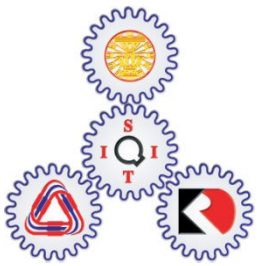

Sirindhorn International Institute of Technology

Group Assignment Report

Assignment 1 (Wireless Technologies)
ITS323 (Introduction to Data Communication)

Group Member (Group No. 12)

Mr. Weera Jangtanasombat Student ID 5122781792
Mr. Chayanon Mokasak Student ID 5122790017
Mr. Sorawich Narkwichit Student ID 5122792369
Section 2 (Computer Sciences)

Instructor

Asst. Prof. Dr. Steven Gordon

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Table of Participation

Section	Percentage of Participation		
	Mr. Weera	Mr. Chayanon	Mr. Sorawich
1.1	33	33	33
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1.4	33	33	33
2	33	33	33
3	33	33	33

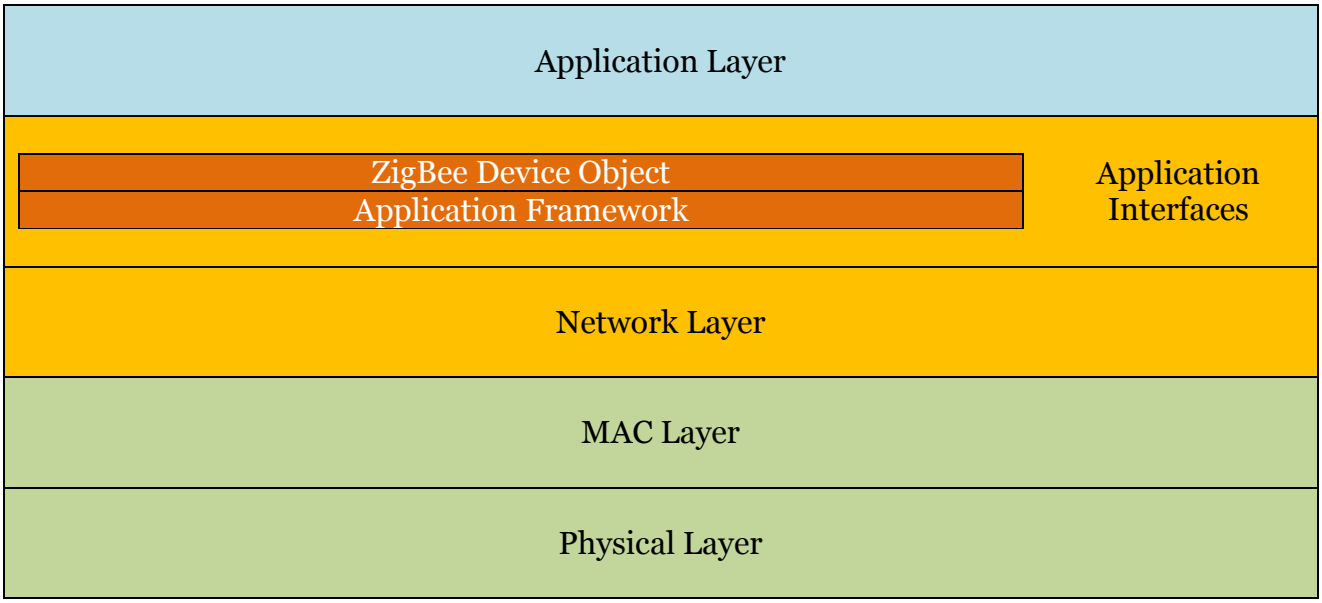
Section 1.1 (ZigBee)

Introduction

ZigBee is a high level communication protocol that use small and low-power digital radios signal.

Protocol Architecture

Protocol Stack



Note for Protocol stack:

Application of IEEE 802.15.4 (ZigBee)
Implement in the ZigBee
Other layers in TCP/IP Protocol Model of IEEE 802.15.4

Protocol Architecture

Application Layer This layer provides user interface for end user. This layer is used ZigBee in the application manufacturer.

Application Interfaces This layer provides data and services management. There are 2 Sub-Layers which are ZigBee Device Object Sub-Layer and Application Framework Sub-Layer. For ZigBee Device Object Sub-Layer is control and management of Application objects. For Application Framework Sub-Layer is defines input and output to Application Interface.

Network Layer This layer locates between Application Support and MAC Layer. It provides network configuration, manipulation and message routing.

MAC Layer to access the network to provide reliable transmission.

Physical Layer to transmit information and receive information from the source.

Standard

IEEE 802.15.4: The standard is built by 802.15 groups. It is the basis of ZigBee that focus on low-cost, low-power consumption.

IEEE 802.15.4a: The standard is developed to IEEE 802.15.4 that has two additional Physical Layers, one Physical Layers using Direct Sequence Ultra wideband (UWB) and another using Chirp Spread Spectrum (CSS).

IEEE 802.15.4c: The standard is developed to IEEE 802.15.4 that has several additional Physical Layers. It is 780 MHz using O-QPSK or MPSK.

IEEE 802.15.4d: The standard is developed to IEEE 802.15.4 that has several additional Physical Layers. It is 950 MHz using GFSK or BPSK**.**

Standard Organization

The Institute of Electrical and Electronics Engineers (IEEE) is an organization for Wireless Personal Area Network, especially task group 4 that focus on low data rate solution, including ZigBee.

Data Transmission

Standard	Spectrum (GHz)	Frequency (GHz)	Bandwidth (MHz)	Data Rate (Mb/s)
IEEE 802.15.4	2.4	2.4	0.25	0.25

Transmission Media

Standard	Transmitted Power (dbM)	Received Threshold (dbM)	Antennas	Distance (Meters)
IEEE 802.15.4	-3	-92	Module, Chip	10 – 75

Signal Encoding Techniques

ZigBee is used several techniques to encoding from digital data to analog signal.

Standard	Signal Encoding Techniques
IEEE 802.15.4	Offsset-Quadratic Phase Ship Keying (O-QPSK) Binary Phase Ship Keying (BPSK)

Error

Error Detection

When transmitter sends a frame to receiver but the frame becomes corrupt. So the receiver is required to checking the system using Preamble and Packet Error Detection.

Error Correction

To correcting errors in a ZigBee, it is used retransmission. When two nodes start transmission but their packet will collide at node that wouldn't be able to successfully receive. So it needs to retransmit again for the packet. But this method is causes unnecessary energy waste.

ARQ

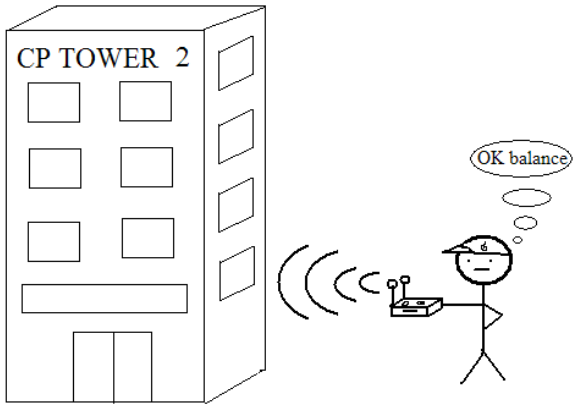
ZigBee is used hybrid-ARQ. This technology is used for hard-decision making likes ZigBee. This is the combination of Existing Error Detection (ED) and Forward Error Correction (FEC). It is allowed requesting for the new repeatly retransmission. This technology that implement in ZigBee is using commodity off-the-shelf hardware.

Other Issues of ZigBee

Application

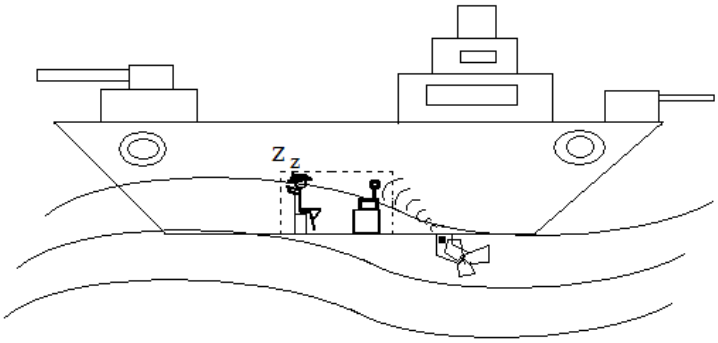
Censors

These technologies are designed for monitoring physical things which can converting to the signals that can show up on the electrical instrument. The ZigBee application is applied to these technologies, in the sense of transmit or encoding from analog signal that censored from physical thing to digital signal. For example, an engineer is use the balance checking machine, when he censored to the constructed building, then the censored signal is encoding and transmit to the machine to show up result.



Automation

These technologies are designed for self-processing, in detail, received an analog signal that automate the vehicle and encodes it to digital data which will show up on the screen monitor. For example, propulsion control system; it receiving a signal from the propulsion and showed up how many round-per-seconds is process by the propulsion on the screen monitor.



Usage

In Thailand, many people are used these technologies in everyday life (especially engineer). For example, the civil engineers are used the balance checking machine (check for the balance of constructed buildings) which apply the ZigBee technologies, in the sense of the encoding from balance (analog) to showed up digital data on the monitor. More for everyday life such as data exchange, static networks with low-cost device and much more. In other countries, they are used this technologies to study and develop on basic robots, especially in Japan, and many more quantity in everyday life.

Costs

Since ZigBee is a low cost technology. So, the ZigBee chip become cheaper, approximately USD 6-10 per quantity. In the sense of everyday life, we need to purchase the application that applies ZigBee, not ZigBee chips itself. For example, we need to purchase the balance checking machine (for engineering using), approximately USD 50-70, which is much more expensive.

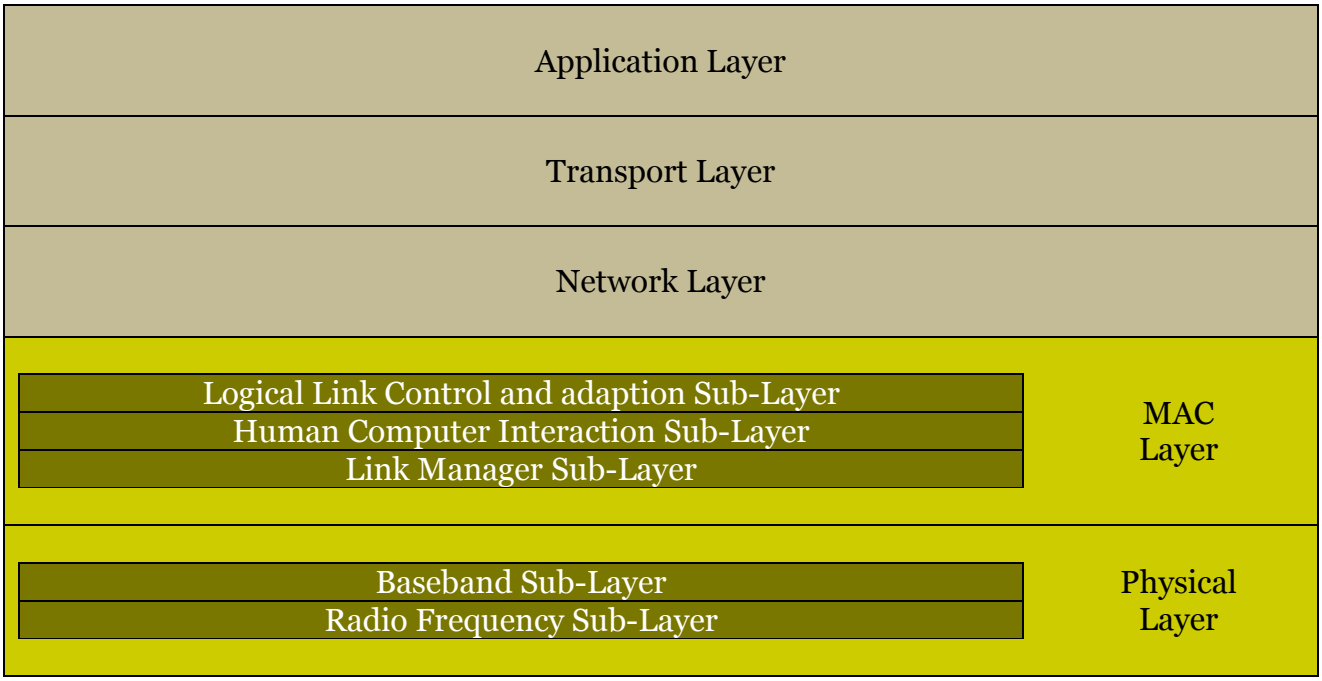
Section 1.2 (Bluetooth)

Introduction

Bluetooth is the wireless technology for transmitting (or) and exchanging data in the short distance. It is using the short wavelength transmission.

Protocol Architecture

Protocol Stack



Note for Protocol stack:

Implement in the Bluetooth (IEEE 802.15)
Other layers in TCP/IP Protocol Model

Protocol Architecture

Application Layer	Provides user interfaces and support for applications.
Transport Layer	Transfer of data between origins and destinations.
Network Layer	Provide routing across the network for data transmission.
MAC Layer	Transferring across the link with addressing and error control. There are 3 sub-layers for this MAC layer which are Logical Link Control and adaption Sub-Layer, Human Computer Interaction Sub-Layer and Link Manager Sub-Layer.
Physical Layer	Receive signal and control link connection. There are 2 sub-layers for this physical layer which are Baseband Sub-Layer and Radio Frequency Sub-Layer.

Standards

IEEE 802.15: This original standard of Bluetooth which is implementing for wireless personal area networks (WPAN). It is implementing with communication of devices within a Personal Operating Space.

IEEE 802.15.1: This modified standard of IEEE 802.15 is designed for portable digital devices, including notebook.

IEEE 802.15.2: The enhancement version is the standard that provides wireless personal area networks (WPAN) with another application that does not use this technology such as wireless local area networks (WLAN).

IEEE 802.15.3: This edited version of IEEE 802.15. This is the high data rate version, with MAC layer amendment.

IEEE 802.15.4: This modified version of IEEE 802.15.3 with low data rate. Moreover, resolving ambiguities, reducing unnecessary complexity and increasing flexibility in security key usage

Standard Organization

The Institute of Electrical and Electronics Engineers (IEEE) is an organization that working for Wireless Personal Area Network (WPAN), including Bluetooth.

Data Transmission

Standard	Spectrum (GHz)	Frequency (GHz)	Bandwidth (MHz)	Data Rate (Mb/s)
IEEE 802.15	2.4	2.4	1	1-3
IEEE 802.15.1	2.4	2.4	1	1-3
IEEE 802.15.2	2.4	2.4	1	>20
IEEE 802.15.3	2.4	2.4	0.25	0.25
IEEE 802.15.4	2.4	2.4	1	1-3

Transmission Media

Standard	Transmitted Power (dbM)	Received Threshold (dbM)	Antennas	Distance (Meters)
IEEE 802.15	20	-70	Low-Profile	10
IEEE 802.15.1	20	-76	Single, Dual	10
IEEE 802.15.2	20	-82	Whip	10
IEEE 802.15.3	20	-87	Zard, Flat	10
IEEE 802.15.4	20	-92	Module, Chip	10

Signal Encoding Techniques

Bluetooth is used several techniques to encoding from digital data to analog signal.

Standard	Signal Encoding Techniques
IEEE 802.15	Frequency Shift Keying (FSK)
IEEE 802.15.1	Differential Phase Encoding (DPE)
IEEE 802.15.2	Dirty paper coding (DPC)
IEEE 802.15.3	Physical Layer Modulation and Coding (PLMC)
IEEE 802.15.4	Offset Quadrature phase-shift keying (QPSK)

Error

Error Detection

Cyclic Redundancy Check is used to detect the error on communication of Bluetooth. Errors caused by noise in transmission channels. It is used binary sequence. Then, data blocks are stored. When blocks are processing; if the new CRC did not match the earlier, then show up a data error.

Error Correction

There are 3 kinds of error correction which is baseband protocol: 1/3 rate FEC, 2/3 rate FEC and ARQ scheme. For every 1/3 rate FEC, 3 times is repeat for Cyclic Redundancy Check. For 2/3 rate FEC, 10 – 15 Bit Code is used.

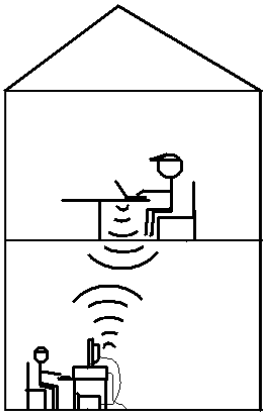
ARQ

The packet is retransmitted till an ACK is received. Bluetooth uses ACK which is acknowledgement that uses positive and negative ACK with setting appropriate of ARQN values. The Bluetooth is process the next packet, if the timeout values are showed up.

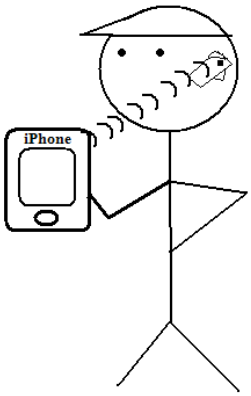
Other Issues of Bluetooth

Application

Home Network: These technologies become popular to enhance people with convenience of their wireless communication inside their house. Bluetooth is does not required to install to home computers. Moreover, the people in the house can access same data as the creator by TV, fax, PC, notebooks and communication devices.



Bluetooth Headset: When people connecting their mobile phone with Bluetooth headset, they will not to use their mobile phone anymore. They just use Bluetooth headset to communicate with people. But, it can use for incoming calls only, not for outgoing calls. These technologies are used Bluetooth wireless transmission technology to connect mobile phones and the Bluetooth headset.



Usage

In Thailand, a lot of people (especially modernize student) is used the application which apply the Bluetooth transmission technologies. For example, Bluetooth headset is often used to enhance the people with mobile phone (without using mobile phone) to communicated to the destines. In other countries, they are used this technologies too to provide their citizen communication, especially in Europe and US.

Costs

Since, Bluetooth is used low-cost electronic devices. Then, the costs from manufacturing are very low. Bluetooth Chips' price is estimated to costs around USD 4. Then, it enforces the customer to pay for Bluetooth docks that approximated USD 66 – 100 which is very expensive.

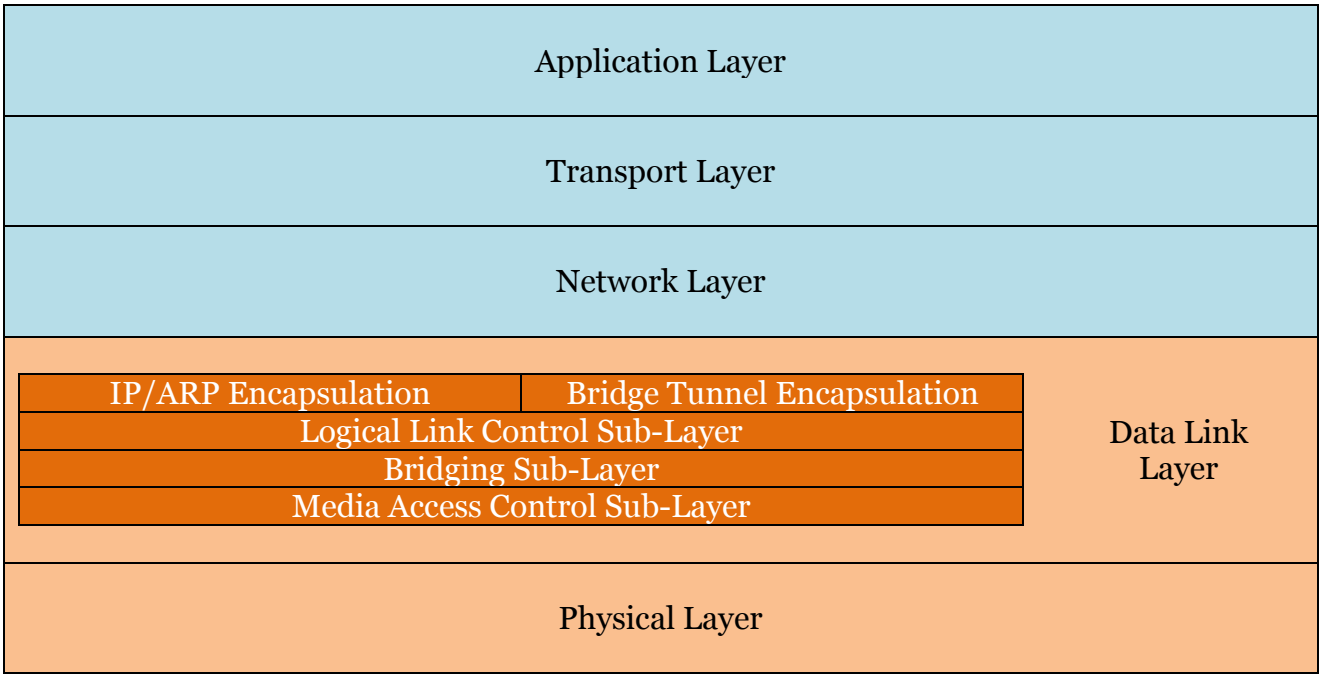
Section 1.3 (Wireless LAN)

Introduction

Wireless LAN is the technology that transmit a signal from the origin to the destine(s) by the wireless transmission signal, which provide the connection between two people (or) organization or outside the agents.

Protocol Architecture

Protocol Stack



Note for Protocol stack:

Implement in the Wireless LAN (IEEE 802.11)
Other layers in TCP/IP Protocol Model

Protocol Architecture

Application Layer	Provides user interfaces and support for applications
Transport Layer	Transfer of data between origins and destinations
Network Layer	Provide routing across the network for data transmission.
Data Link Layer	Transferring across the link with addressing and error control. There are 3 sub-layers for this data link layer which are Logical Link Control, Bridging and Media-Access Control. The above two sub-layers is concerned when the network is used.
Physical Layer	Physical signals that transmission through devices and Medium.

Standard

IEEE 802.11: The protocol version of IEEE 802.11 which is not used in our today life. It is used Frequency Hopping Spread Spectrum or Direct Sequence Spread Spectrum encoding scheme in wireless transmission.

IEEE 802.11a: The edited version of IEEE 802.11 which provide larger bandwidth. It is used an orthogonal frequency division multiplexing encoding scheme. It is used in Asynchronous Transfer Mode in wireless transmission.

IEEE 802.11b: The modified version of IEEE 802.11 which provides technologies for Wireless Fidelity (or Wi-Fi) and Ethernet System.

IEEE 802.11g: The extension to the protocol version of IEEE 802.11 which provide technologies for short distance wireless transmission. It is still used an orthogonal frequency division multiplexing encoding scheme.

IEEE 802.11n: The current version of IEEE 802.11 which amended with MIMO (Multiple-input and multiple-output) antennas. Moreover, it is added more throughputs.

Standard Organization

The Institute of Electrical and Electronics Engineers (IEEE) is an international organization which responsible for produce and development of Wireless LAN standards.

Data Transmission

Standard	Spectrum (GHz)	Frequency (GHz)	Bandwidth (MHz)	Data Rate (Mb/s)
IEEE 802.11	2.4	2.4	20	2
IEEE 802.11a	5.3/5.8	3.7/5	20	54
IEEE 802.11b	5.3/5.8	2.4	20	11
IEEE 802.11g	5.3/5.8	2.4	20	54
IEEE 802.11n	5.3/5.8	2.4/5	20/40	72.2/150

Transmission Media

Standard	Transmitted Power (dbM)	Received Threshold (dbM)	Antennas	Distance (Meters)	
				Indoor	Outdoor
IEEE 802.11	17	-86	Cantenna, Biquad	20	100
IEEE 802.11a	15	-54	Directional	35	120
IEEE 802.11b	18	-86	Homebrew	38	140
IEEE 802.11g	23	-68	Twin	38	140
IEEE 802.11n	20	-65	MIMO	70	250

Signal Encoding Techniques

Wireless LAN is used several techniques to encoding from digital data to analog signal.

Standard	Signal Encoding Techniques
IEEE 802.11	Frequency Shift Keying (FSK), Phase Shift Keying (PSK), Pulse-Position Modulation (PPM)
IEEE 802.11a	Quadrature Amplitude Modulation (QAM)
IEEE 802.11b	Phase Shift Keying (PSK)
IEEE 802.11g	Orthogonal frequency-division multiplexing (OFDM)
IEEE 802.11n	Asymmetrical Advance Coding (AAC)

Error

Error Detection

To detecting errors in a wireless LAN, a receiver is received a branch of data from the wireless station; a signal is duplicated itself with the receiver to defines the signal for a received data; and continues with manage resources, then monitor the received data and the signal, to detect error data and produce a receive data error signal.

Error Correction

In the IEEE 802.11 standard, error will be correct, if the errors are worst, but will not happen. We can use Fountain codes and a resolution adaptive ADC to correct error with not-worst error or good condition error.

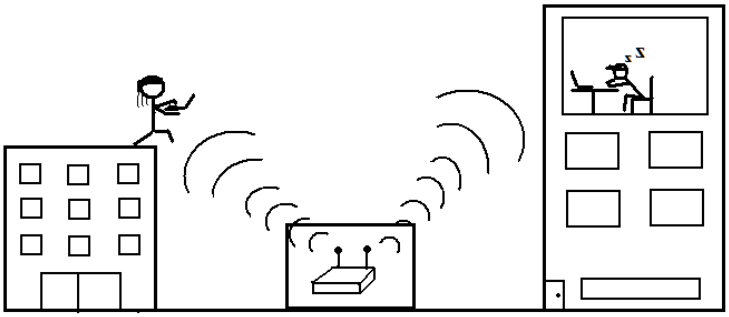
ARQ

The "no-acknowledgement" (NACK) ARQ in medium access control (MAC) sub-layer is to be used when the bandwidth is inefficiency. The physical layer have lower packet error probability (PER) and higher data rate in newer standard.

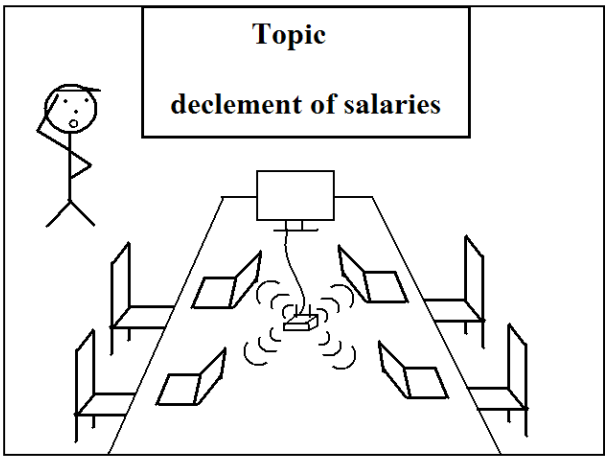
Other Issues of Wireless LAN

Application

Cross-Building These technologies provide us to have connection between multiple building which in the same area. A point-to-point wireless link is used with the connection provided by Router. This is usually used in two modern building which does not have much space between. For example, a student in SIIT is connected to the SIIT Wireless LAN system that can connect around agents and outside the agents.



Ad Hoc Network It is decentralized wireless system. The temporary network is used; there are stations which provided the range into a temporary network. This is suitable for temporary linkage. For example, at Rangsit campus, a SIIT student's computer was use the Wireless LAN connection router to connect to another SIIT student's computer to transfer the files or the data to the destine (another computer).



Usage

In Thailand, every organizations or agents, which have wireless networks transmission, are provided or established Wireless LAN for the short-time communication between in the agents. In advance, other countries outside Thailand, it is still used these technologies to provided their citizen with the wireless communication.

Cost

From the establishment, Wirelesses' LAN costs is just slightly increased all the time due to wide use in our today life. The current costs for Wireless LAN transmission usage are approximated as USD 60 - 120. For nearby cost, you need to purchase more hardware for transmission such as router (for approximate of USD 60 - 80).

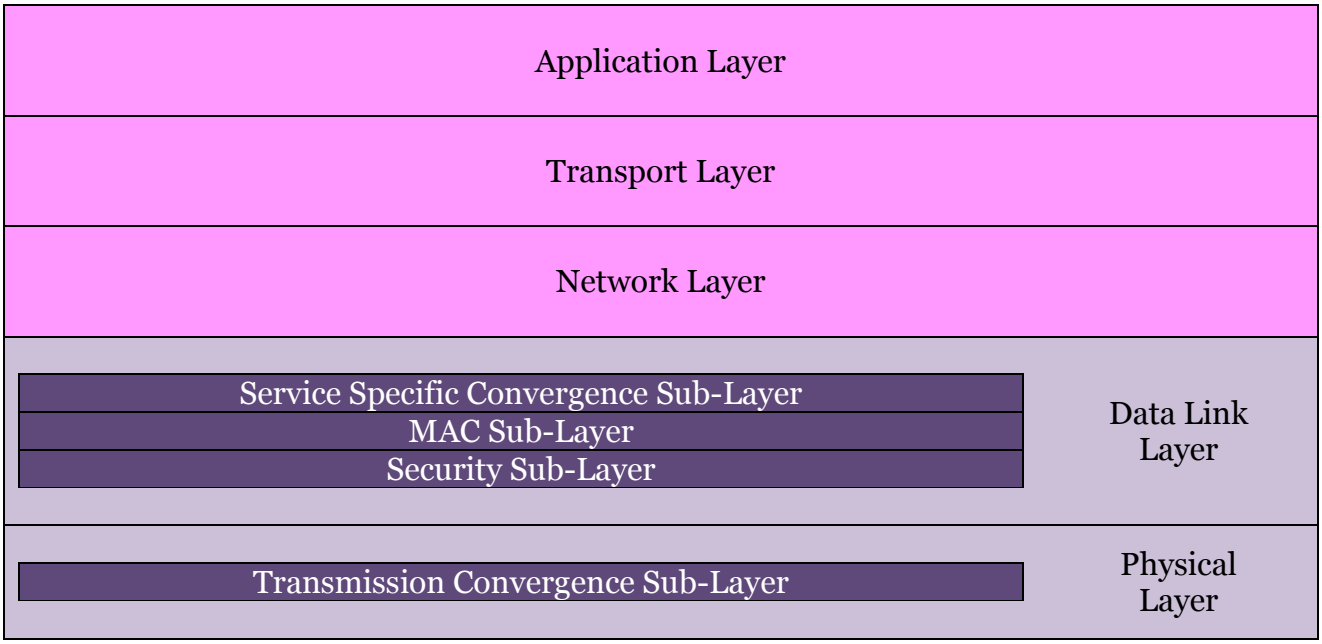
Section 1.4 (WiMax)

Introduction

WiMax is the wireless communication technology which provides mobile internet access. It is widely used today, especially student usage.

Protocol Architecture

Protocol Stack



Note for Protocol stack:

Implement in the WiMax (IEEE 802.16)
Other layers in TCP/IP Protocol Model

Protocol Architecture

Application Layer	Provides user interfaces and support for applications
Transport Layer	Transfer of data between origins and destinations
Network Layer	Provide routing across the network for data transmission.
Data Link Layer	Transferring across the link with addressing and error control. There are 3 sub-layers for this data link layer which are Service Specific Convergence Sub-Layer, MAC Sub-Layer and Security Sub-Layer.
Physical Layer	Physical signals that transmission through devices and Medium. There is a sub-layer which is Transmission Convergence Sub-Layer.

Standards

IEEE 802.16: This standard is promoted by WiMax forum which is the original one. It is concerned with air interfaces between subscriber's receiver station and a base receiver station.

IEEE 802.16d: It is also called as 802.16-2004. The modified version of IEEE 802.16. It is implementing in the sense of broadband wireless access service. In addition, it is create Fast Fourier Transform (or FFT).

IEEE 802.16e: It is also called as 802.16-2005 or WiBro. The enhancement standard of IEEE 802.16 is provides the mobility service. But it is still allow the fixed wireless application to use.

Standard Organizations

The Institute of Electrical and Electronics Engineers (IEEE) is an international organization which responsible for produce and development of WiMax standards. WiMax Forum is the organization which is responsible for clarity the product that implement by WiMax technologies.

Data Transmission

Standard	Spectrum (GHz)	Frequency (GHz)	Bandwidth (MHz)	Data Rate (Mb/s)
IEEE 802.16	66	11	28	134
IEEE 802.16d	11	11	20	75
IEEE 802.16e	6	6	20	15

Transmission Media

Standard	Transmitted Power (dbM)	Received Threshold (dbM)	Antennas	Distance (Meters)
IEEE 802.16	43	-81.5	MIMO	48,000
IEEE 802.16d	18	-86	Adaptive	10
IEEE 802.16e	9	-80	MIMO	5

Signal Encoding Techniques

WiMax is used several techniques to encoding from digital data to analog signal.

Standard	Signal Encoding Techniques
IEEE 802.16	Binary Phase Shift Keying (BPSK), Quadrature amplitude modulation (QAM), Quadrature phase-shift keying (QPSK)
IEEE 802.16d	Binary Phase Shift Keying (BPSK), Quadrature amplitude modulation (QAM), Quadrature phase-shift keying (QPSK), Orthogonal frequency-division multiplexing (OFDM)
IEEE 802.16e	Orthogonal Frequency Division Multiplexing (OFDM)

Error

Error Detection

To detecting error, when noise occurs during data transmission, the error will be detected by comparing FEC bits by using Forward Error Correction (FEC). