

# **ITS 323 Assignment 1**

## **Introduction to Data Communications**

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# ZigBee

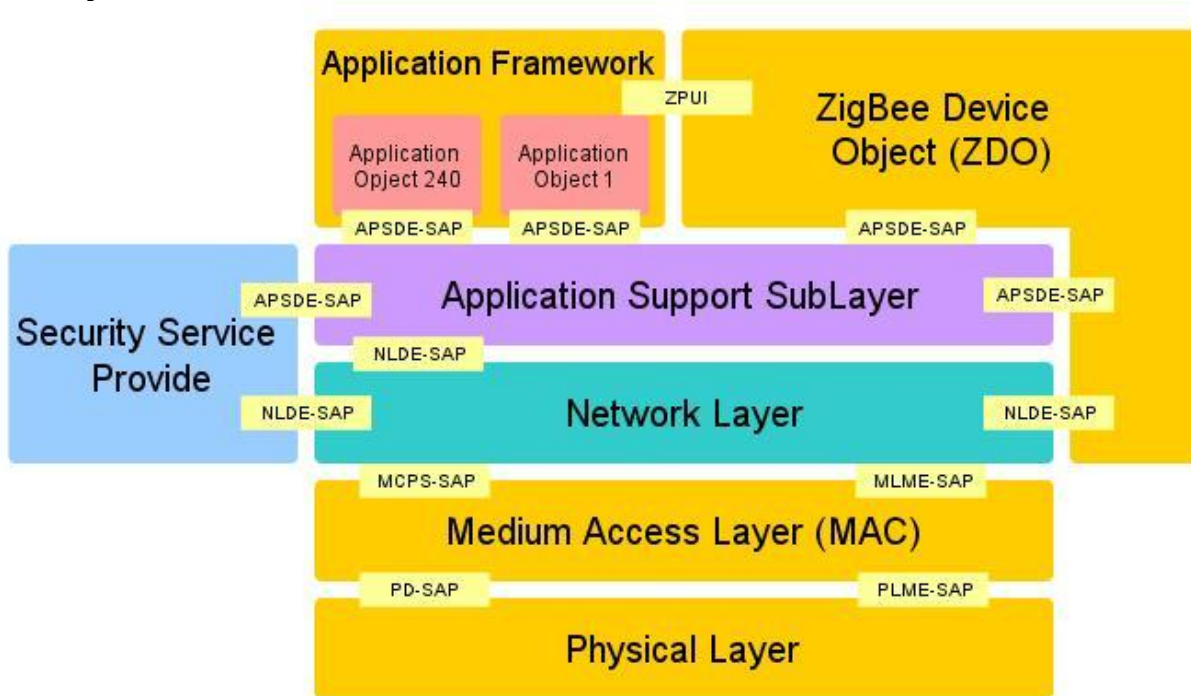
ZigBee is a wireless network technology that supports low data rates, low power, and low cost. ZigBee is a wireless standard for personal area network (PAN) sensor monitoring and control.

ZigBee have three different types of data transmission:

- Transmission from a device to the coordinator
- Transmission from the coordinator to the device
- Transmission between any two devices

## 1. Protocol Architectures

### 1.1 Layer stacks



*Figure: Stack Architectures*

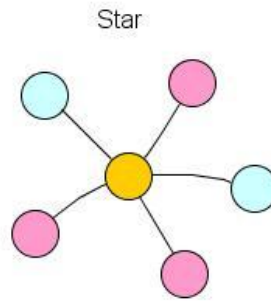
- **Physical Layer:**

Physical layer includes features such as receiver energy detection, link quality indication, and clear channel assessment.

