

**ITS323**

**Assignment 1**

**Comparison of 4 wireless  
telecommunication technology**

**To**

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**On 8<sup>th</sup> September, 2010**

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## Table of participation

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## Wireless LAN

Wireless LAN or WLAN is connection between networks without any wire (similarly function like normal LAN connection), properly use in public place or place that not easy to use a wire for many computer such as airport, restaurant, home, etc. WLAN use Access Point to spread a signal to many devices. Most Access Point, in theory can connect up to 253 clients. WLAN using IEEE 802.11 as standard, IEEE 802.11 is support by Institute of Electrical and Electronics Engineers (IEEE) and nowadays we have many generations of 802.11 as you can see in fig.1, the latest generation is 802.11n.

Wi-Fi Generations			
Wi-Fi Technology	Frequency Band	maximum data rate	Approximate Outdoor range
802.11a	5 GHz	54 Mbps	120
802.11b	2.4 GHz	11 Mbps	140
802.11g	2.4 GHz	54 Mbps	140
802.11n	2.4 GHz, 5 GHz,	450 Mbps	250
	2.4 or 5 GHz (selectable), or 2.4 and 5 GHz (concurrent)		250

Fig.1

### Protocol Architectures

Most WLAN using TCP/IP as protocol but WLAN can also use some other protocol (AppleTalk, IPX) too.

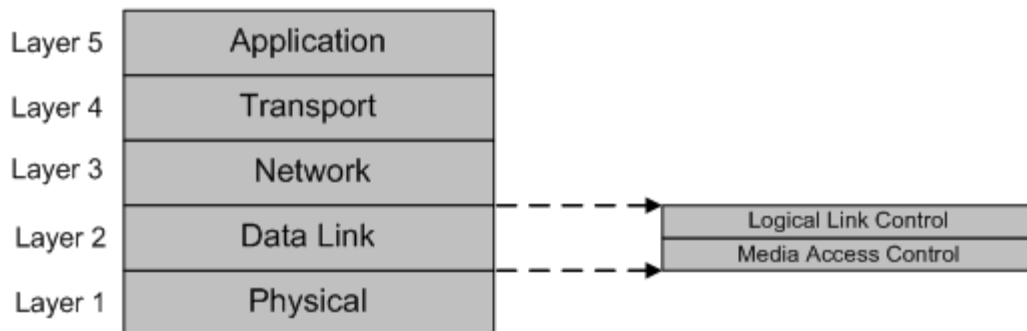


Fig.2 <http://software.intel.com/en-us/articles/wi-fi-and-wimax-protocols-of-security/>

As we can see in fig.2 WLAN which using IEEE 802.11 as standard is applied to TCP/IP protocol in Data Link layer using Media Access Control (MAC). MAC is a sub-layer of data link layer. MAC provides the channel access control. This makes several stations connected to share the same physical medium. MAC can use both half and full duplex but for compatibility reasons full-duplex is often available in the equipment.

Data Transmission

Difference generation of IEEE 802.11 has difference data rate, some use difference frequency band and difference bandwidth as shown in Fig.3

Wi-Fi Technology	Frequency Band	maximum data rate	Bandwidth
802.11a	5 GHz	54mbps	20 MHz
802.11b	2.4 GHz	11mbps	20 MHz
802.11g	2.4 GHz	54mbps	20 MHz
802.11n	2.4 GHz, 5 GHz	200mbps	40 MHz

Fig.3

The IEEE 802.11b, 802.11g, 802.11n(2.4 GHz) use spectrum ranges from 2400MHz to 2483MHz, and is divided up into 14 channels from 2412MHz to 2462MHz. In USA, only channels 1-11 are available but some country such as Japan also available up to 14 channels, it's spaced 5MHz apart.

