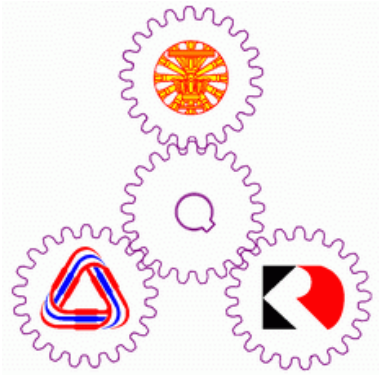

Assignment Topic
Current wireless communication technologies

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ZigBee

1. Protocol Architecture

A) Layered Stacks

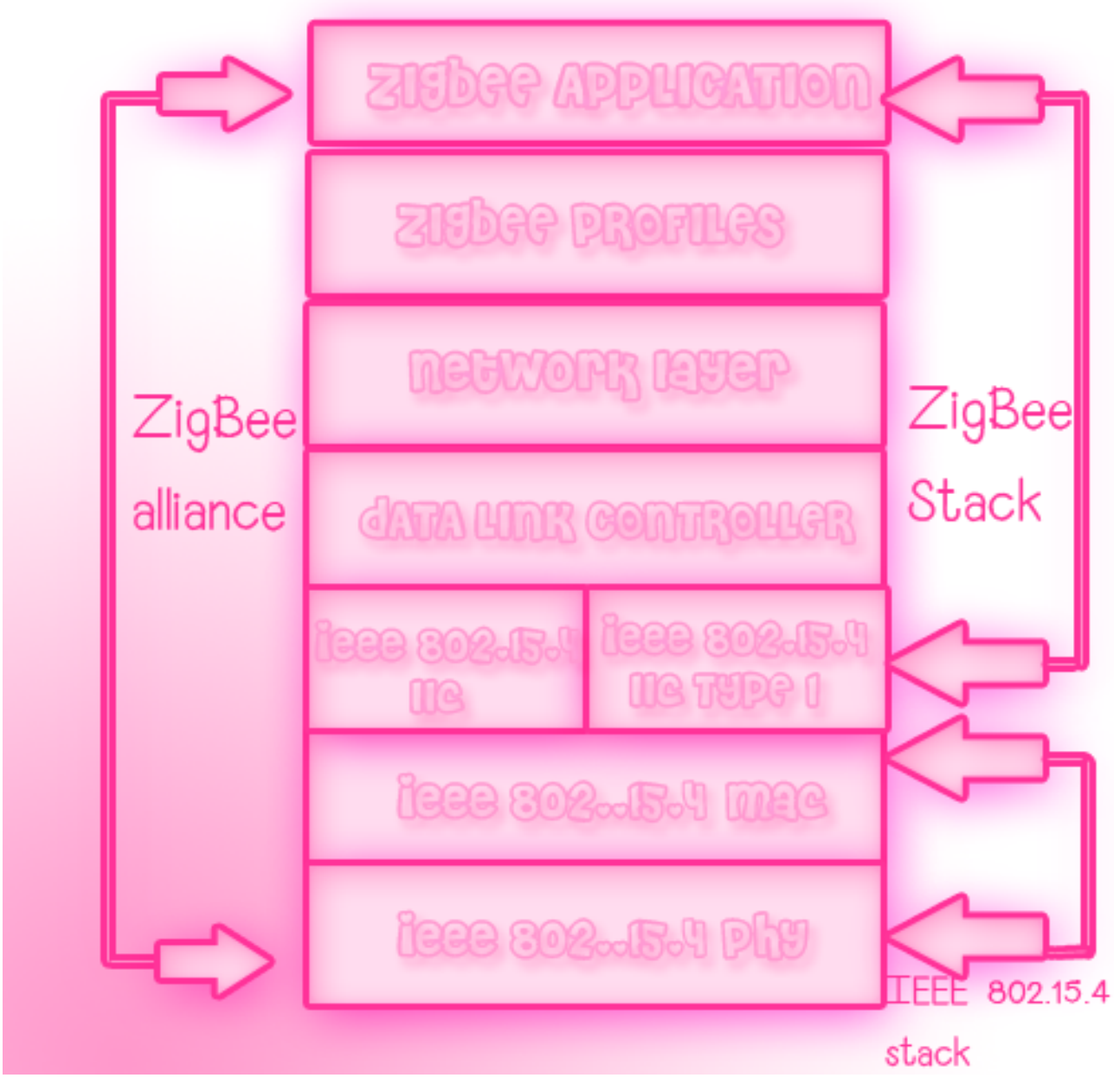


Figure 1 : ZigBee stack

Layered like OSI (Open System for Interconnection) model as can be seen in Figure 1

Compose of Application Layer, Network layer (routing) , MAC (Medium Access Control) , PHY (Physical Layer) , Radio.

It minimizes the time for which the radio is on to reduce the power use.

The ZigBee stack defines the multiply accumulate and PHY of the protocol.

MAC and PHY define the RF (Radio Frequency) and communications components of neighboring devices.

On the other hand, include a network layer, an application layer and a SSP (Security Service Provider) .

The PHY defines radio characteristics and supports the 2.45GHz and 868/915MHz radio bands.

The MAC layer is responsible for single-hop data communication between neighboring devices which supports association/disassociation and MAC-level security. Also provides a reliable link between two devices.

A ZigBee stack provides all the functionality required by the Zigbee specification so that manufacturers can focus on developing their product applications.

B) Protocols

The protocols build on algorithm to construct a low speed ad-hoc network of nodes and minimize the time radio is on and reduce power

C) Standards

It provides for the connectivity of simple fixed and mobile devices.

Based on the IEEE (Institute of Electrical and Electronics Engineers) 802.15.4-2003 standard for wireless home area network which define the characteristics of the physical and MAC layer.

It also defines the network layer specifications and provides structure for application program in application layer.

It was created to address the market need for a cost-effective, standard-based wireless networking solution that

support low data rate, low power consumption, security and reliability.

D) Standard Organisations

The ZigBee Alliance and its members are already working with a variety of organizations focused on smart grid technologies. Those organizations include

ASHRACE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) , DALI (Digital Addressable Lighting Initiative) , HomePlug Powerline Alliance , IEEE , EPRI (Electric Power Research Institute) , ESMIG (European Smart Metering Industry Group) , NARUC (National Association of Regulatory Utility Commissioners) , NEMA (National Electrical Manufacturers Association) , Open Smart Grid, other industry organizations and various governmental authorities worldwide.