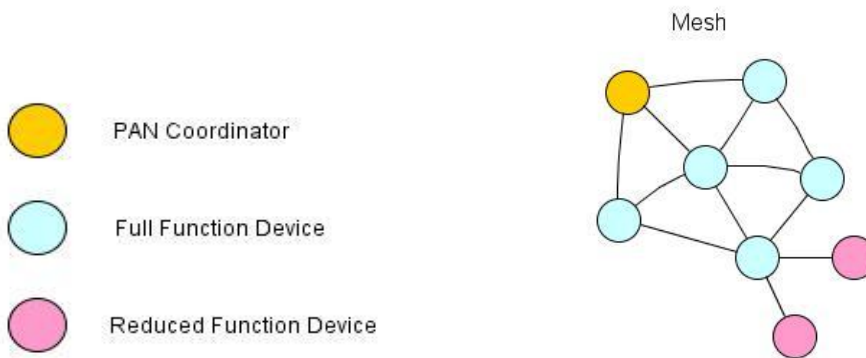
- **Media Access Control (MAC) Layer:**

Media Access Control provides reliable transmission. ZigBee layers define the network layer and security management. ZigBee's network layer supports three networking topologies: star, mesh, and cluster tree.

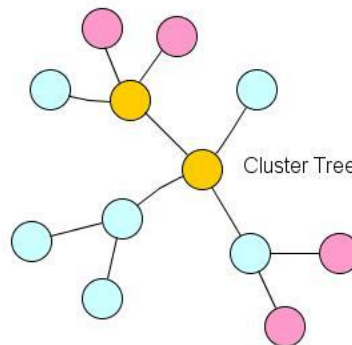
- **Star network** are common and provide for very long battery life operation.



- **Mesh network** provides high reliability and larger range.



- **Cluster tree** are used for applications such as access or industrial control sensing. The advantage of cluster tree is increased coverage area and disadvantage is increased message latency.



- **Application support sublayer:**

Application support sublayer is responsible for binding tables, reliable data transport, and message forwarding between bound devices.

- **Application framework profile layer:**

Application framework is an execution environment for application objects to send and receive data. And define ZigBee Device Object is responsible for defining the

operating mode of the device, device discovery and determination of which application services the device provides.

## ***1.2 Protocols***

IEEE 802.15.4 MAC sublayer controls the access to the radio channel using slotted CSMA/CA (Carrier Sense Multiple Access With Collision Avoidance) in superframe structure and using unslotted CSMA/CA in non-beacon enable network.

## ***1.3 Standards***

ZigBee is designed to provide highly efficient connectivity between small packet devices. ZigBee use IEEE 802.15.4 as its Medium Access Layer (MAC) and Physical Layer.

IEEE 802.15.4 standard intends to offer the basic lower network layers of a type of wireless personal area network (WPAN) which focuses on low cost, low speed all area with communication between devices.

## ***1.4 Standard organizations***

ZigBee is using the Institute of Electrical and Electronics Engineers (IEEE).

# ***2. Data Transmission***

## ***2.1 Spectrum and Frequency***

Frequency Bands that include 16 channels at 2.405GHz (global), 10 channels at 902 to 928MHz (USA), and 1 channel at 868 to 870MHz (Europe).

## ***2.2 Bandwidth***

ZigBee use of a 5 MHz channel bandwidth enables devices to achieve a data rate of up to 250Kbps in a reasonably power-efficient manner.

## ***2.3 Data rates***

ZigBee is support data rates of 20Kbps and up to 250Kbps at a range of 30m and up to 70m. ZigBee's technology is slower than Bluetooth (1Mbps). ZigBee is low power usage consumption. ZigBee is direct sequence spread spectrum.

# ***3. Transmission Media***

## ***3.1 Transmit power***

IEEE 802.15.4 radio has a receive mode current consumption of 9mA and 17mA in transmit mode with a power output level of 5dBm. The sleep mode current consumption is down to 0.2 $\mu$ A.

## ***3.2 Receive thresholds***

The 802.15.4 standard specifies a minimum receiver sensitivity of -85 dBm for 2.4 GHz radios and -92 dBm for 900 MHz radios and adjacent channel rejection is 0dB minimum.

### ***3.3 Antennas***

ZigBee protocol used form XBee module is embedded solution providing wireless end-point connectivity to device. These modules use the IEEE 802.15.4 networking protocol for fast point-to-multipoint or peer-to-peer networking. They are designed for high-throughput applications requiring low latency and predictable communication timing.

### ***3.4 Distance***

The transmission distances ranging from 10 to 100 meters, it's depending on power output and environmental characteristics.