CHANNEL NUMBER	LOWER FREQUENCY MHZ	CENTER FREQUENCY MHZ	UPPER FREQUENCY MHZ
1	2 401	2 412	2 423
2	2 406	2 417	2 428
3	2 411	2 422	2 433
4	2 416	2 427	2 438
5	2 421	2 432	2 443
6	2 426	2 437	2 448
7	2 431	2 442	2 453
8	2 436	2 447	2 458
9	2 441	2 452	2 463
10	2 446	2 457	2 468
11	2 451	2 462	2 473
12	2 456	2 467	2 478
13	2 461	2 472	2 483
14	2 473	2 484	2 495

Fig.4

The IEEE 802.11a,802.11n use spectrum ranges from 5.145GHz-5.25GHz, 5.25-5.35GHz, and 5.725-5.825GHz. and is divided up into 8 channels from 5160MHz to 5340MHz, 5 channels from 5725MHz to 5845MHz, it's spaced 20MHz apart as shown in Fig.5.

CHANNEL NUMBER	LOWER FREQUENCY	CENTER FREQUENCY	UPPER FREQUENCY
	MHZ	MHZ	MHZ
36	5160	5180	5200
40	5180	5200	5220
44	5200	5220	5240
48	5220	5240	5260
52	5240	5260	5280
56	5260	5280	5300
60	5280	5300	5320
64	5300	5320	5340
149	5320	5745	5765
153	5745	5765	5785
157	5765	5785	5805
161	5785	5805	5825
165	5805	5825	5845

Fig.5

### Transmission Media

WLAN is unguided signal, travelling by air, as radio signal on 2.4GHz or 5GHz so, WLAN use an antenna to increase transmission power to direction that people want.

### Directional Antennas

Directional antenna is antenna that point to direction that people want to maximize these transmission powers, often use for point to point connection.

### Omni-Directional Antennas

Omni directional antenna is antenna that not specific point to any client. These antennas are look like normal radio base that we can see, often point to the sky for spreading signal as far as possible.

Transmit power, Receive thresholds, Distance of varies generation of WLAN are difference as shown in Fig.6

Wi-Fi Technology	Transmit power	Receive thresholds	Max Distance
IEEE 802.11a			120
802.11b			140
IEEE 802.11g			140
IEEE 802.11n			250

Fig.6

### Signal Encoding Techniques

Difference generation of IEEE 802.11 has difference encoding techniques, some use more than one technique, we can see at Fig.7

Wi-Fi Technology	Encoding Techniques
IEEE 802.11a	OFDM
IEEE 802.11b	DSSS
IEEE 802.11g	OFDM,DSSS
IEEE 802.11n	OFDM

Fig.7

What is OFDM (Orthogonal frequency-division multiplexing)?

OFDM is a technique that transfers data by radio frequency. These techniques transfer a data by space in orthogonal wave, a data is sorted to many channel and these techniques can handle many channels easily.

What is DSSS (Direct-sequence spread spectrum)?

DSSS is technique that transfers data by radio frequency. This technique transfers a data by noise, this noise is contain 1 or -1 as data. This technique required higher frequency than original signal to transfers a data.

### Errors Detection and Errors Correction

Errors Detection and Errors Correction for Difference generation of IEEE 802.11 was difference by their encoding techniques

Wi-Fi Technology	Encoding Techniques	Error Detection method	Error Correction method
IEEE 802.11a	OFDM		Forward Error Correction (FEC)
IEEE 802.11b	DSSS		
IEEE 802.11g	OFDM,DSSS		
IEEE 802.11n	OFDM		

Fig.8

### Application

WLAN is connection use for connect many devices to be a network; people can use this technology to connect their devices to network or Internet. Almost newer notebook are supported by WLAN already, many cell phone tend to supported by WLAN too.

### Usage

WLAN now using around the world! In Thailand, city with high density of population such as Bangkok are provided with free WIFI network, Bangkok green WIFI for example. Many mobile and fixed line carriers are opening their WIFI AP (Access Point) for their customer. Peoples are buying WLAN AP router for their house. WLAN is spreading around the world because it's easy to use and easy to install.

### Cost

For home use, price for WLAN AP is about 1000-3000THB plus price for client device. A newer device such as notebook are supported by WLAN already, or we use USB or PCI WLAN card which pricing at 200-500THB.