2. Data Transmission

Table 2 : Comparison among the important factors in different frequency.

Frequency	868 MHz	915 MHz	2.4 GHz
Data rate	20 kbps	40 kbps	250 kbps
Bandwidth	20 kbps	40 kbps	250 kbps
Modulation	BPSK	BPSK	OQPSK

A) Spectrum

It modulated using DSSS (Direct Sequence Spread Spectrum) which divides the 2.402-2.480 GHz spectrum into 16 channels or 10 channels in the 915 MHz spectrum.

It can also use Parallel Sequence Spread Spectrum which is coding technique for RF signal.

There may be tradeoff between data rate, energy efficiency and multipath fading resistance at a low electronic complexity.

B) Frequency

IEEE 802.15.4 provides three frequency bands for communication:

1. 2.4 GHz coverage worldwide which has maximum data rate. There are 16 channels are available.
2. 868 MHz coverage in Europe which provides 20 Kbps burst rate. There is 1 channel available.
3. 915 MHz which serve the United State. There are 10 channels available.

C) Bandwidth

From Table 2, it has been shown that the more frequency, the more bandwidth. Since, higher bandwidth can increase the number of channel or widen channel which can enhance the frequency of transferring data. Thus, the amount of information that can be sent is higher in the 2.4 GHz band.

D) Data rate

It is proportional to Bandwidth. Hence, the more bandwidth, the more data rate.

Zigbee device requires a very low data rate, the core Physical layer communicates at 250 kbps. Compared to other RF system targeting the same application range. This is a high data rate that allows minimizing time that use to spend on air and reduce the opportunity to collision.

3. Transmission Media

A) Transmit Power

It is between 0 dBm (1 mWatt) and 3 dBm (2 mWatts)

It requires radios to have a minimum output power of -3dBm or 0.5 mWatts.

Reducing the transmitter output power to the minimum necessary for a reliable communication link will help reduce the interference to other wireless node.

B) Receive Thresholds

Receive sensitivity limit approximately -85 dBm for the 2.4 GHz band.

In the receiver path, the required sensitivity is defined as a threshold input signal power of the receiver that yield less than 1 percent PER (Packet Error Rate) .

The minimum sensitivity is -92 dBm for the 868/915 MHz bands.

The ZigBee receiver should be able to receive an input level up to -20 dBm. With the transmit power of 0 dBm, the typical operational range of ZigBee application is 10-20 m.

C) Antennas

It is independent antennas not shared antennas.

The PCM (Pulse Code Modulation)-ZigBee uses a SMA (Security Monitoring and Automation) connector for the most flexible cabling and antennas options.

A dipole omni-directional or yagi antenna can be used.

D) Distance

ZigBee is meant to offer short distance low-speed transmissions that employ very little power.

Its distance is approximately 50 m.

4. Signal Encoding Techniques

As shown in Table 2, for the lower bands, it will employ BPSK (Binary Phase Shift Keying) modulation. While the highest band, it will employ OQPSK (Offset-Quadrature-Phase-Shift-Keyed).

OQPSK

The 2.4-GHz band, in which ZigBee transceivers are most commonly deployed, uses the OQPSK modulation scheme.

This is a derivation of traditional QPSK (Quadrature Phase Shift Keying) and is used because it requires less power than similar schemes while achieving the same level, or better, of throughput.

It takes four values of the phase (two bits) at a time to construct a QPSK symbol.

BPSK

Only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate.

It takes the highest level of noise therefore, error can easier occur.

5. Errors

A) Error Detection

802.15.4 ZigBee uses repeated transmissions and error detections for reliable communications. In error detection, if sent packet is not received correctly, it retransmits the message again.

In CRC (Cyclic Redundancy Check) , at the end of block or a frame group of n-k bits (8, 16, and 32) are added to K bits of data, this group is called as FCS (Frame Check Sequence). The predetermined number should divide n bits exactly to calculate FCS bits. The receiver divides the block of received data by the same number and if remainder is zero then block is free from the error else it asks for retransmission.

B) Error Correction

FEC (Forward error correction) which is an error control for data transmission , whereby the sender add redundant data to its messages, also known as an error-correcting code. This allows the receiver to detect and correct errors without the need to ask the sender for additional data.

C) ARQ

In ZigBee it will use hybrid-ARQ technique that will encode message in to a low rate code then codeword is broken in to several blocks and transmit one by one until the receiver is able to decode and sent back ACK (Acknowledgement)

6. Applications

ZigBee protocols are intended for use in embedded applications requiring low data rates and low power consumption. ZigBee's current focus is to define a general-purpose, inexpensive, self-organizing mesh network that can be used for industrial control, embedded sensing, medical data collection, smoke and intruder warning, building automation, home automation, etc. The resulting network will use very small amounts of power so individual devices might run for a year or two using the originally installed battery.

Typical application that user can use in these areas include:

1. Home Entertainment and Control: Smart lighting, advanced temperature control, safety and security, movies and music
2. Home Awareness: Water sensors, power sensors, smoke and fire detectors, smart appliances and access sensors
3. Mobile Services: m-payment, m-monitoring and control, m-security and access control, m-healthcare and tele-assist
4. Commercial Building: lighting, access control
5. Industrial Plant: Process control, asset management, environmental management, energy management, industrial device control

Type of required device

There are three different types of ZigBee devices:

ZC (ZigBee Coordinator) : The most capable device, the coordinator forms the root of the network tree and might bridge to other networks. There is exactly one ZigBee coordinator in each network since it is the device that started the network originally. It is able to store information about the network, including acting as the Trust Centre & repository for security keys.

ZR (ZigBee Router) : As well as running an application function, a router can act as an intermediate router, passing on data from other devices.

ZED (ZigBee End Device) : Contains just enough functionality to talk to the parent node (either the coordinator or a router); it cannot relay data from other devices. This relationship allows the node to be asleep a significant amount of the time thereby giving long battery life. A ZED requires the least amount of memory, and therefore can be less expensive to manufacture than a ZR or ZC.

7. Usage

Not only ZigBee is extensively used in several countries, but it is also widely used in Thailand. The reason that ZigBee is chosen by user following:

It is low cost allows the technology to be widely deployed in wireless control and monitoring applications.

The low power-usage allows longer life with smaller batteries.

The mesh networking provides high reliability and more extensive range.

