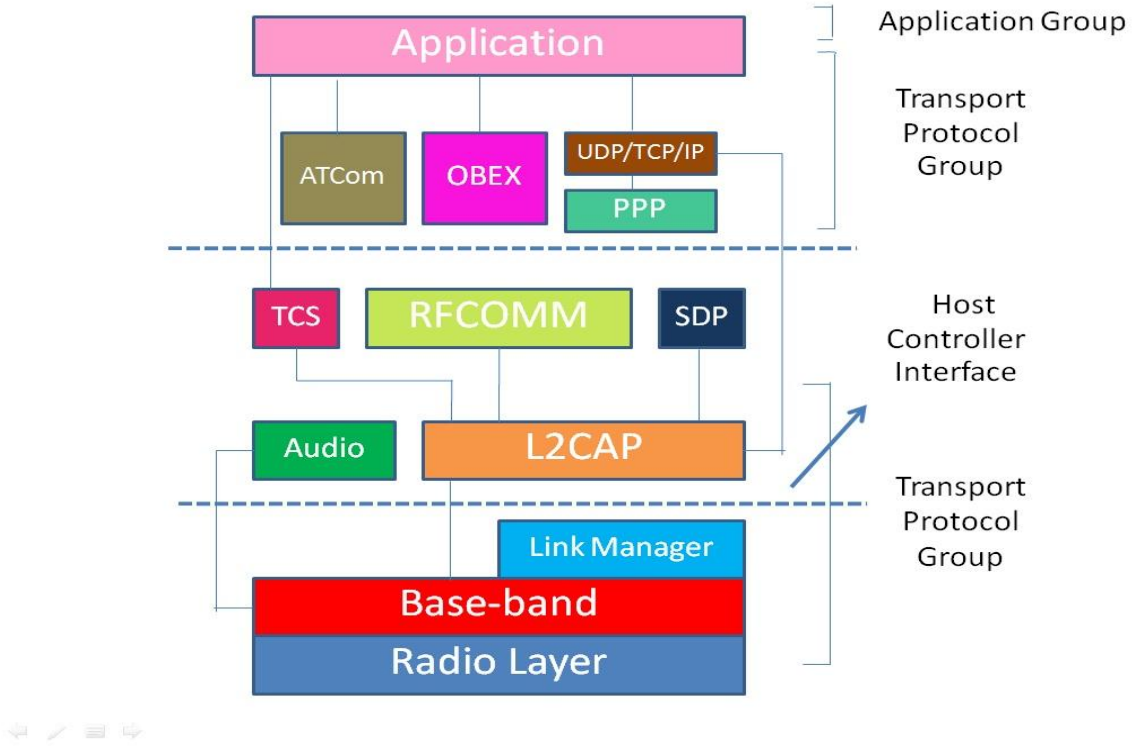


Figure.4: Bluetooth protocol Stack

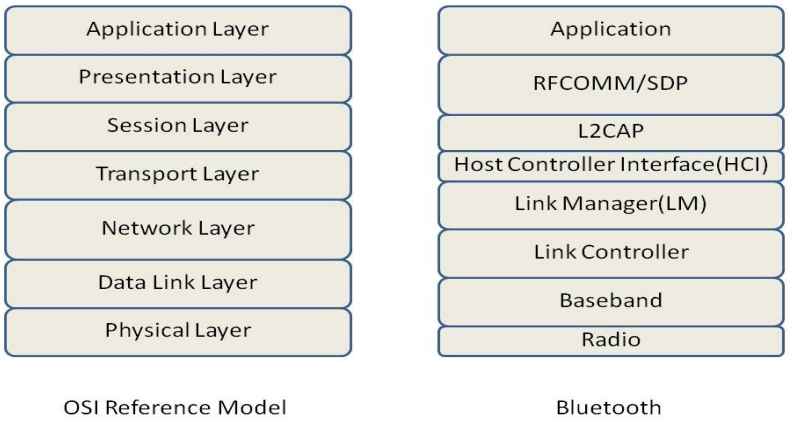


Figure.5: Bluetooth protocol stack compared to OSI reference model

Transmission Media

Bluetooth technology was designed and intended to work all around the world. Therefore, the frequency band is common throughout all territory across the global. Bluetooth transceiver operates in the 2.4 GHz band. The unlicensed 2.4 GHz band is identified by the International Telecommunications Union-Radio regulations as an Industrial, Scientific and Medical applications. This means that, within this band, there are also other devices, which are not actually radio communication systems but which do affect the quality and usefulness of the spectrum. The radio waves are referred to electromagnetic waves for comprise of both electrical and magnetic fields. These two fields sum up together are term electromagnetic fields. It is perpendicular to each other and energy flows to and from these two fields. This movement of energy is called Oscillation. The radio waves possess the quality of travelling through space and are similar in behavior and speed that of light. The wavelength of a Bluetooth radio signal is 12.5 cms and of visible light is 5*(10 power -5) cms. Wavelength of a signal is the total distance travelled by the signal to complete one penetrates through obstructions. However, the radio signals penetrate though obstacles, it become slower in frequency and their wavelength becomes longer due to the various preoperational effects. The power consumption of the radio unit is extremely low, ranging from 1mWatt (0 dBm) to 100mWatt (30 dBm) depend on the required operation mode. The receive thresholds are -70 dBm

Antenna

Antenna is name to device it can transmit or receive radio signals. It possesses the ability to convert a radio frequency field into power levels and vice versa. Antennas use free air space signal carrier medium. The antenna, it depends on its function could be categorized into 2 different types:

- Receiver
- Transmitter

The receiver collects radio signal energy levels, interprets and converts them to the electronic equipment. On the other hand, a transmitter receives level from their respective electronic device and interprets them into RF fields ready for transmission. A transmitter basically excites the signal at the base to transmit it.

Antennas form an integral part of devices that employ radio system. They act an interface between their respective devices and the carrier medium. When the transmitter of an antenna transmits a signal, a magnetic field is radiated. This radiated magnetic field, on striking any metallic surface, produces an electric current. Such induced current will be stronger or weaker depend on the relation between surface area/length of the metal surface and the wavelength of the signal. For example, a Bluetooth signal having a cycle length of about 12 cms on striking an antenna of 12 cms or fractions of it, i.e. 6 cms or 3cms produces a stronger induced current than that is produced on striking a metallic body without such relative length. Such a relation is termed "Resonance". Each antenna has at least one exact resonance point.