# WiMAX

WiMAX is connection technology that invented for main purpose to replace old school cable or ADSL. WiMAXs are expected to be a future of wireless connection. Unlike Wi-Fi, WiMAX IEEE 802.16 is licensed frequency bands. WiMAX also offer better range than Wi-Fi. Nowadays, we have 2 types of WiMAX for difference purport as show in Fig.1

**WiMAX types**

	<b>802.16d (802.16-2004)</b>	<b>802.16e (802.16-2005)</b>
Application	DSL replacement	Mobility
Data rate	75 Mbps	30 Mbps
Distance	75 km	2-4 km
Frequency Band	2-66GHz	2-11 GHz

Fig.1

In 802.16d have better data rate and far distance than 802.16e, why people want 802.16e?

Because 802.16d will not stable while moving, so it better to use in unmoving device like PC. 802.16e is better for movable device like mobile phone or notebook, but data rate and distance is fewer.

## Protocol Architectures

WiMAX using TCP/IP as protocol and applied in Data Link layer using MAC

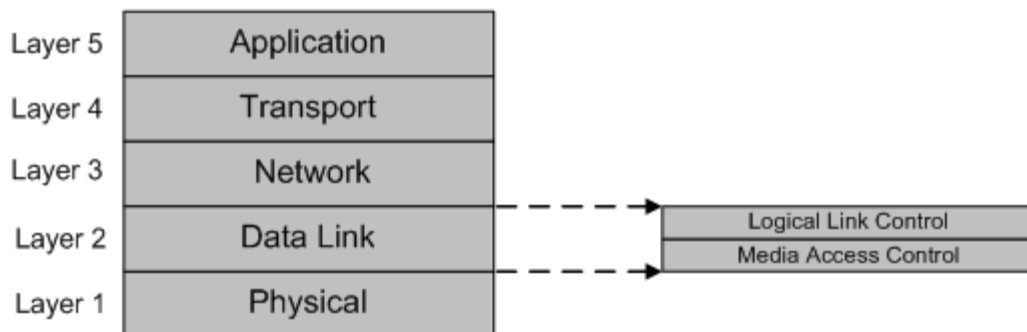


Fig.2 <http://software.intel.com/en-us/articles/wi-fi-and-wimax-protocols-of-security/>

As we can see in fig.2 WiMAX which using IEEE 802.16 as standard is applied to TCP/IP protocol in Data Link layer using Media Access Control (MAC). MAC is a sub-layer of data link layer. MAC provides the channel access control. This makes several stations connected to share the same physical medium. MAC can use both half and full duplex but for compatibility reasons full-duplex is often available in the equipment.

## **Data Transmission**

Difference type of WiMAX has difference Frequency band , data rate, and bandwidth as show in Fig.3

<b>WiMAX Type</b>	<b>Frequency Band</b>	<b>Maximum data rate</b>	<b>Bandwidth</b>
802.16d	2-66GHz	75 Mbps	20 Mhz
802.16e	2-11 GHz	30 Mbps	10 Mhz

Fig.3

Difference country using Difference frequency band, for example in USA use 2.5GHz but Pakistan use 3.5GHz other country may use other frequency band depend on their condition.

## **Transmission Media**

WiMAX is unguided signal, travelling by air, as radio signal on 2-66GHz or 2-11GHz so, WiMAX use an antenna to increase transmission power to direction that people want.

### **Directional Antennas**

Directional antenna is antenna that point to direction that people want to maximize these transmission powers, often use for point to point connection.

### **Omni-Directional Antennas**

Omni directional antenna is antenna that not specific point to any client. These antennas are look like normal radio base that we can see, often point to the sky for spreading signal as far as possible.

Transmit power, Receive thresholds, Distance of 802.16d and 802.16e are difference as shown in Fig.4

WiMAX Type	Transmit power	Receive thresholds	Max Distance
802.16d	approx.43 dBm	Up to 5 dB SNR	75 km
802.16e	approx.23 dBm	Up to 10.5 dB SNR	2-4 km

Fig.4

## **Signal Encoding Techniques**

Difference generation of IEEE 802.16 has difference encoding techniques, we can see at Fig.5

WiMAX Type	Encoding Techniques
802.16d	OFDM
802.16e	OFDMA

Fig.5

What is OFDM (Orthogonal frequency-division multiplexing)?