8. Cost

To use ZigBee technology , users need to have ZC , ZR and ZED which cost about 2000 Baht for ZC , 6000 Baht for ZR and 150 Baht for ZED

Bluetooth

1. Protocol Architectures

A) Layered Stacks

Figure 2 : Bluetooth stack

Bluetooth radio is a transceiver which transmits and receives modulated electrical signals from Bluetooth devices.

Baseband is the physical layer of the Bluetooth which manages physical channels and links apart from other services similar to error correction.

ACL is Asynchronous Connection-Less physical link for transmitting data over the physical channels. ACL link provides a packet switched connection between the master and all the active slaves.

SCO is Synchronous Connection-Oriented physical link for voice-like information. It is a symmetric, point-to-point link between the master and a specific slave. It is like a circuit-switched connection.

Link Manager essentially handles link set-up, security and control. It provides services like authentication, encryption control and power control.

L2CAP is the Logical Link Control and Adaptation Layer protocol. It resides in the data link layer and provides connection-less and connection-oriented data services to upper layer coding technique for RF (Radio Frequency).

SDP is Service Discovery Protocol for applications to discover which services are available and to determine the characteristics of those available services.

RFCOMM (Radio Frequency Communication) is a simple transport protocol, with between two Bluetooth devices.

TCP (Transmission Control Protocol) provides a reliable connection between devices at the transport layer with IP (Internet Protocol) in the network layer. IP provides protocol multiplexing and connections based on IP addresses.

Jini technology provides simple mechanisms which enable devices to plug together to form an impromptu community. Each device provides services that other devices in the community may use.

WAP is Wireless Access Protocol is a standard for providing Internet communications and advanced telephony services

on digital mobile phones, pagers, personal digital assistants and other wireless terminals. These can be shown in Figure 2

B) Protocols

The Bluetooth standard requires a basic level of communication in order to connect each other over airwaves, at the correct frequencies, correct channel and correct destination. Thus, a specific protocol has been created by establish the rule by which all devices need to abide. Most protocols are included to be form of protocol stack.

Bluetooth based on low-cost transceiver microchips in each device. According to the devices use a radio in communications system, they do not have to be in line of sight of each other.

C) **Standards**

There are 3 norms for Bluetooth standard following

IEEE (Institute of Electrical and Electronics Engineers) 802.15.1 defines Bluetooth 1.x, which can reach speeds of 1 Mbps;

IEEE 802.15.2 recommends practices for using the 2.4 GHz frequency band (the frequency also used by Wi-Fi (Wireless Fidelity)). However, this standard has not yet been approved;

IEEE 802.15.3 is a standard currently being developed, which would offer broadband speed (20 Mbps) with Bluetooth;

IEEE 802.15.4 is a standard currently being developed for use with low-speed Bluetooth applications.

D) Standard Organisations

Standard organisation, Bluetooth SIG, is formed

2. Data Transmission

A) **Spectrum**

Bluetooth employs a transmission technique called frequency hopping spread spectrum which chops up the data being sent and transmits chunks of it on up to 79 bands (1 MHz each) in the range 2402-2480 MHz. This is in the globally unlicensed ISM

(Industrial, Scientific and Medical) 2.4 GHz short-range radio frequency band whereby has two major benefits:
1. Improved privacy. By switching the carrier frequency up to 1600 times a second, it becomes harder to listen in on data. This is because the frequency pattern hopping pattern appears random except to the devices communicating with one another.
2. Improved noise and narrowband interference rejection

Spread Spectrum which is the techniques that generated in a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth.

B) Frequency

Bluetooth transmits frequencies around 2.4 GHz. At this high frequency, a direct line of sight is not needed between devices. In the U.S., there are 79 available Bluetooth channels spaced 1 MHz apart from 2.402 GHz to 2.480 GHz. Internationally, there is spectrum available for Bluetooth, but sometimes fewer than 79 channels are available.

C) Bandwidth

Bluetooth devices intended for use in short-range personal area networks operate from 2.4 to 2.4835 GHz. To avoid interfering with other protocols that use the 2.45 GHz band, the Bluetooth protocol divides the band into 79 channels (each 1 MHz wide) and changes channels up to 1600 times per second. The maximum interconnection bandwidth for Bluetooth device is 500 Kbit/s at any one time. It is about 721 kbits/s between the master and any one slave unit, after discounting the overhead

D) Data Rates

Bluetooth contains maximum data transfer rate of 721 kbits/s (3 voice channels).

3. Transmission Media

A) Transmit Power

There are 3 classes for Bluetooth power following:

Class 1 1mW – 100 mW

Class 2 0.25mW – 2.5 mW

Class 3 1mW

B) Receive Thresholds

Receive threshold is inverse from transmit power. The more transmit power, the lower receive threshold. In theory, the receiver threshold defines a minimum level of signal where the receiver starts to function. Receiver sensitivity quantifies the ability of a receiver to respond to weak signal levels. Typically uses -70dBm

C) Antennas

It is dependent antenna which seems that Bluetooth shares same antennas

The Bluetooth antenna provides powerful performance in all directions.

As Bluetooth uses such a high frequency (in the 2.4GHz range) the antennas can be made small while still maintaining efficiency. For everyday experimentation, a 1/4 wavelength piece of wire would do. For more professional setup, a dipole antenna would be better.

D) Distance

Class 3 : The lowest power, the max. range of this is 10m (30 feet)

Class 2 : Max range is about 50m (150ft)

Class 1 : Max range is about 100m (300ft)

4. Signal Encoding Techniques

The modulation in Bluetooth is GFSK (Gaussian Frequency Shift Keying) which is a type of FSK (Frequency Shift Keying) modulation that uses a Gaussian filter to smooth positive/ negative frequency deviations, which represent a binary 1 or 0.

For basic data rate Bluetooth the minimum deviation is 115 kHz. A GFSK modulator is the same as FSK modulator except the baseband data pulse(-1,1) go to the FSK modulator, they need to pass through the Gaussian filter first in order to make the pulse smoother to limit the spectral bandwidth. With GFSK, frequency increases and decreases slowly, but with FSK, it jumps very quickly.

5. Errors

A) Error Detection

Two techniques that is used for detect error in Bluetooth following:

-FEC (Forward Error Correction) is the technique which appends the additional bits to data in which a number can be detected and corrected.

-ARQ (Automatic Repeat Request) is done by using feedback channel from the receiver to transmitter. Whenever the receiver detects an error, a signal would be feedback to transmitter.