A radio signal transmitted at 2.4 GHz has a wavelength less than 12 cms that means an antenna could be built very small. The antenna size could be further reducing if its exterior is coated with a layer of high permittivity material. This is so because the coating provides a resonance point in a much shorter antenna for the same frequency when compared with an antenna without the coating.

Error

Error detection is the detection of errors caused by noise or other impairments during transmission from the transmitter to the receiver.

Error correction is the detection of errors and reconstruction of the original, error-free data. Error correction may generally be realized in two different ways

1. **Automatic repeat request (ARQ)**

Sometimes it also referred to as backward error correction. This is an error control technique therefore an error detection scheme is combined with requests for retransmission of mistaken data. Every block of data received is checked use the error detection code used, and if the check fails, retransmission of the data is requested. This may be done repeated, until the data can be verified. The types of ARQ protocols include

- Stop-and-wait ARQ
- Go-Back-N ARQ
- Selective Repeat ARQ

2. **Forward error correction (FEC)**

The sender encodes the data using an error-correcting code (ECC) prior to transmission. The additional information added by the code is used by the receiver to recover the original data.

ARQ and FEC may be combined, such that minor errors are corrected without retransmission, and major errors are corrected via a request for retransmission. This is called hybrid automatic repeat-request (HARQ).

Three types of error correction are implemented in Bluetooth systems

- 1/3 rate forward error correction (FEC) - every bit is repeated three times for redundancy
- 2/3 rates FEC - a generator polynomial is used to encode 10 bit code to a 15 bit code
- Automatic repeat-request (ARQ) - DM, DH and the data field of DV packets are retransmitted till an acknowledgement is received. Bluetooth uses fast, unnumbered acknowledgement in which it uses positive and negative acknowledgements by setting appropriate ARQN values. If the timeout value is exceeded, Bluetooth flushes the packet and proceeds with the next.

Bluetooth Application

A few other applications are as follows:

- Wireless control of and communication between a mobile phone and a hands free headset. And this application is a popular.
- Travelling in a plane, a person may write but not send e-mail. When the plane touches down the Bluetooth enabled laptop will communicate with the user's phone and will automatically send them.
- Mouse and keyboard will identify themselves to the computer without intervention, or could also be used to command TVs, videos or hi-fis at the touch.
- Transfer of files, contact details, calendar appointments, and reminders between devices with OBEX.
- Wireless bridge between two Industrial Ethernet networks.
- Sending small advertisements from Bluetooth-enabled advertising hoardings to other, discoverable, Bluetooth devices.
- For controls where infrared was traditionally used.
- Allowing a DECT phone to ring and answer calls on behalf of a nearby cell phone.

Future Application for Bluetooth

- Retail and Mobile e-Commerce Bluetooth is support use that of a mobile device as a method of payment for goods and services. It used for retail transactions could incorporate Bluetooth wireless technology and thus connect to other Bluetooth devices to complete retail transactions.
- Medical will use Bluetooth for remote patient monitoring, wireless biometric data, and medicine dispensers.
- The travel industry is always seeking new ways to save time and enhance convenience for travelers. This present a few ways in which Bluetooth wireless technology could enhance travel scenarios.
- Home networking, in-home networks are becoming more common as people want to enhance their convenience, security

and safety at home and use their personal devices in home environments

Usage of Bluetooth

Bluetooth is a technology that simplifies the process of having two or more devices communicate with each other wirelessly. Originally developed to eliminate serial cabling, Bluetooth has become a robust technology with multiple applications. It is used in headsets, cell phones, computers, and other game consoles.

The most advantage of Bluetooth is that it is wireless. Wiring causes clutter, limits mobility and can be an added expense to an installation. Bluetooth removes to need for wiring and the problems that come along with it.

Bluetooth is activated devices within 30 feet of each other will find another. Some Bluetooth devices will require you to enter a security code to complete pairing, but overall Bluetooth is light years easier to configure than your home wireless network.

The low amount of power consumption for the devices makes it ideal for small, portable devices. The average Bluetooth device uses about 2.5 miliwatts of power. Bluetooth is also designed to have the ability to power its radio down during periods of inactivity.

Standardizing Bluetooth technology ensures that it will be always be compatible, even with devices made by different manufacturers. This means yours Nokia Bluetooth-capable cell phone will work with your Plantronics Bluetooth headsets.

Bluetooth is inexpensive to manufacture and implement. The devices contain inexpensive circuitry, and the ease of installing it passes the savings on to the end user.

Advantage/Disadvantage

Advantage

Bluetooth has a lot to offer with an increasingly difficult market place. Bluetooth helps to bring with it the promise of freedom from the cables and simplicity in networking that has yet to be matched by LAN (Local Area Network).

In marketplace, of wireless and handheld devices, the closest competitor to Bluetooth is infrared. Infrared holds many key features, although the line of sight it provides doesn't go through walls or through obstacles like that of the Bluetooth technology. Unlike infrared, Bluetooth isn't a line of sight and it provides ranges of up to 100 meters. Bluetooth is also low power and low processing with an overhead protocol. What this means, is that it's ideal for integration into small battery powered devices. To put it short, the applications with Bluetooth are virtually endless.

Disadvantage

Bluetooth has several positive features and one would be extremely hard pressed to find downsides when given the current competition. The only real downsides are the data rate and security. Infrared can have data rates of up to 4 Mbps which provides very fast rates for data transfer, while Bluetooth only offers 1 Mbps.

For this very reason, infrared has yet to be dispensed with completely and considered by many to be the complimentary technology to that of Bluetooth. Infrared has inherent security due to its line of sight. The greater range and radio frequency (RF) of Bluetooth make it much more open to interception and attack. For this reason, security is a very key aspect to the Bluetooth specification. Although there are very few disadvantages, Bluetooth still remains the best for short range wireless technology. Those who have tried it love it, and they know for a fact that Bluetooth will be around for years to come.

Bluetooth Costs

Bluetooth devices use low-cost transceiver microchips, so the cost of manufacturing Bluetooth enabled devices is relatively low. Bluetooth chips are estimated to cost around $4 to manufacture. As a result, the prices of consumer Bluetooth devices are low. Moreover, since Bluetooth technology operates on an unlicensed radio spectrum, there is no charge for communicating between two Bluetooth devices. It's FREE. The only cost the consumer receives is the cost of the actual product that is enabled with Bluetooth technology. However, some use of Bluetooth technology, data, or voice, using your cell phone is part of your regular cell phone bill. There is no account or service registry associated with using Bluetooth technology.

.: WIRELESS LAN :.

Wireless LAN technology is a lot of attention. Due to technology of Wireless LAN (WLAN) can applied to the organization, schools and Government agencies. And save costs to the installing of the Wireless LAN network, it's a high flexibility of moving equipment connected to the network.

Wireless LAN is a flexible data communication system implemented as an extension or as an alternative for, a wired LAN within a building or campus. Using electromagnetic waves, WLAN's transmits and receive data over the air, minimizing the need for wired connections. Thus, WLANs combine data connectivity with user mobility, and, through simplified configuration, enable movable LANs. Over the last seven years, WLANs have gained strong popularity in a number of vertical markets, including the health-care, retail, manufacturing, warehousing, and academic arenas. These industries have profited from the productivity gains of using hand-held terminals and notebook computers to transmit real-time information to centralized hosts for processing. Today WLANs are becoming more widely recognized as a general-purpose connectivity alternative for a broad range of business customers.

A Wireless Local Area Network (WLAN) implements a flexible data communication system frequently augmenting rather than replacing a wired LAN within a building or campus. WLANs use radio frequency to transmit and receive data over the air, minimizing the need for wired connections.

Protocol Architectures

802.11 Protocol Stack

A protocol stack is a particular software implementation of a computer networking protocol suite. The terms are often used interchangeably. Strictly speaking, the suite is the definition of the protocols, and the stack is the software implementation of them. Individual protocols within a suite are often designed with a single purpose in mind. This modularization makes design and evaluation easier. Because each protocol module usually communicates with two others, they are commonly imagined as layers in a stack of protocols. The lowest protocol always deals with "low-level", physical interaction of the hardware. Every higher layer adds more features. User applications habitually deal only with the topmost layers. The protocols used by all the 802 variants including Ethernet have certain.

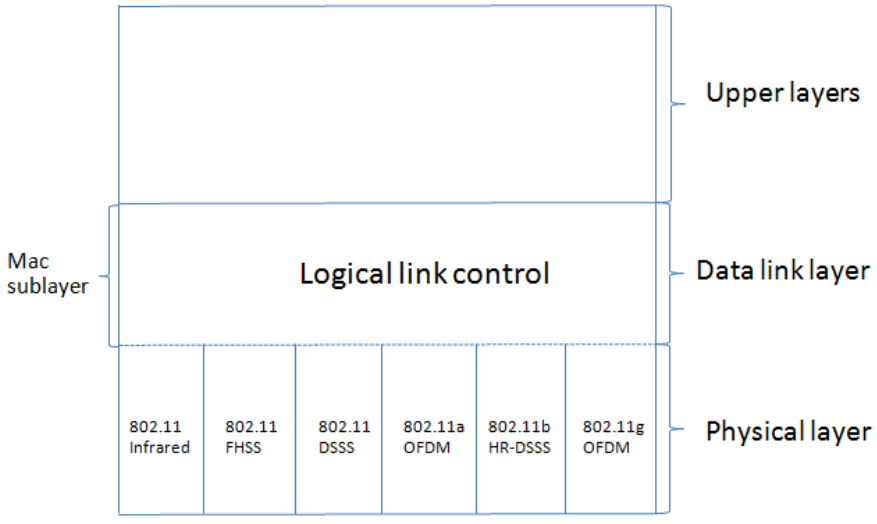


Figure 1: Protocol Architecture of Wireless LAN

Wireless LAN standards

The 802.11a, b, and g standards are the most common for home wireless access points and large business wireless systems. The differences are:

802.11a: A standard relies on a technology that called OFDM (Orthogonal Frequency Division Multiplexing and standard for govern wireless networking transmission methods. It has data transfer rates maximum up to 54Mbps per second and broadcasts in the 5GHz frequency range. It is faster than 802.11b.and can support more simultaneous connections. The 802.11a has the shortest range of the three standards and have an expensive cost so it isn't popular

802.11b: The 802.11b use the standard called CCK (Complimentary Code Keying) and DSSS (Direct Sequence Spread Spectrum).It supports data transfer maximum speeds up to 11Mbps and using the same 2.4 GHz band but doesn't support as many simultaneous connections. This standard is a frequency that allows use in the public science, industry and medical. This standard is supported Bluetooth devices, Cordless telephones, Baby monitors and Microwave ovens. It's more susceptible to Irritant because it use the same frequency but the advantage of 802.11b is support a wider area than 802.11a

802.11g: The 802.11g uses the standard called OFDM (orthogonal frequency-division multiplexing) on the radio wave that has frequency 2.4 GHz. It supports data transfer maximum rates up to 54Mbps at the ranges of the comparable with 802.11b that it has a slightly shorter range than 802.11b, but still better than 802.11a. But still has the same problems with interference as 802.11b**.**

The IEEE Standard

For over a century, the IEEE-SA has offered an established standards development program that features balance, openness, processing, and consensus.

The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) is the leading developer of global industry standards in a broad-range of industries, including:

- Power and Energy
- Biomedical and Healthcare
- Information Technology
- Telecommunications
- Transportation
- Nanotechnology
- Information Assurance

Standard Organizations of 802.11 Wirelesses LAN

IEEE Standard 802.11-1997 Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks- Specific requirements

International Standard ISO/IEC 8802-11: 1999(E) ANSI/IEEE Standard 802.11, 1999 Edition Information technology- Telecommunications and information exchange between systems- Local and metropolitan area networks- Specific requirements

IEEE Approved Draft P802.11c/D6.1, 1998 AE 5688 Information Technology- Telecommunications and information exchange between systems-Local area networks

Data Transmission

Spread Spectrum

Most of the wireless LAN systems use a spread-spectrum technology, a wideband radio frequency technique for use in reliable, security and mission-critical communications systems.

Spread-spectrum is designed for trade off bandwidth efficiency for reliability, integrity, and security.

There are two types of spread spectrum radio: frequency hopping and direct sequence.

Frequency-Hopping Spread Spectrum Technology

Frequency-hopping spread-spectrum (FHSS) uses a narrowband carrier that changes frequency in a pattern known to both of transmitter and receiver. Properly synchronized, the net effect is to maintain a single logical channel. To an unintended receiver, FHSS appears to be short-duration impulse noise.

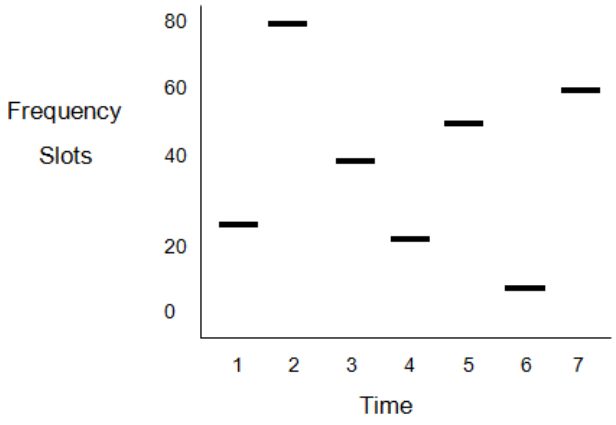


Figure 2: Frequency-Hopping Spread Spectrum Technology

Direct-Sequence Spread Spectrum Technology

Direct-sequence spread-spectrum (DSSS) generates a redundant bit pattern for each bit to be transmitted. This bit pattern is called a chip or chipping code. The longer chip has the probability that can be recovering the original data when the chips are damaged during transmission. In the statistical techniques, the radio can recover the original data without the need for retransmission.

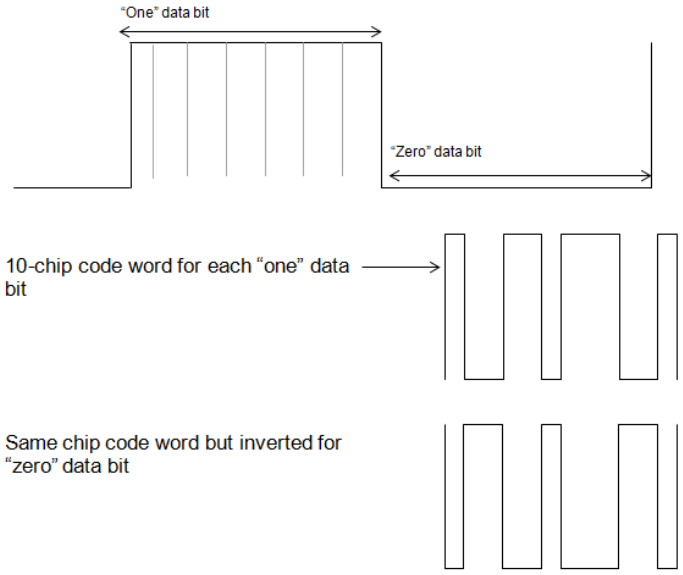


Figure 3: Direct-Sequence Spread Spectrum Technology

Frequency of Wireless LAN

The IEEE 802.11a/b/g standards has the general frequency bands are 2.4 GHz and 5 GHz ,However it depend on individual countries to allow on their current frequency spectrum to use, and what maximum transmission power is allowed**.**

For 802.11a covers maximum to 5 GHz frequency spectrum. There are 24 for non-overlapping channels for a total of 480 MHz of useable spectrum. And 802.11b/g has a total of 14 channels or 20 MHz each within a 100 MHz useable spectrum in the 2.4 GHz range. That has only 3 from 14 channels are non-overlapping. The overlapping channels allow only home users to fine tune their frequency and other devices for example cordless phones, microwave ovens are also use the same frequency range and so it can disturb Wi-Fi transmissions.

Bandwidth

Wireless Bandwidth of Wireless depends on the standard that you use (802.11b. 802.11g, etc.) and how much of the signal is available for processing. The smaller the signal the less bandwidth you get. For Wireless LAN bandwidth can provide from 20-40 MHz

Data Rates

The practical data rates in the WLAN based on the Wi-Fi technology. Its difference depends on the specific standard (802.11a/b/g).

The data rates are very sensitive to the distance between the device and the access point.

In the following tables, the maximum data rates for various technologies are listed.

802.11a/b/g Data Rates

Access/Modulation Method	***802.11b***	***802.11a***	***802.11g***
DSSS/DBPSK	1 Mbps	-	1 Mbps
DSSS/DQPSK	2 Mbps	-	2 Mbps
CCK/DQPSK	5.5 – 11 Mbps	-	5.5 – 11 Mbps
OFDM/BPSK	-	6 – 9 Mbps	6 – 9 Mbps
OFDM/QPSK	-	12 - 18 Mbps	12 - 18 Mbps
OFDM/16-QAM	-	24 – 36 Mbps	24 – 36 Mbps
OFDM/64-QAM		48 – 54 Mbps	48 – 54 Mbps

Transmit Power Levels

Most Wireless LAN devices have a power output of only 30 mW, which is far less than a typical cellular phone or walkie-talkie.

Receive Thresholds

The receiver has a minimum received power threshold that the received signal must have to achieve certain bit rate. If the received signal power is lower than the threshold, the maximum bit rate could be decreased, impacting performance. Receiver sensitivity depends both on RF and baseband design.

For the receiver threshold of Wireless LAN is around -86.5 dBm

Antenna

There are two types of antennas used for 802.11: directional and omnidirectional.

A directional antenna concentrates energy in a narrow conic path when sending and rejects signals outside a single direction when receiving.

An omnidirectional antenna transmits in a 360^{o} arc and receiving signals from any direction.

Most of 802.11b devices implement an omnidirectional antenna. The antenna type and location are important when setting up a wireless network. Users should experiment with several locations for their access point and antenna in order to determine the optimal location for maximum performance.

Distance

The signal covers approximately 100 meters in the clear area and in the building it covers around 30 meters. The signal is affected by many things around them such as mobile phones, thickness of the wall, Electronic devices and including the human body as well. All of these are an affect when use wireless networks.

Error of Wireless LAN

- **Error Detection**

Frequency-selective and time-variant property of wireless channel together with additive noise and mismatch of oscillators between transmitter and receiver, there are always time and frequency synchronization errors in a practical OFDM system

- **Error Correction**

The current error correction layer of IEEE 802.11a WLAN is designed for the worst case scenarios, which often do not apply. In this paper, we propose a new opportunistic error correction layer based on Fountain codes and a resolution adaptive ADC.

The key part in the new proposed system is that only packets are processed by the receiver chain which has encountered "good" channel conditions. Others are discarded. With this new approach, around 2/3 of the energy consumption can be saved compared with the conventional IEEE 802.11a WLAN system under the same channel conditions and throughputs.

- **Automatic Repeat Request (ARQ)**

ARQ is a protocol for error control in data transmission. There are several commonly used ARQ techniques, such as Stop & Wait", "Go back to n" and "Selective repeat". Each has its own advantages and disadvantages. In 802.11b, ARQ is implemented at the link layer .The link-layer ARQ employs the Stop & Wait ARQ scheme. With Stop & Wait ARQ, each transmitted packet must be acknowledged before the next packet can be sent. If either the packet or its acknowledgement is lost, the sender of the packet will not receive any acknowledgement, and the sender will retransmit the packet after a certain time -out period.

Application of Wireless LAN

In the past wireless LAN introduced in the late of 1980s, were marketed as substitutes for traditional wired LANs.

Wirelesses LAN saves the cost for the installation of LAN cabling and easy to relocation and move the network to other modification

Examples include buildings with large open areas, such as manufacturing plants, stock exchange trading floors, and warehouses. In all of these cases, a wireless LAN can provide an effective and more attractive.

Usage of Wireless LAN

- Flexibility: within radio coverage, nodes can communicate without further restriction.
- Planning: wireless ad hoc networks allow for communication without planning. Wired networks need wiring plans.
- Robustness: wireless networks can survive disasters
- Reduced cost- of-ownership
- Installation speed and Simplicity
- Small workgroups can increase productivity due to quick network to setup.
- Network managers can make quicker decisions because they have real-time information.

Advantages/Disadvantages

Advantages

Wireless Internet provides super-fast broadband speed, approaching 2 megabytes per second or faster. More customers are expecting broader bandwidth, so this number should creep up steadily over the next few months to years. Wireless Internet is more affordable and more reliable than satellite broadband, since satellite signals typically have to travel tens of thousands of miles.

Wireless Internet is also incredibly responsive, when you call up web pages, download emails, and engage in teleconferencing or video conferencing over the net, your wireless Internet system will yield ultra-fast transmission. Weather, radio frequencies, and traffic congestion can all impede wireless Internet flow. Moreover, with the construction of transmission towers across the nation, it's a safe bet that if you live within a reasonable proximity of an urban area, you will be near to a wireless Internet tower.

The wireless Internet broadband service offers rural Web surfers a way to tap into high speed telecommunications without laying down fiber or reconfiguring the public switched telephone network system based on new DSL standards. Thus, delivering communications to a small town in an area which lacks cable infrastructure or merely looking to avoid the slower speeds and sometimes confusing plans associated with DSL, wireless Internet is a wonderful way to optimize your surfing time.

Disadvantage

One of the major problems that present, it is the already limited spectrum available for communications. The remaining free spectrum has to be used to its maximum potential, spread spectrum technology presenting itself as a suitable means of increasing performance. Splitting up of the environment into a number of small cells also increases the overall accessible bandwidth of the communication system, but also increases the cost as more cell sites are required. Techniques such as diversity combining can also be used to increase the available bandwidth through improved reception capabilities.

Cost

In the present, Wireless LAN is very popular in our world. It's easy and comfortable to use. In the first time when the investor installation for Wireless LAN, it has an expensive cost but it has a long run.

Wireless network don't have to pay maintenance. And don't have to pay for the network expansion is less than the original investment many times because it's easy to installation.

So the benefit of Wireless LAN can make it popular for the real world, it can reduce overall costs for the investment and it has an effect that make a wireless cost drop down because many company want to sell it, it has a fighting with the cost.

For the chipset of wireless LAN , the price has come down around $ 16.06 in 2002 and sell in 2003 around $6.61, and will drop down to $4 in 2011.

.: WiMAX :.

WiMAX is stand for **W**orldwide **I**nteroperability for **M**icrowave **Acc**ess. It is a newest wireless broadband. The main points of the WiMAX are providing internet in faraway area that cable cannot access to and saving cost.

Protocol Architectures

WiMAX Protocol is based on IEEE802.16 (IEEE stands for Institute of Electrical and Electronics Engineers) that is intended for wireless "Metropolitan Area Networks". It uses Mesh Topology and smart antenna for saving cost. And it has the Quality of Service (QoS) so it can support function of video and voice.

WiMAX is in a service of Time Division Multiplexed (TDM) or Voice over IP (VoIP) which can organize or give priority of the work in proper ways. In security side, WiMAX added more privacy property or encryption to make more security.

WiMAX has two types of usage models a **Fixed WiMAX** usage model and a **Mobile WiMAX** usage model. The different between two types are the ground speed. The mobile WiMAX, the wireless access systems are designed to operate on the move without any disruption of service.

Fixed WiMAX access is expected to reflect fixed wire-line service, with many of the standards-based requirements being limited to the air interface. It access air interface that need to be set up high quality radio links capable of data rates compare to wired **broadband service**, the equipment that can be self-installed by users.

Mobile WiMAX is new capabilities that develop from Fixed WiMAX. It able to hand off between **WiMAX base station**s and device, it enables users to roam between service areas.

Figured 1: The different characteristic of Fixed WiMAX and Mobile WiMAX

Characteristic	Fixed WiMAX	Mobile WiMAX
Industry Standard	802.16 - 2004	802.16e – 2005
Access Type	Fixed	Fixed, Portable and Mobile
Modulation	OFDM*	OFDMA**
Duplexing	TDD***, FDD****	TDD, FDD Optional
Handoffs	No	Yes
Types of Service Providers	DSL, Cable Modems and Competitive Access Providers	Mobile Operators, DSL, Cable Modems, Wireless and Wired ISPs
Subscriber Units	High Performance Outdoor and Indoor CPE	Low Cost Consumer Electronics CPE and Embedded Modules
Preferred Frequency Bands	2.5GHz, 3.4 – 3.6 GHz, 5.8 GHz	2.3 – 2.4 GHz, 2.5 – 2.7 GHz,3.3 -3.4 GHz, 3.4 – 3.8GHz

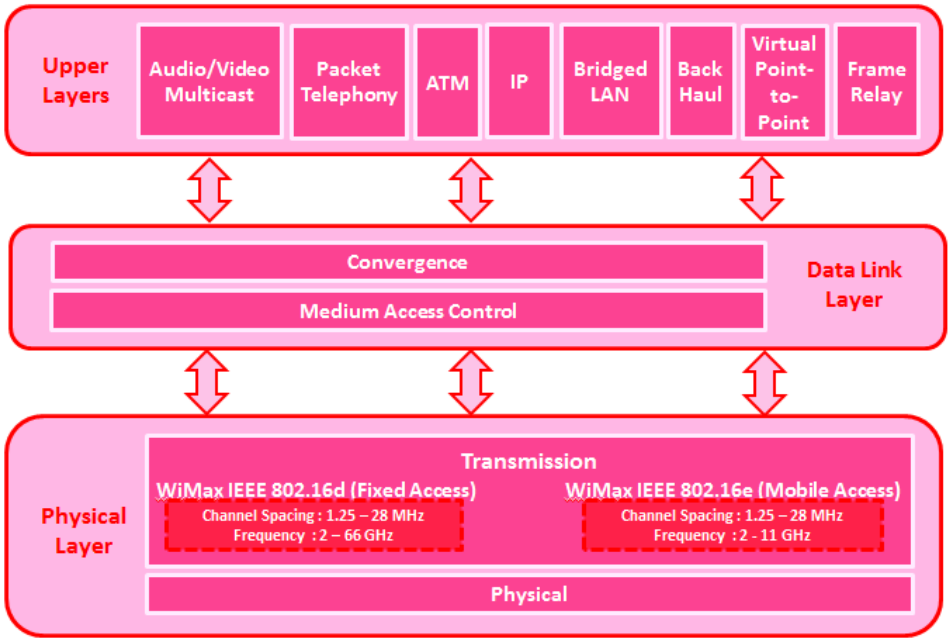
OFDM* = Orthogonal Frequency Division Multiplexing

OFDMA** = Orthogonal Frequency Division Multiple Access

TDD*** = Time Division Duplexing

FDD**** = Frequency Division Duplexing

WiMax Layer Stack Protocol



Figured 2: Layer stack protocol

In physical layer have 2 main layers inside which are Physical layer and transmission layer.

Physical and transmission layer functions:

- It can encoding and decoding of signals
- Introduction in generation and removal
- Bit transmission and reception

In data link layer have 2 main layers inside which are medium access control layer and convergence layer.

Convergence layer functions:

- Adapt time dependency of upper layer traffic into equivalent MAC service
- Introduce Protocol Data Unit (PDU) framing of upper layers into 802.16 MAC/PHY frames.
- Translate upper layer QoS parameters into 802.16 MAC format
- Map upper layer's address into 802.16 address

Medium access control layer functions:

- On transmission, it combines data into a frame with address and error detection.
- On reception, it demolishes frame and perform address recognition and error detection
- Govern access to the wireless transmission medium.

In upper layer have 8 layers inside which are audio/video multicast, packet telephony, ATM , IP, bridged LAN, back haul, virtual point-to-point and frame relay

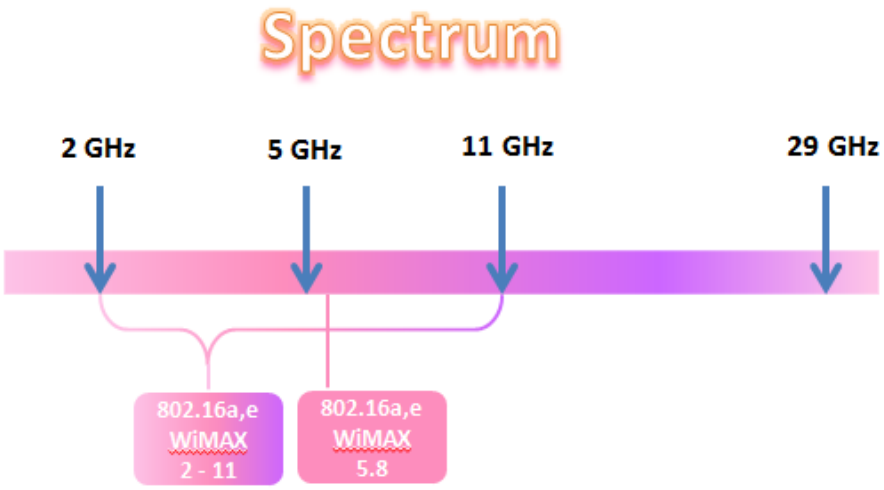
- **Audio/Video multicast:** one-way(broadcast radio and video) or two-way(teleconferencing)
- **Packet telephony:** multiplex digital telephone streams
- **ATM**(Asynchronous Transfer Mode)**:** transfer ATM cells
- **IP**(Internet Protocol)**:** transfer IP datagrams
- **Bridged LAN:** transfer data between two LANs
- **Back haul:** wireless trunks for wireless telephone base stations
- **Virtual point-to-point**
- **Frame relay:** transfer variable-length frames

The standard of WiMAX

Number	Description
802.16	Original fixed wireless broadband air Interface for 10 – 66 GHz. The only one that support Line-of-sight transmission. Point-to-multipoint architecture with rooftop or tower-mounted antennas (Antenna with a variety of radiation patterns are used e.g. directional or Omni-directional)
802.16a	Developed from 802.16, it extends the frequency to 2-11 GHz. It is non-line-of-sight transmission and point-to-multipoint applications. The signal can pass through the object such as tree, building etc. Provide network signal up to 48 km. (31 miles) and transmission rate is up to 75 Mbps
802.16d	It supports both time division duplex (TDD) and frequency division duplex (FDD) services. It usually uses to connect device in small area like a house.
802.16e	Enhance to support mobility such as mobile device, laptop etc. The radius is around 1.6 – 4.8 km. and the frequency is 2-6 GHz. It has a system that can give a stable quality in communication even though the device is moving.

Figured 3: The IEEE802.16 Standards related to WiMAX

Data Transmission



Figured 4: Spectrum diagram

Spectrum: Actually there are no uniform of WiMAX spectrum. But the WiMAX forum separate spectrum into 2.3 GHz, 2.5GHz, and 3.5GHz for standard and cost. The International standard of 3.5 GHz spectrum was the first WiMAX products. The US license free spectrum at 5.8 GHz has a few WiMAX vendors building products. Licensed spectrum at 2.5 GHz used

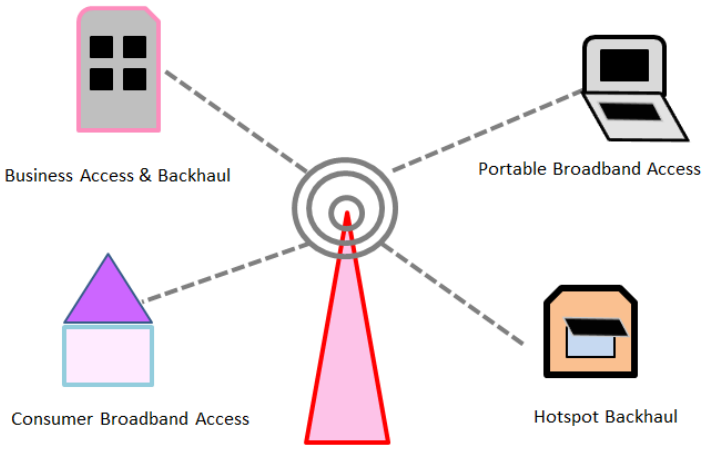
both domestically in the US and fairly widely abroad is the largest block in the US.

WiMAX Frequency: WiMAX has different operate both on FCC (Federal Communications Commission) licensed frequencies and on unlicensed frequencies. Licensed WiMAX operates in the 10 to 66GHz range and unlicensed WiMAX operates in the 2 to 11GHz range. The frequencies are usually between 2 to 11 GHz. But actually in the mobility support (IEEE 802.16e), the frequencies are about 2 to 6 GHz.

Bandwidth: WiMAX can use radio channel bandwidths that can provide from 1.25 MHz to 28 MHz. The types of data connections on WiMAX radio channels include basic (physical connection), primary (device control), and secondary (configuration) and transport (user data).

Data rate: WiMAX can transfer data in about 75 Mbps.

Transmission Media



Figured 5: WiMAX Transmission

Transmission power: A fixed WiMAX base station transmits at power levels of approximately +43 dBm (20 W), and the mobile station transmits at +23 dBm (200 mW). A WiMAX tower is similar in concept of a cell-phone tower. A single WiMAX tower can provide coverage to a very large area about 8,000 km.

Receive thresholds: A WiMAX receiver could be a small box or PCMCIA card (Personal Computer Memory Card International Association), or could be built into a laptop.

Antennas: WiMAX can use in 3 antenna which are an Omni-directional, sector and panel antenna. An Omni-directional antenna can provide signal 360 degrees from the base station and it used for point-to-multipoint configurations. Sector antennas are focused on smaller sectors or the focused area. Panel antennas are usually a flat panel and it most often used for point-to-point applications.

Distance: The IEEE802.16a or WiMAX can provide the signal in form of Point-to-multiple and can pass through the object such as tree, building etc. So it can expand internet network more widely up to access up to 50 km. (30 miles) for fixed station and 5 – 15 km. (3 – 10 miles) for mobile station. Service ranges up to 10 miles are very likely in line of sight (LOS) applications depend on frequency. Ranges beyond 10 miles are possible, but for the quality may not be desirable for heavily loaded networks. In most cases, additional cells are indicated to sustain high quality of service (QOS) capability.

Error

WiMAX technology has built-in error detection techniques to reduce the system Signal to Noise Ratio (SNR). Interleaving algorithms are used to identify and correct errors to enhance throughput. These strong error correction techniques assist to recover corrupted frames that may have been missing due to frequency selective fading or burst errors. To remove the errors, Automatic Repeat Request (ARQ) is used that cannot be corrected by the Forward Error Detection (FEC) by resending the error information again. This notably improves the Bit Error Rate (BER) performance for a similar maximum level.

Applications

WiMAX will allow people to connect to network at everywhere. It can serve the business, residential and mobile segments. The applications in these areas are

Residential users

- Bundled voice and data services
- Basic (dialup speed) to advanced (over 1Mbps) data connections
- Basic voice services, low cost domestic & international calls

Business users

- Feature-rich, low cost voice services (VoIP)
- Basic data connectivity for small businesses
- Advanced data services to medium and large businesses

Mobile users (mobile WiMAX only)

- Data connectivity for international visitors
- Data connectivity for mobile workforce

Usage

WiMAX is a protocol that allows faster bandwidth use with less interference and it allows higher transfer of data rates which travel longer distance. So the main point of WiMAX is the long distance with high speed and does not need to use the wire. And WiMAX has the high encrypt security. It is easy to install in everywhere so it make the provider can provide more internet area and the cost for install is not too expensive. So compare installing with the ADSL, WiMAX is much faster, less cost and longer distance. And with the long distance that WiMAX can provide, it is useful for the area that cable and telephone line cannot access to.

Advantages/Disadvantages

Advantages

1. Single station can serve hundreds of users.
2. Much faster deployment of new users comparing to wired networks.
3. Speed of 10 Mbps at 10 kilometers within line-of-site.
4. It is standardized, and the same frequency equipment should work together.

Disadvantages

1. Line of sight is needed for more distant connections.
2. Bad weather conditions such as rain could interrupt the signal.
3. Other wireless equipment could cause interference.
4. Multiplied frequencies are used.
5. WiMAX is a very power-consuming technology and requires significant electrical support.

Cost

WiMAX is cheaper than wired DSL because it does not require placing wires around the area to be covered, which represents a big investment for the provider. Not requiring this investment opens the door to many service providers who can start retailing out wireless broadband with low capital, thereby causing prices to drop due to competition. If you intend to use WiMAX, you will only have to invest on a WiMAX-supporting hardware or device that will connect to your existing hardware.