OFDM is a technique that transfers data by radio frequency. These techniques transfer a data by space in orthogonal wave, a data is sorted to many channel and these techniques can handle many channels easily.

What is OFDMA (Orthogonal frequency-division multiple access)?

OFDMA is extended version of OFDM which offer flexible to release various frequency bands, decrease radio interference from other station, release difeernce data rate for difference user, lower and stable delays, which better than OFDM.

## **Errors Detection and Errors Correction**

WiMAX or IEEE 802.16 use HARQ to Correct the errors.

What is HARQ (Hybrid automatic repeat request)?

HARQ is combination of Forward Error Correction (FEC) and automatic repeat request (ARQ). HARQ is added FEC as extra bit for checking an errors (error detection bit). HARQ is better than ARQ in low signal condition but required more data than normal ARQ, so throughput of HARQ is lower than ARQ.

## **Application**

WiMAX can use in many place in many devices such as replace DSL for PC in house, replace Wi-Fi in public place like airport or use in small device like cell phone. WiMAX also can use with notebook or moveable device that need for better signal, In USA WiMAX also called as one of 4<sup>th</sup> generation of cellular wireless standards.

## **Usage**

WiMAX are using around the world, In USA mobile carrier using WiMAX as 4G signal, many of newer mobile phone in USA already supported WiMAX. In Thailand WiMAX is still waiting to use in public place, trial use only in Mae Fah Luang University.

## **Cost**

In Thailand, WiMAX device is difficult to found, but you can buy it from the Internet.USB WiMAX or PCI WiMAX card is about 25 USD per unit. WiMAX router is about 63 USD according from ebay.

## Zigbee

Zigbee is a wireless system designed for covering sensors and control devices. Which don't need high bandwidth and high data rate but low latency, low energy consumption, and low cost. Zigbee use 2 physical devices types for the network, full function device and reduced function device. ZigBee uses IEEE 802.15.4 Physical Layer and Media Access Control (MAC) allows networks to handle any number of devices. It can connect up to 18,450,000,000,000,000 devices by 64 bit IEEE address and up to 65,535 networks.

### Zigbee's Layer Stack

1. Application (APL) layer discovers devices and binds two or more devices based on their services and needs. Then forwarding the messages between these bounded devices.
2. Network (NWK) layer controls the network like starting, joining and leaving a network, addressing and routing. And also apply the security to the outgoing frames.
3. Media access control (MAC) layer enables transmission and reception of MAC protocol data unit.
4. Physical (PHY) layer controls the activation and deactivation of the radio transceiver, energy detection, link quality indication, channel selection, clear channel assessment and transmission. It also control receiving packets across the physical medium.
- 5.

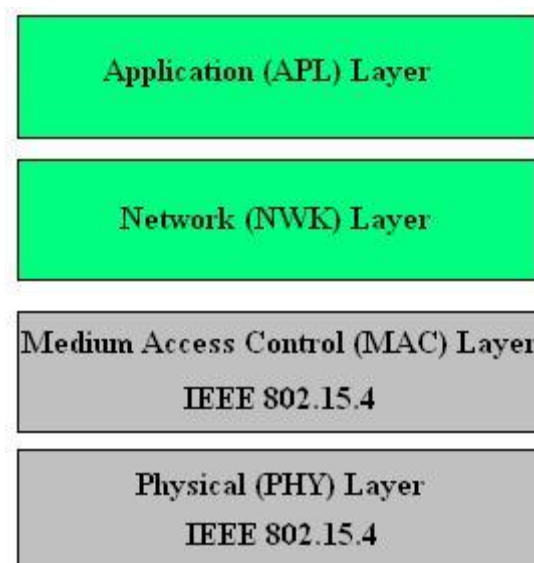


Figure 1 : Zigbee Stack Layer

### Frequency Band

Zigbee has been designed for the 3 frequency bands. 868 MHz band in Europe with the data rate of 20 kbps, the 915 MHz band in North America, Australia, etc. with the data rate of 40 kbps, and the 2.4 GHz band used in global band with the data rates of 250 kbps. The range for using Zigbee is 50 meters in typical but can be 5 – 500 meters based on the environment.