## ***4. Signal Encoding Techniques***

The modulation mode used by 802.15.4 is phase-shift key (PSK) based, chosen because of its strong ability to be recovered even in very low signal to interference environments.

ZigBee is used Direct Sequence Spread Spectrum (DSSS).

## ***5. Errors***

### ***5.1 Error detection and Error Correction***

Error detection and Error correction are the reliable techniques for delivering the digital data in the network. Error detection techniques can detect the error in the communication such as channel noise while error correction can detect errors and reconstruct the original. As the well-known description of Zigbee network, which is the reliable technology, it uses fully handshake protocol for transfer reliability. So, the failures in essential parts must be efficiently detected and automatically recovered. Besides, from the Zigbee network topology, it also allows multiple hops to route messages from any device to any other device in the network. Thus, Zigbee can provide reliability by multipath routing. Moreover, Zigbee also perform to detect error by retransmitting the digital data if packet unacknowledged instead of correcting the error.

## ***6. Applications***

ZigBee can create network a refer standard by IEEE 802.15.4. There are two different types of device:

- A full function device (FFD) can talks to any other device and network coordinator capable, and it can operate in three modes serving:
  - Device
  - Coordinator
  - PAN Coordinator



- A reduced function device (RFD) can't become a network coordinator, and talks only to a network coordinator. It's very simple implementation. A reduced function device can only operate in a mode serving:

- Device

An IEEE 802.15.4 network requires at least one FFD to act as a network coordinator.

ZigBee have three different types of device:

1. ZigBee coordinator: Initializes a network, manages network nodes, and stores network node information.
2. ZigBee Router: A router is passing on data from other devices.
3. ZigBee End Device: the sensor nodes, the ones which take the information from the environment.

The technology would be used by a typical user:

- Human Input Device: Keyboard, Mouse / Pointing Device, Remote Controls (controls for audio & video equipment), Gaming Device
- Home Automation and Control: Automation Devices, Control Devices
- Home Security
- Interactive Toys

## **Advantage**

- Low cost.
- Low power consumption
- High capacity. ZigBee composing of up to 65,000 network node.
- License-free frequency band
- Cheap and easy to installation
- Flexible and extendable networks
- Integrated intelligence for network set-up and message routing
- Low offered message throughput

## **Disadvantages**

- Short range
- Low complexity
- Low data speed
- Additional overhead
- Restricted to home or office use
- Not yet a mature technology

## **7. Usage**

Zigbee can be adapted and used in various matter due to its special specifications such as

- Wireless home security

- Remote thermostats for air conditioner
- Remote lighting, drape controller
- Call button for elderly and disabled
- Universal remote controller to TV and radio
- Wireless keyboard, mouse and game pads
- Wireless smoke, CO detectors
- Industrial and building automation and control (lighting, etc.)

## ***8. Cost***

Xbee chip, which was developed by Digi International., is the product of Zigbee Technology. Nowadays, the cost of Xbee is likely to be the bluetooth's cost. The approximate cost is around 100 -2000 baht. The range of Xbee cost is depended on the difference in its specification such as the data rate, type of the end-point device, serial, range, etc. In between, the further information about Xbee specification can be found from <http://www.digi.com/>.

# Bluetooth

## 1. Protocol Architecture

### 1.1 Bluetooth Protocol Stack

Figure 1 shows the Bluetooth protocol stack, which is divided into two parts, lower layer stack and upper layer stack. The Host Controller Interface (HCI) is used to separate between the layer stack.