B) Error Correction

Three types of error correction are implemented in Bluetooth systems,

1. 1/3 rate FEC which is the method where the sender adds redundant data to its messages his allows the receiver in order to detect and correct errors (within some bound) without the need to ask the sender for additional data.
2. 2/3 rate FEC
3. ARQ also known as Automatic Repeat Query, is applied for data transmitted in one slot. It is directly acknowledged by the receiver in the next slot.

C) ARQ

For Bluetooth Stop and Wait ARQ has been used which is the simplest kind of ARQ method. This method sender sends only one frame at a time which is inefficient compared to other ARQs.

6. Application

Bluetooth is intended for non-resident equipment and its applications. The category of applications is outlined as the WPAN (wireless personal area network) which can also support fixed location applications such as smart energy functionality in the home. The examples application of Bluetooth has been given following

1. A Bluetooth-keyboard could also be used to talk to more than one computer.
2. Whenever we receive an e-mail, we will get an alert on our mobile phone. We can also browse all e-mails which has been come to our inbox
3. We can use a Bluetooth-mouse at a further distance from a monitor
4. We can use PC or PDA as hands free phone.

Bluetooth also exists in many products, such as telephones, the Wii, PlayStation 3, PSP Go, Lego Mind storms NXT, iPod Touch and in some high definition watches, modems and headsets. The technology is useful when transferring information between two or more devices that are near each other in low-bandwidth situations. Bluetooth is commonly used to transfer sound data with telephones or byte data with hand-held computers. Devices which require Bluetooth such as headset, camera, handy, PDA, PC, printer and mobile so on and so forth.

7. Usage

Bluetooth is widely used not only in Thailand, but also other countries all over.

8. Cost

To use Bluetooth technology users have to has a Bluetooth USB modem and a device that can support Bluetooth technology which will cost about 1000 Baht and 20000 Baht for device such as Laptop.

Wireless Lan

1. Protocol Architecture

A) Layered Stacks

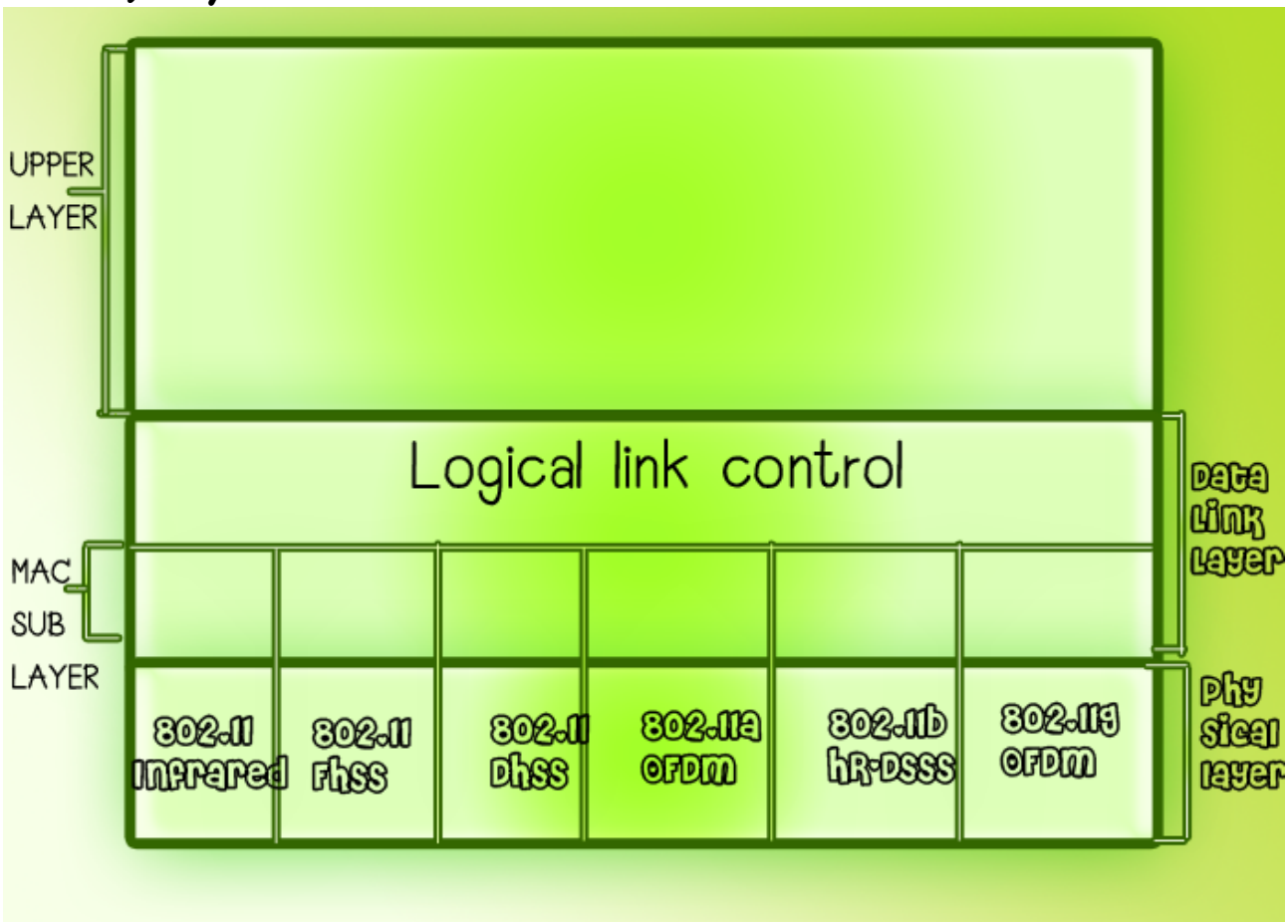


Figure 3 : Wireless Lan stack

IEEE (Institute of Electrical and Electronics Engineers) 802.11 define the PHY (Physical Layer) and MAC (Medium Access Control) based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). These can be illustrated in Figure 3

B) Protocols

Use the Ethernet protocol and CSMA/CA for path sharing and include an encryption method

C) Standards

There are several standards for Wireless Lan hardware but can divide in to 4 major part

1. 802.11a has fast maximum speed and control frequency to prevent signal interference from other devices but has highest cost and short range signal
2. 802.11b has lowest cost and good signal range but has slowest maximum speed and appliances may interfere on the uncontrol frequency
3. 802.11g has fast maximum speed and good signal range but higher cost and appliances may interfere on the uncontrol frequency
4. 802.11n has fastest maximum speed , best signal range and more resistant to signal interference from outside source but has higher cost