Frequency Band	Maximum Data Rate
868 MHz	20 kbps
915 MHz	40 kbps
2.4 GHz	250 kbps

For the 2.4 GHz band, Zigbee divide it into 16 non-overlapping channels, which are 2-MHz wide and 5-MHz apart.

Channel Number	Lower Frequency (MHz)	Center Frequency (MHz)	Upper Frequency (MHz)
11	2404	2405	2406
12	2409	2410	2411
13	2414	2415	2416
14	2419	2420	2421
15	2424	2425	2426
16	2429	2430	2431
17	2434	2435	2436
18	2439	2440	2441
19	2444	2445	2446
20	2449	2450	2451
21	2454	2455	2456
22	2459	2460	2461
23	2464	2465	2466
24	2469	2470	2471
25	2474	2475	2476
26	2479	2480	2481

For 868 MHz band, there are 1 channel (channel 0) using 868 – 868.6 MHz

frequency and 10 channels (channel 1 – 10) in 915 MHz band using 902 – 928 MHz frequency.

### **Transmit Power and Receiver Maximum Input Level**

Transmit power shall be at least -3 dBm, but maximum transmit power is limited by local regulatory bodies. And a receiver shall have a receiver maximum input level greater than or equal to -20 dBm.

### **Antenna**

The best antenna for Zigbee is Inverted-F antenna. Which size is 25.7 x 7.5 mm and have the gain of 1.1 dB in XY plane, 3.3 dB in XZ plane, and 1.6 dB in YZ plane.

### **Signal Encoding Techniques**

Zigbee use direct-sequence spread spectrum (DSSS) as a modulation technique, which consists in using a pseudo-random code sequence to directly modulate the basic carrier signal and encode the data being transmitted.

Moreover, binary phase-shift keying (BPSK) is used in 868 and 915 MHz bands. And offset quadrature phase-shift keying (O-QPSK) is used in 2.4 GHz band. But 868 and 915 MHz bands can use O-QPSK and amplitude shift keying (ASK) also(in optional).

### **Errors Detection and Errors Correction**

Zigbee use the IEEE 802.15.4 for the error detection and error correction.

If an error is found, a frame check sequence (FCS) mechanism employing a 16-bit International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) cyclic redundancy check (CRC) is used to detect error in every frame. Then the re-transmissions of the error frame will occur.

### **Application**

Zigbee is used in controlling home appliances, such as air condition, lighting, heating, smoke and fire alarm, and some security devices.

### **Usage**

Zigbee devices are used in many countries, such as USA, Canada. Zigbee alliance is large and has many famous electronic companies. For example, Philips, LG,

Intel, Sony, and Atmel.

**Cost**

Zigbee's cost per chip is very low, about \$1 and module is about \$40-50.



## Bluetooth

Bluetooth is a wireless technology for exchanging the data in short range with low cost and low power. It is designed for using in wide range of devices to connect and communicate with each other.

### Bluetooth Stack

1. Logical Link Control and Adaptation Protocol (L2CAP) Layer support high level protocol multiplexing, packet segmentation, and reassembly, and the conveying of quality of service information.
2. Link Manager Layer controls the operation between two devices. Including setting up and controlling logical transports and logical links.
3. Baseband Layer specifies or implements the medium access and physical layer procedures between Bluetooth devices.
4. Radio Layer controls mode of modulation.

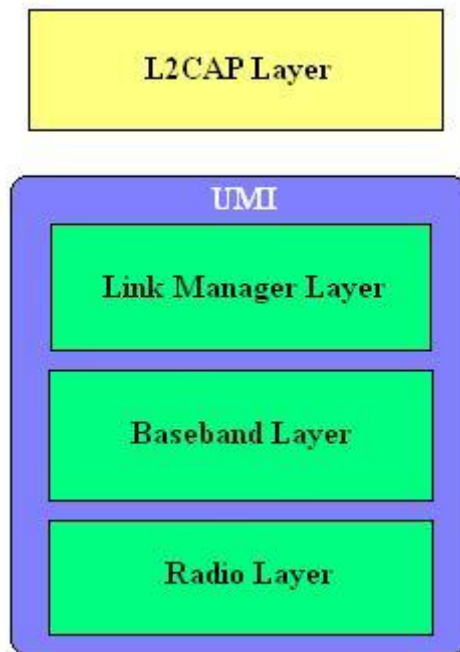


Figure 1 : Bluetooth Stack Layer

### Frequency Band

Bluetooth operates in the unlicensed industrial, scientific and medical (ISM) band of 2.4 – 2.485 GHz. In addition, it uses adaptive frequency hopping (AFH) technology to reduce the interfering from the other wireless technology sharing in this spectrum. The data rate is depending on the version of this technology, 1 Mbps

for Version 1.2, up to 3 Mbps supported for Version 2.0 Enhanced Data Rate (EDR), up to 24 Mbps supported for Version 3.0 High Speed (HS). And the ranges vary depending on the class of radio used in an implementation.

- Class 3 radios
- Class 2 radios commonly used in mobile devices.
- Class 1 radios most found in industrial use.

### **Transmission and Receive Power**

Bluetooth has 3 classes of transmission power, 100 mW (20 dBm), 2.5 mW (4 dBm), and 1 mW (0 dBm). As shown in the table.

Radio Class	Transmission Power (dBm)	Distance (meter)
Class 1	20	100
Class 2	4	10
Class 3	0	1

Bluetooth receiver requires an actual sensitivity level of -70 dBm or better.

### **Antenna**

The most popular type of the antenna for Bluetooth is ceramic chip antenna. The next is Printed Inverted-F Antenna (PIFA) by its low cost.

### **Signal Encoding Techniques**

Bluetooth use 2 modes for the different modulation.

1. Basic Rate (Mandatory Mode) uses a shaped, binary Frequency Modulation (FM) to minimize transceiver complexity.
2. Enhanced Data Rate (Optional Mode) uses Phase Shift Keying (PSK) modulation.

### **Errors Detection and Errors Correction**

Generally, Bluetooth use 1/3 rate forward error correction (FEC), 2/3 rate FEC or, Automatic Repeat Request (ARQ) for the error detection in Baseband Layer. But L2CAP Layer can provide further error detection.

### **Application**

Nowadays, Bluetooth is used for many devices that can see in daily life, such

as mobile phone, computer, even on Wii or Playstation 3.

### **Usage**

Bluetooth is used in wide range of devices and used widely in the world. In Thailand, it is usually used in connection of mobile phone and computer in short range for the data transfer.

### **Cost**

Bluetooth devices are easy to buy in Thailand. Bluetooth USB's price is about 100 Baht.

## Comparison

	Wireless LAN	WiMAX	ZigBee	Bluetooth
Maximum Data Rate	200 Mbps	75 Mbps	250 kbps	24 Mbps
Max Distance	250 m	75 km	50 m	100 m
Frequency Band	2.4 GHz, 5 GHz	2-66 GHz	868 MHz, 915 MHz, 2.4 GHz	2.4 GHz
Encoding Technique	OFDM, DSSS	OFDM, OFDMA	DSSS	FM, PSK
Error Detection, Correction	Stop-and-Wait ARQ	HARQ	CRC	FEC, ARQ
Cost	200-500THB	700-1000THB	30-40THB	100THB

### **Conclusion**

As you can see in the table, difference technology was invented for difference purpose. For smallest data with small distance ZigBee is the best choice from lowest cost. For little bigger data such as mp3, Bluetooth is better from faster data rate but also little bigger cost. For biggest data WLAN is fastest and distance is double from Bluetooth but cost also double too. And finally WiMAX, the greatest for telecommunication distance but cost is highest and still not popular.

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