The cost is depending on how it will be used. There are two ways WiMAX can be achieved that are a zone for wireless connections that single users go to when they want to connect to the Internet on a laptop, or as a line-of-sight hub used to connect hundreds of customers to a steady, always-on, high-speed wireless Internet connection.

For example, a city might pay to have WiMAX base stations set up in key areas for business and commerce and then allow people to use them for free. City already do this with Wi-Fi, but instead of putting in a bunch of Wi-Fi hot spots that cover a few hundred square yards, a city could pay for one WiMAX base station and cover an entire financial district. This could provide a strong draw when city leaders try to attract businesses to their area.

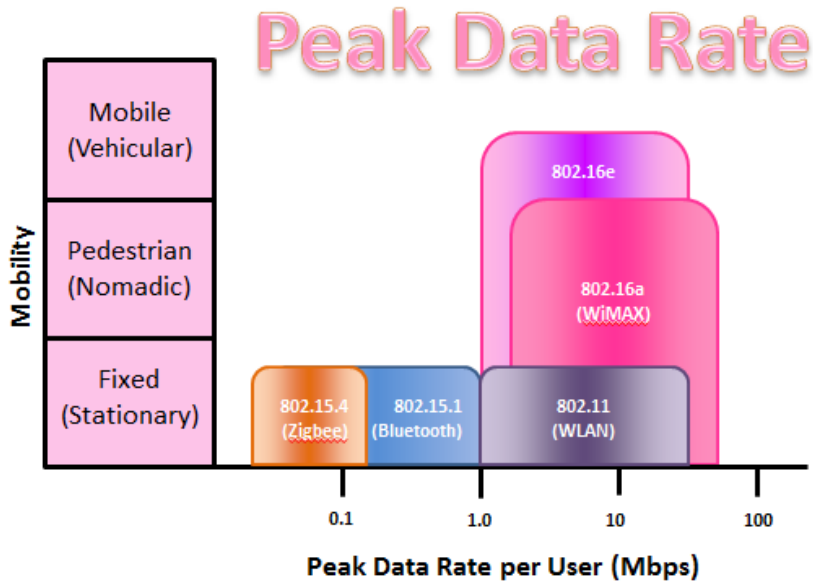
Some companies might set up WiMAX transmitters and then make people pay for access. So this is similar to strategies used for Wi-Fi, but a much wider area would be covered.

For the chipset of mobile WiMAX, the prices have come down from the $35 range a few years ago to below $25, and will drop below $10 in 2011.

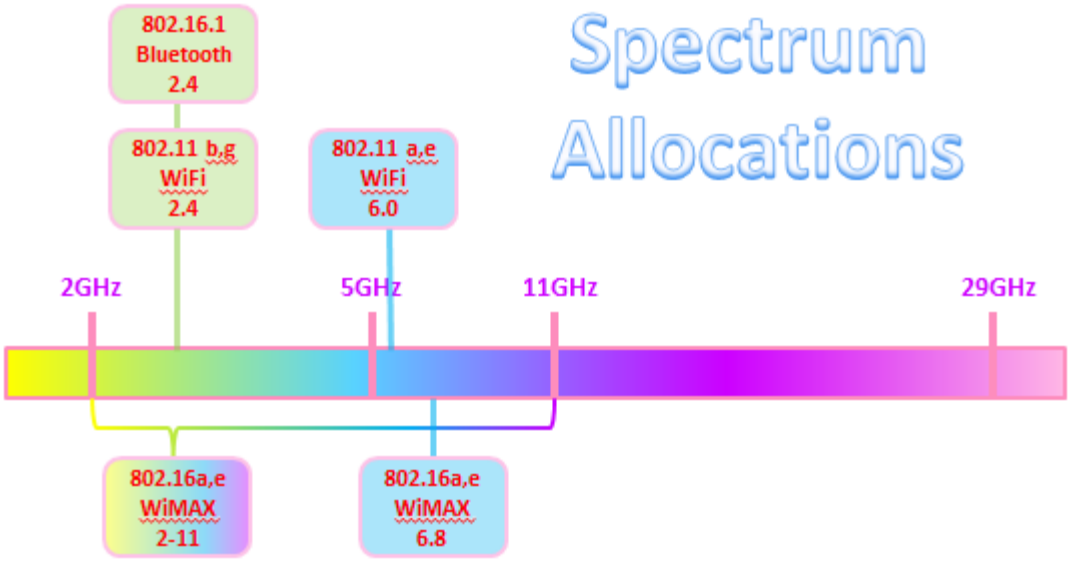
Comparision

	Zigbee	Bluetooth	Wireless LAN	WiMAX
Standard	802.15.4	802.15.1	802.11	802.16
Spectrum	2.4 GHz	2.4 GHz	2.4 GHz	2 – 11 GHz
Frequency	Licensed : 2.4 GHz Unlicensed : 2.4 GHz	Licensed :2.4 GHz Unlicensed : 2.4 GHz	Licensed :2.4 -5.8 GHz Unlicensed : 2.4– 5.8 GHz	Licensed :10 – 66 GHz Unlicensed : 2 – 11 GHz
Bandwidth	5 MHz	1 MHz	20 – 40 MHz	1.25 – 28 MHz
Data rate	Up to 0.24 Mbps	Up to 1Mbps	Up to 54 Mbps	75 Mbps
Transmission	-4 to 20 dBm	0 to 30 dBm	2 to -17 dBm	Fixed station: +43 dBm (20 W) Mobile station: +23 dBm (200 mW)
Receive thresholds	-85 dBm	-70dBm	-86.5 dBm	-91 dBm
Antenna	Omni-directional antennas	Vertical, Dipole antennas	Directional, Omni-directional antennas	Omni-directional, Sector, Panel antennas
Distance	Normal: 10-75 m Pro: upto 1.5 km	10-100 m	100 m	Fixed station: up to 50 km Mobile station: 5 – 15 km
Application	Monitoring and control	Cable replacement	Web, e-mail, video	Mobile Broadband
Usage	Reliability, power, cost	Cost, convenience	Speed, flexibility	Speed , Large range , Security
Cost	≈$3	≈$4	≈$4	≈$25

This table is show the comparison between ZigBee, Bluetooth, WiMAX



This graph shows the peak data rate.



This picture shows the spectrum allocations.

. : Reference : .

ZigBee

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