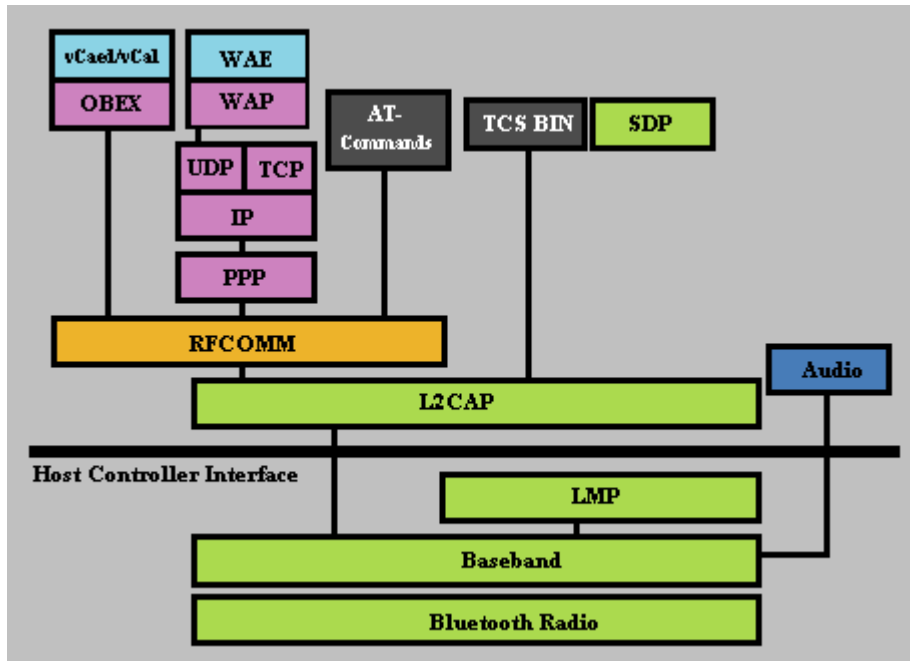


Figure1 : Bluetooth Protocol Stack

Bluetooth is defined as a layer protocol and is divided into 4 categories, namely Bluetooth Core Protocol, Cable Replacement Protocol, Telephony Control Protocol and Adopted Protocol. For each layer, the mandatory protocols are shown in table 1.

Bluetooth Core Protocol	Baseband, LMP, L2CAP, SDP
Cable Replacement Protocol	RFCOMM
Telephony Control Protocol	TCS Binary, AT Commands
Adopted Protocol	PPP, TCP/IP, OBEX, WAP, vCard, etc.

Table1: Bluetooth mandatory protocols

### 1.2 Protocols

This section reviews the brief information of some protocol that use in Bluetooth.

#### a. Baseband

The Baseband enable the physical radio frequency between Bluetooth devices.

- b. LMP  
The Link Manager Protocol (LMP) is used for set up a link channel between Bluetooth units and provided some security like authentication and encryption.
- c. RFCOMM  
The RFCOMM is the simple transport protocol that use in cable replacement usage of Bluetooth.
- d. TCS Binary  
To control signaling for the establishment of speech and data calls between Bluetooth devices, the TCS Binary protocol is used.
- e. PPP  
Point-to-Point Protocol (PPP) is used to perform the direct connection between two networking nodes.
- f. TCP/IP  
TCP/IP is the set of protocols that used for the Internet connection.
- g. WAP  
Wireless Application Protocol (WAP) is the application layer protocol uses in a wireless-communication network.

### ***1.3 Standard***

Bluetooth wireless technology is based on IEEE 802.15.1, which designs to use in the wireless personal area network. This standard is defined by IEEE organization.

## ***2. Data Transmission***

Bluetooth wireless technology is operated in the unlicensed radio frequency band at 2.4 GHz using 79 channels between 2.402 GHz to 2.480 GHz.

## ***3. Transmission Media***

Bluetooth technology is divided into 3 classes with difference in specification. For the communication distance and maximum permitted power is shown in Table 2.

Class	Maximum Permitted Power		Range (approximate)
	mW	dBm	
Class1	100	20	~100 meters
Class2	2.5	4	~10 meters
Class3	1	0	~1 meter

**Table 2: Bluetooth Transmission Range**

For the data rate of Bluetooth is shown in Table 3. The difference versions of Bluetooth provide the difference data rate.

<b>Version</b>	<b>Data Rate</b>
Version 1.2	1 Mbit/s
Version 2.0 + EDR	3 Mbit/s
Version 3.0 + HS	24 Mbit/s

**Table 3: Bluetooth Data Rate**

#### ***4. Error***

In Bluetooth technology, there are 3 types of error correction.

- 1/3 rate forward error correction
- 2/3 rate forward error correction
- Automatic repeat-request

#### ***5. Application***

Bluetooth technology is designed to be a short range communication networking that use in the small area of communicating. The target devices of Bluetooth is the mobile phone and a hand free headset. There are many application that can apply with Bluetooth, for example,

- Short range transmission of sensor data devices to mobile phone.
- Data transmission on mobile phone, PDA, etc.
- Wireless controller for console game e.g. PS3, PSP Go and Wii
- Dial-up internet access on personal computer or PDA.

#### ***6. Usage***

Nowadays many countries around the world, including Thailand are extensively using Bluetooth wireless technology, because almost of the mobile phone is integrated with Bluetooth wireless technology.

#### ***7. Cost***

In the present day, the cost Bluetooth devices is around 500 – 4000 Baht, according to the quality and specification of the integrated devices.

# Wireless LANs

## 1. Protocol Architectures

The 802.11 is WLAN standard that use for implement WLAN. WLAN have 2Mbps throughput. Next two year the standard upgrade to 802.11b that raised the throughput to 11 Mbps make it more comparable to wired equivalent and support high speed data communication.

OSI Reference Model		
Application		
Presentation		
Session		
Transport		
Network		
Data Link	Logical Link Control (LIC)	802
	Media Access Control (MAC)	.
Physical		11

Fig1 shown the relation between standard and OSI layers

The 802.11 affects to the Physical layer and Data Link layers. In the Physical layer defines how data is transmission over the physical medium. The Data Link layer defines how transmitted data is packaged, address and managed within the network.

## 2. Data Transmission

WLAN sends the data over the radio wave signals from the wireless router to the network adapters within individual workstations. The WLAN data have a narrow bandwidth, 5 GHz for 802.11a standard and 2.4 GHz for 802.11g standard.

For IEEE 802.11a standard they have specific that data transfer rate is 54 Mbps over 5.2GHz radio band

For IEEE 802.11b standard they have specific that data transfer rate is 11 Mbps over 2.4GHz radio band

For IEEE 802.11g standard, it will provide backward compatibility with other two standards and additional security over 2.4GHz radio band.

There are 2 types of setup WLAN, ad Hoc (peer to peer) and Infrastructure (Client/Server).

### ***3. Transmission Media***

In wireless technologies there are not necessary need transmission medias because radio waves and infrared signals use air or space as a transmission media so they are not require to use any cables.

There are 2 types of transmission media for radio wave:

The radio waves in a wide range of wireless communications are many different frequencies such as AM radio (300 to 3000 KHz), FM radio (30 to 300 MHz), cellular telephone & personal communications systems (300 to 3000MHz), satellite communications (radio waves of frequency more than 1GHz commonly called Microwaves) and Wireless Local Area Networks (1 to 10GHz).

Infrared light (300GHz to 400 THz) can be used in the Wireless Local Area Networks (WLANs) but the networks are only limited within a room because infrared light cannot pass through the walls.

Mostly WLAN devices have a power transmit at 30 mW.

### ***4. Signal Encoding Technique***

Wireless routers receive the analog signal and send it through the air or space in analog signal form.

In sending data LAN card will transform the digital signal from computer to analog signal and send it out as a radio wave and in receiving data LAN card will transform the analog signal to digital signal for computer.

### ***5. Errors***

To detect the error use CRC (Cyclic Redundancy Check) as a tool. CRC can detect accidental change to row computer data and this technique commonly uses in digital network and storage devices.

CRC is a data 2 bytes at the end of the message that send by modbus protocol for detecting the error.

### ***6. Applications***

WLAN is brought to used for a long time because it make users more comfortable than wire line communications unless it less speed than that. Typical user can setup and config the systems by themselves but in term of securities it too hard for the typical user to protect especially in the company its must have the administrator for maintain and set the security from the hacker. There are 6 types that is the main problems of WLAN securities

- Rogue access points
- Interception and Monitoring of Wireless Traffic
- Jamming
- Client-to-Client Attacks
- Brute Force Attacks Against Access Point Passwords
- Misconfiguration

## ***7. Usages***

At present almost the countries there use WLAN technology but in poor countries the usages is only hold in some groups of people because of many conditions such as installation cost, service cost and service area. We can see in Thailand WLAN is use widely in Bangkok but in the urban there have a few place that you can find the WLAN services.

## ***8. Cost***

There are many WLAN devices at present some of them are cheap but some of them are very expensive the cost is depend on a data rate and the distance of use area. In using WLAN there are requires to have access point and WLAN card.

The cost of access point is around 750 – 12,500 baht

The cost of WLAN card is around 850 – 5,000 baht



# Wimax

## 1. Protocol Architectures

The standard of the group of broadband wireless communication is 802.16 so WiMax (Worldwide Interoperability for Microwave Access) is also use IEEE802.16 as a standard and that standard is update version to IEEE802.16e now.

The two flavors of wimax are used for different applications and although they are based on the same standard, the implementation of each has been optimized to suit its particular application

IEEE 802.16d standard

This standard as known as “DSL Replacement” because this standards based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. It also provides the data rates up to 75 Mbps and the cell radii can be up to 75 kilometers.

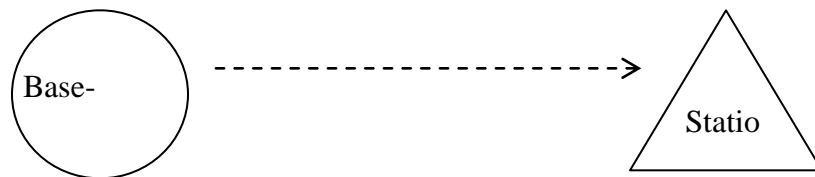
IEEE 802.16e standard

This standard also known as “Nomadic/Mobile” and widely known as “802.16-2005”. It currently provides the ability for users to connect to a wimax cell from a variety of locations, and there are future enhancements to provide cell handover. 802.16e provides a data rates up to 15 Mbps and the cell radius distance up to 2 – 4 kilometers

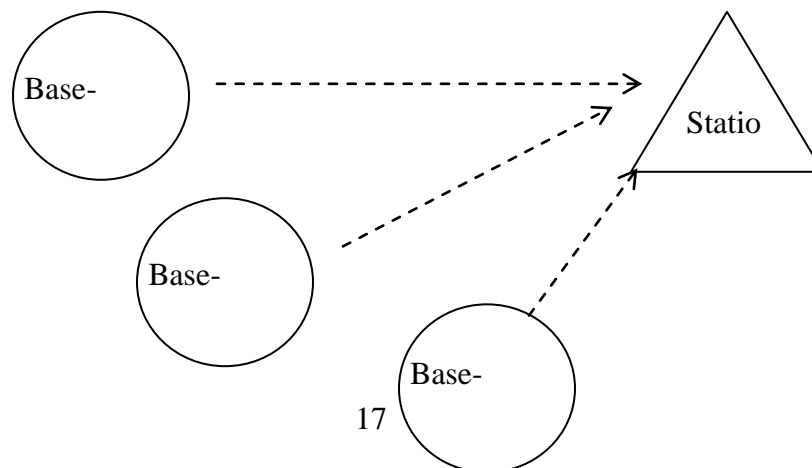
## 2. Data Transmission

There are three different kinds of transmission in wimax;

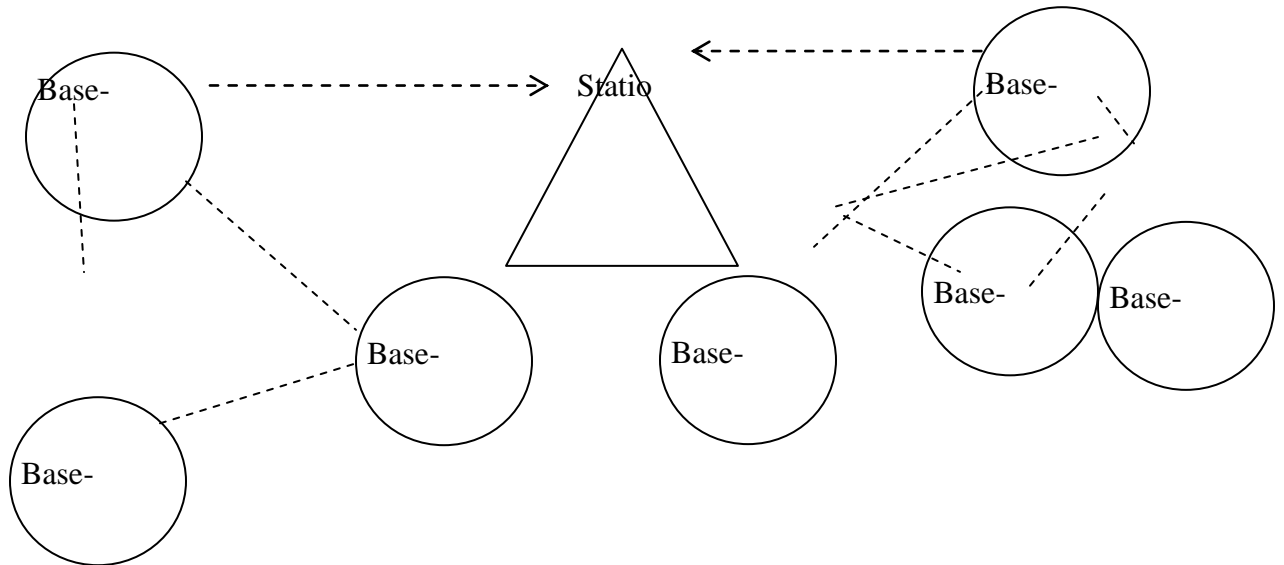
- Point – to – Point (PTP)



- Point – to – Multipoint (PTM)



- Mesh Topology



Wimax uses OFDM (Orthogonal Frequency Division Multiplexing) technique in data transmission. Wimax is allowed to use multiple broadband frequency ranges. In IEEE 802.16a standard, data transmission is fixed at 10 – 66 GHz but in IEEE 802.16d standard, it is allow lower frequency at 2 – 11 GHz. The data rate of wimax is around 75 Mbps.

### ***3. Transmission Media***

There are two types of typical wimax's station:

Base station :

The approximate power level is +43 dBm (20 watt). Wimax can deliver high bandwidth connectivity as far as 48 kilometers away from the base station.

Mobile station:

The approximate power level is +23 dBm (200 milli watt). Wimax can deliver high bandwidth connectivity as far as 1.6 – 4.8 kilometers away from the mobile station.

### ***4. Signal Encoding Techniques***

Wimax uses combination signaling techniques for higher bit rate. Wimax not only use amplitude modulation or frequency modulation but it uses both of them for improving bit rates that called QAM (Quadrature Amplitude Modulation).

### ***5. Errors***

Because of using more efficient signal modulation so the likelihood of encountering errors are increase. To offset that, the FEC (Forward Error Correction coding) is suggested. The idea of using FEC is to include redundant bits in the transmission that will allow the receiver to detect and correct the certain percentage of the encountered error.

## **6. Applications**

Wimax operates as same as wifi, a computer equipped with wimax radio card connected to the wimax – enabled network via wimax tower. Wimax supports many kinds of wireless connection, high broadband MANs, cellular backhaul, clustered Wi-Fi hotspot backhaul, last-mile broadband, cell Phone replacement, and other application such as ATMs, vehicular data and voice, security application and VoIP.

## **7. Usage**

In Thailand, The National Telecommunications Commission has just allowed the vendor to service wimax in two bandwidths, 2.3 – 2.4 GHz is brought to use in wimax application for the citizen and 2.5 – 2.69 GHz is brought to use in USO (Universal Service Obligation) projects.

But in the other countries, there are wimax serviced already such as in Canada, USA, Middle East and Africa, Russia, Asia Pacific include China, India Australia etc. by using many bandwidth in operates wimax, 2.3, 2.5, 3.5 and 5.8 GHz.

## **8. Cost**

The cost of installing and equipments for the base station is 43,000 € (This cost is estimates form the successful trend of this technology deployment.). It can divide into 2 parts;

Base station	40,000 €
Sector Antennas	3,000 €

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