D) Standard Organisations

The Wi-Fi Alliance is a nonprofit organization that specializes in the 802.11 Wireless Lan industry. This organization was formed to address the exchange and make use of Wireless Lan by certification , device that already pass the test would display the Wi-Fi (Wireless Fidelity) certified logo . In the security Wi-Fi Alliance has developed WPA (Wi-Fi Protected Access) to address the security gaps in WEP (Wired Equivalent Privacy) offered by the 802.11 specification

2. Data Transmission

A) Spectrum

Spread Spectrum allow for great bandwidth by adjust frequency of the transmit signal and transmission is secure , reliable and easy to detect. Spread Spectrum can divide in to 2 technology

1. FHSS (Frequency Hopping Spread Spectrum) synchronizes the changing frequency of transmitter and receiver to produce a single transmission signal
2. DSSS (Direct Sequence Spread Spectrum) break down the transmit data into small pieces over a frequency channel. A

redundant bit pattern or chipping code will be generated for each bit transmitted. DSSS use more bandwidth but more reliable and resist interference

B) Frequency

1. 802.11a use 5GHz frequency
2. 802.11b use 2.4GHz frequency
3. 802.11g use 2.4GHz frequency
4. 802.11n use 2.4GHz frequency

C) Bandwidth

1. 802.11a supports bandwidth up to 54 Mb/s
2. 802.11b supports bandwidth up to 11 Mb/s
3. 802.11g supports bandwidth up to 54 Mb/s
4. 802.11n supports bandwidth up to 100 Mb/s

D) Data Rates

1. 802.11a has data transfer rates up to 54 Mb/s
2. 802.11b has data transfer rates up to 11 Mb/s
3. 802.11g has data transfer rates up to 54 Mb/s
4. 802.11n has data transfer rates up to 600 Mb/s

3. Transmission Media

A) Transmit Power

Most of Wireless Lan devices have a power output only 30 mW

B) Receive Thresholds

Receiver has a minimum receive threshold that the signal have to achieve a certain bitrate and for Wireless Lan there will be around -94 to -77 dBm

C) Antenna

Antenna in Wireless Lan is dependent and has 2 types

1. Directional Antenna concentrate energy in a narrow path when sending and reject signals

2. Omnidirectional Antenna transmit and receive signal for from any direction and most of 802.11b devices use this kind of antenna

D) Distance

A Wireless Lan signal can be broadcast to cover an average size of area , most commonly Wireless Lan provide access with a radius of 65-300 feet.

4. Signal Encoding Techniques

There are 2 techniques

1. OFDM (Orthogonal Frequency Division Multiplexing) divide the allocated frequency range into sub-ranges which simultaneously transmit the pieces of data , OFDM may operate PSK (Phase Shift Keying) or ASK (Amplitude Shift Keying) method
2. DSSS the chipping code add sime security to the communication as the receiving must know this code in order to encode the original data , DSSS usually operate BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Phase Shift Keying) method

5. Errors

A) Error Detection

Use Parity check and CRC (Cyclic Redundancy Check) , CRC is commonly used in many forms of communication because it provides a high level of error detection

B) Error Correction

Use FEC (Forward Error Correction) that send additional information to correct problem if possible at destination

C) ARQ

ARQ (Automatic Repeat Request) allow a receiving device to detect errors in transmission and request a retransmission from the sender , Wireless Lan operates Stop & Wait ARQ scheme that

each transmitted packet must be acknowledged before the next packet can be sent

6. Applications

Wireless Lan is a wireless network that cover an area to connect to the network, it can be use in office or a campus and everyone can use it if you have a device (i.e. laptop , mobile phone) that has Wi-Fi technology.

Wireless Lan Application is intended for buildings with large open areas, such as manufacturing plants, stock exchange trading floors, and warehouses, Furthermore, it is intended for historical buildings with insufficient twisted pair and small offices where installation and maintenance of wired LANs is not cheap. In all of these cases, a Wireless Lan provides an effective and more attractive alternative.

7. Usage

Nowadays Wireless Lan technology is usually use all over the world since it is easy to use and connect with everywhere that has signal

8. Cost

To use Wireless Lan , all you need is a modem router and a device that can receive Wi-Fi signal that will cost about 3000 baht for modem router and 20000 baht for device and it also has an additional cost for using that you need to pay to ISP (Internet Service Provider) per month and cost will be vary from speed and each ISP , for Wireless Lan, The cost of installing and maintaining a Wireless Lan is generally lower than the cost of installing and maintaining a Wired aLn

WiMax
(Worldwide Interoperability for microwave Access)

1. Protocol architecture

A) Layered Stacks

Figure 4 : WiMax stack

Physical layer supports multiple frequency bands. Thus, it can support half-duplex and full-duplex equipment. While MAC (Media Access Control) layer is connection oriented. It combines sub layers which interface to upper OSI (Open Systems Interconnection) layers. It offers many services via same link. For convergence sub layers which stays at the top of the MAC. This layer allows Ethernet, ATM (Automatic Teller Machine), TDM (Time-division multiplexing) voice and IP (Internet Protocol) service. These can be exemplify in Figure 4

B) Protocols

WiMax provides many user applications and interfaces similar to Ethernet , TDM , ATM , IP , and VLAN (Virtual LAN).

The IEEE 802.16 standard is versatile enough to accommodate TDM or FDD (Frequency Division Duplexing) deployments.

The MAC (Medium Access Control) was developed for a point-to-multipoint wireless access environment. It can accommodate protocols like ATM , Ethernet and IP. The MAC frame structure dynamic uplink and downlink profiles of terminals as per the link conditions. This is to ensure a trade-off of capacity and real-time robustness.

The 802.16 MAC protocol performs mainly two tasks: Periodic and Aperiodic activities. Fast activities (periodic) such as scheduling, packing, fragmentation and ARQ (Automatic Repeat Request) are hard-pressed for time and have hard fixed deadlines. They must be performed within a single frame.

C) Standards

WiMAX is a wireless industry coalition whose members organized to advance IEEE 802.16 standards for BWA (Broadband Wireless Access) networks. WiMAX 802.16 technology is expected to enable multimedia applications with wireless connection and, with a range of up to 30 miles, enable networks to have a wireless last mile solution.

D) Standard Organizations

MAC and PHY (Physical Layer) Specification, Backbone Network Architecture, Network Control and Upper Layer Protocols, Selection of mandatory Features and Profile Definition, Product Certification

IEEE 802.16 X, Y Z – the ABC of a Standard

IEEE 802.16.1, IEEE 802.16.2, IEEE 802.16a, IEEE 802.16b, IEEE 802.16c, IEEE 802.16-2001, IEEE 802.16.2-2001, IEEE 802.16d, IEEE 802.16-2004, IEEE 802.16e-2005 with CORRIGENDUM 1 for IEEE

802.16-2004, CORRIGENDUM 2 for IEEE 802.16-2004, IEEE 802.16f, IEEE 802.16g, IEEE 802.16h, IEEE 802.16i, IEEE 802.16j, IEEE 802.16k, IEEE 802.16l, IEEE 802.16m . The WIMAX-Forum and its Organization SPWG, AWG, NWG, TWG, CWG, RWG, MWG

2. Data transmission

A) Spectrum

The 802.16 specification applies across a wide swath of RF (Radio Frequency) spectrum. In order to be standardization, Wimax has published 3 licensed spectrum which are 2.3 GHz, 2.5GHz and 3.5 GHz

However, the biggest segment that is available around 2.5 GHz,

The most bands that are used will be around 3.5 GHz, 2.3/2.5 GHz, or 5 GHz, with 2.3/2.5 GHz probably being most important in Asia.

B) Frequency

WiMAX can provide two forms of wireless service:

Non-line-of-sight: WiMAX uses a lower frequency range from 2 GHz to 11 GHz which similar to Wi-Fi (Wireless Fidelity).

Line-of-sight: which is stronger and more stable, so it's able to send a lot of data with fewer errors, Line-of-sight

transmissions use higher frequencies, with ranges reaching a possible 66GHz

C) Bandwidth

It supports bandwidth 74Mbps. This bandwidth can be achieved using 64QAM ¾ modulation. Moreover, it shares bandwidth among users. Therefore, if there are several active users in specific area, each user will get a shared bandwidth.

D) Data Rates

It offers very high speed in order to access internet. The maximum data rate is 74Mbps. WiMax provides very good signal so, higher data rate can be achieved with several antennas.

3. Transmission media

A) Transmit Power

Wimax basestations (BS) transmit at power level approximately +43dBm. While mobile station (MS) generally transmits at 23 dBm. Since Wimax requires higher modulation in order to achieve high throughput, thus, Wimax needs better SNR (Signal-to-Noise Ratio). For the transmit power number between BS and MS seems to be large difference. This means that, MS can easily receive transmission from BS. Typically, MS is relatively low transmitting power. Hence, it is too difficult to translate. In order to solve this problem by moving the mobile closer to base-station this can improve the SNR.

B) Receive thresholds

The receiver threshold depends on the signal bandwidth, the modulation and the coding scheme. The IEEE 802.16 standards are providing minimum reference values. Its receive threshold is approximately -99 dBm.

C) Antenna

Wimax has Advanced antenna system (AAS) which allow it to transmit multiple simultaneous signals in different directions to stations

Wimax antennas are designed in order to optimize performace of applications. Type of Wimax antennas that are commonly used following:

1. Ommi directional antennas are used for point-to-multipoint configuration which is good where there are many subscribers reside very close to base station
2. Sector antenna which offer great range and throughput with less energy.
   It is more commonly used than Omni directional antennas.
3. Panel antennas are used when radio is contained in the square antenna enclosure.

D) Distance

WiMAX can transfer around 70M bit/sec over a distance of 30 miles to thousands of users from a single base station.

4. Signal Encoding Techniques

WiMAX/802.16 uses digital modulation. The digital modulation is to modulate an analogue signal with a digital sequence in order to transport this digital sequence over a medium: fibre, radio link, etc.

This has great advantages with regard to traditional analogue modulation: better resistance to noise, use of high-performance digital communication and coding algorithms, etc

Four modulations are supported by the IEEE 802.16 standard

4.1 BPSK (Binary Phase Shift Keying)

The BPSK is a binary digital modulation gives high immunity against noise and interference and a very robust modulation. A digital phase modulation, which is the case for BPSK modulation, uses phase variation to encode bits: each modulation symbol is equivalent to one phase.

4.2 QPSK (Quadrature Phase Shift Keying)

When a higher spectral efficiency modulation is needed, more b/s/Hz, greater modulation symbols can be used. For example, QPSK considers two-bit modulation symbols.

4.3 QAM (Quadrature Amplitude Modulation) : 16-QAM and 64-QAM

The QAM changes the amplitudes of two sinusoidal carriers which depend on the digital sequence that must be transmitted; the two carriers being out of phase of $+\pi/2$, this amplitude modulation is called quadrature. QAM-4 and QPSK are the same modulation. The 64-QAM is the most efficient modulation of 802.16

4.4 Link Adaptation

Link adaptation can be used for having one more modulation (this process is also used in GSM (Global System for Mobile Communitions) / EDGE (Enhanced Data rates for GSM Evolution) , UMTS (Universal Mobile Telecommunications System) , Wi-Fi , etc.). When the radio link is good, use a high-level modulation; when the radio link is bad, use a low-level, but also robust, modulation.

5. Errors

A) Error Detection

Use technique FEC (Forward Error Correction) to compare transmit codeword and receive codeword to detect error

B) Error Correction

Use FEC technique that send additional information to correct problem if possible at destination

C) ARQ

WiMax use Selective repeat which is the most complex of a flow control, however it is the most efficiency.

6. Application

WiMAX is intended for mobile data which is efficient support for many simultaneous users. It increased throughput and range with MIMO (Multiple Input/Multiple Output) which is antenna technology that uses several antennas in order to carry more data traffic.

Wimax is used in order to:

Mobile Broadband Mobile WiMAX offers 4G connectivity, allowing end users to access Internet anytime, anywhere.

Fixed Broadband enables high-speed connectivity at a fixed location such as a home or office.

Full access to the system.

WiMax device

Type of device that is required by Wimax needs to be the device for laptop and other portable devices, which means something that is small and lightweight such as Laptop computer which include PDA (Personal Digital Assistance) , hand-held computers and TabletPC's.

7. Usage

In Thailand, Wimax can't be use because the Wimax frequency is the same as the army frequency

But other country can use such as

1. North America use in 2.5 and 5 Ghz
2. South America use in 2.5,3.5 and 5 Ghz
3. Europe south America and asia use in 3.5 and 5 Hz

8. Cost

To use WiMax technology you need to have WiMax router , WiMax USB modem and device that support this technology which cost about 3000 Baht for WiMax router , 2000 Baht for WiMax USB modem and 20000 Baht for device (i.e. laptop) but it has an additional cost that you have to pay to ISP (Internet

Service Provider) each month to use WiMax which will vary to speed and each ISP

Comparison Wireless Protocols technology

Table 3 : Comparison of ZigBee, Wireless Lan, Wimax and Bluetooth Features in the aspect of data transmission.

Market name Standard	ZigBee (IEEE 802.15.4)	Wireless Lan (IEEE 802.11)	Wimax (IEEE 802.16)	Bluetooth (IEEE 802.15)
Data rate	20-250kbps	11-600Mbps	74Mbps	721kbps
Bandwidth	20-250 kbps	11-100Mbps	74Mbps	721kbps
Frequency	868MHz-2.4GHz	2.4GHz-5GHz	2-66GHz	2.402-2.480 GHz
Power Consumption	lowest	highest	Low	Low

Discussion

As shown in Table 3, the minimum data rate of Wireless protocol is ZigBee which allows for a 20-250 kbps. That can lead Zigbee protocol is explicitly too slow- speed for any meaningful data communication between nodes. The maximum data rate is Wireless Lan which allows for 11-600 Mbps. Since Wireless Lan is very high data rate, thus it can send data very quickly. High data rate is preferable for some applications that need data to be sent in real time in order to be rapid response time.

According to table 3, we can see that data rate is proportional to bandwidth. To summarize, the more data rate, the more bandwidth. Bandwidth actually tells us in the amount of data that it is carried from source to destination. Thus, Wireless Lan is such a protocol that able to carry most information of other protocols. Since Wireless Lan is high bandwidth hence, less chance of error. On the other hand, ZigBee is the wireless protocol which is more chance of error. As Wimax and Bluetooth has got a moderate of data rate and bandwidth as compared to Zigbee and Wireless Lan.

In case of frequency, the lowest frequency explicitly show that ZigBee still be the protocol which not only low data rate, low bandwidth, but also low frequency. Therefore, sent data by ZigBee is very slow as compared to Wireless Lan which able to send data rapidly.

Table 4 : Comparison of ZigBee, Wireless Lan, Wimax and Bluetooth Features in the aspect of transmission media.

Market name Standard	ZigBee (IEEE 802.15.4)	Wireless Lan (IEEE 802.11)	Wimax (IEEE 802.16)	Bluetooth (IEEE 802.15)
Transmit power	0-3dBm	30mW(15 dBm)	+23dBm	0.25-100mW (0-20 dBm)
Receive threshold	-85dBm	-94 to -77dBm	-99dBm	-70dBm
Distance	50m	20-91 m	30 mile	10-100m

Discussion

As shown in Table 4, The minimum transmit power of Wireless protocol is Bluetooth which allows for 0-20 dBm. Theoretically, higher transmission power, longer transmission data. Thus, Bluetooth can transmit data only short distance. For the maximum transmit power of Wireless protocol is Wimax. So, Wimax can send data over long distance. However, delivering higher transmit powers comes at a cost to power consumption. With Wireless Lan

Receive threshold is inverse from transmit power. The more transmit power, the lower receive threshold. In theory, the receiver threshold defines a minimum level of signal where the receiver starts to function. The smaller number, the more sensitive the receiver it is. Thus, with the lowest receive threshold of WiMax, so Wimax is the most sensitivity (the most chance of error). That error may come from the noise. While Bluetooth seems to be the lowest sensitivity, therefore, Bluetooth is less chance of error.

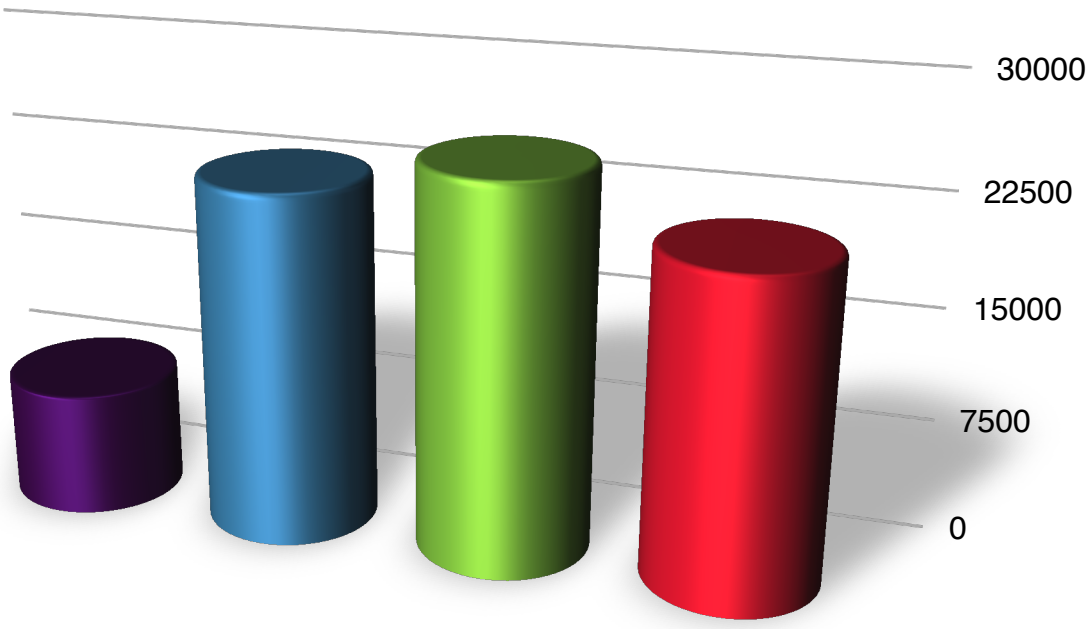
Undoubtedly, when a signal is transmitted over any medium, the signal is attenuated (loss of signal). The impacts of attenuation increase with distance. Especially, over long distance, it is difficult to interpret the signal correctly. Since signal degrades with distance. Noise can be another factor that can make the signal degrades. According to, long distance leads to the smaller Signal-to-Noise ratio. So, it is very low from the minimum. However, Wimax solved this severe problem by moving the mobile closer to base-station which can improve the SNR. Therefore,

over long distance, it is suitable for using Wimax for data transmission.

Table 5 : Comparison of application and cost among ZigBee, Wireless Lan, Wimax and Bluetooth

Market name Standard	ZigBee (IEEE 802.15.4)	Wireless Lan (IEEE 802.11)	Wimax (IEEE 802.16)	Bluetooth (IEEE 802.15)
Application	Low-cost control and monitoring	Internet inside buildings	Mobile Broadband, Fixed Broadband, Full access to the system	Computer & phone peripherals
Cost	about 8150 Baht	about 23000 + Baht	about 25000 + Baht	about 21000 Baht

Figure 5 : Chart represents cost comparison among protocol



Discussion

Even, in many aspects of data transmission, it seems that Zigbee is not a perfect protocol. However, as shown in the table 3, with lowest data rate, it is the lowest power consumption.

Since ZigBee can sleep most of the time, result a long life battery. Moreover for some application such as embedded application which not require high data rate, ZigBee seems to be a suitable protocol.

According to the advantage of Wireless Lan such as high data rate, high bandwidth, the value has been shown in table 5. Thus, it is suitable for the application which does not need to be long distance but require several amounts of data to be sent in real time.

However, in order to transfer data over long distance, it seems that Wireless Lan is not the best choice. Refer to table 4, Wireless Lan can transfer data just short distance. To transfer data over long distance, it is achieved by applying Wimax Technology. For certain applications such as Mobile broadband require Wimax in order to transmit data over long distance.

The most security way for connecting and exchanging information between devices such as faxes, mobile phones, telephones, laptops, personal computers, printers, Global Positioning System (GPS) receivers, digital cameras, and video game consoles over short distance is accomplished by using Bluetooth technology. Nevertheless, as shown in table 3, Bluetooth is low bandwidth. Thus, it cannot send large amount of data. To send large amount of DATDA may use Wireless Lan instead of using Bluetooth. Since, Bluetooth is using low transmit power as referred to table 4 and low power consumption which is shown in table 3 , so it requires less energy than Wimax. It is very beneficial for mobile device namely Laptop since it won't drain the battery.

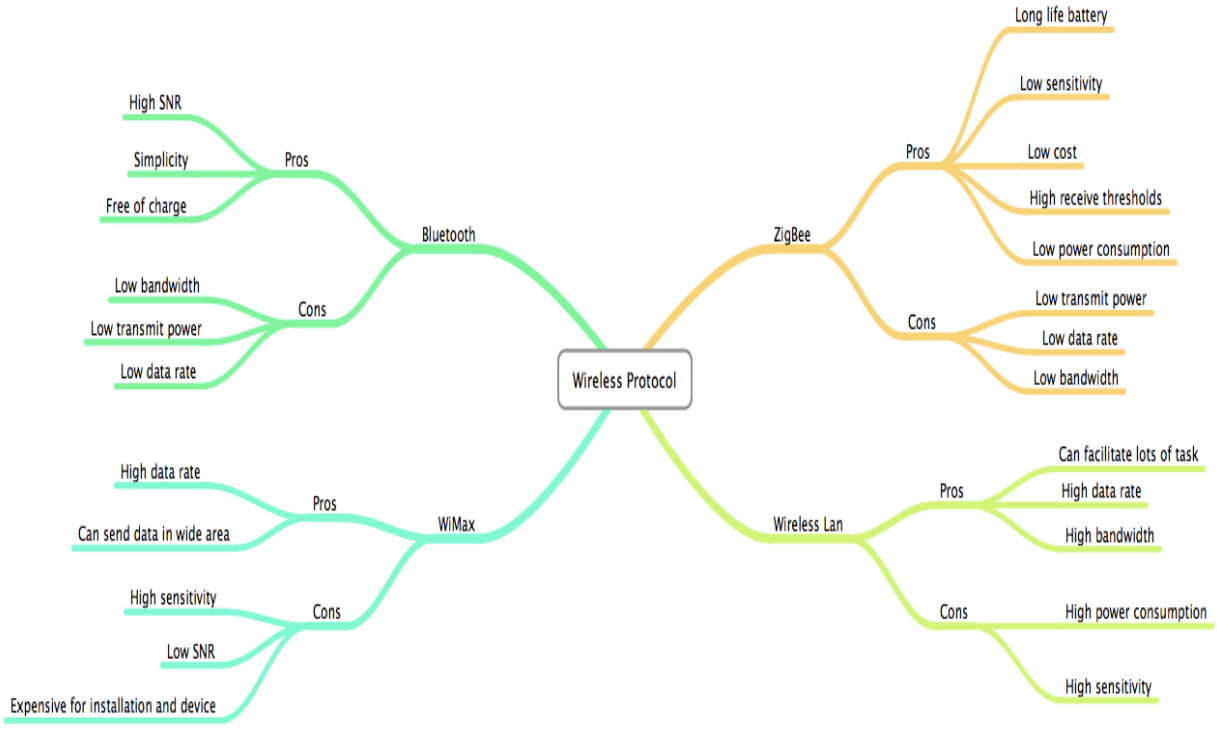
To obtain high data rate, high bandwidth, the cost seems to be high as well. Thus, the high potential aspect may not to be the best choice for certain users. Some user can't afford in order to get the high specification. Therefore, cost is regard as one factor that affect to user decision.

As shown in Table 3 that even ZigBee has lowest data rate, lowest bandwidth. However, it is lowest cost. That is the advantage of ZigBee. However, it may use only some tasks. In order to be able to send data in the wide area, Wimax seems to be suitable. However, the user may need to expense high cost in order to get highest data rate for connecting the wide area network. In order to connect only local area, most of user prefers using Wireless Lan. Owing to highest data rate as well as highest bandwidth which is shown in Table 3, Therefore, it prospers to use this wireless protocol. However, the estimate cost of using this seems to be high. This cost can be illustrate in Figure 5 However, it is not high as compared to Wimax thank to it can transmit data or signal only short distance.

Currently, Laptop or portable computer plays a role in business world. Not only businessman, student or workers use this, but also kids use. The wireless protocol which relevance to this devices are Wireless, Wimax including Bluetooth. Not surprisingly that the cost of these are quite high as compared to Zigbee. Moreover, users need to pay an additional cost per month to the Internet Service Provider (ISP). There are several ISP which it depends on users to choose which ISP they desire. So, the cost may be vary for each ISP.

Conclusion

Even high specification may seem to be good in the aspect of theoretical. However in practical there are several factors that users may need to concern namely appropriateness cost and efficiency for each Wireless protocol all may have pros and cons. To summarize pros and cons for each technology , this can be represented using mind mapping



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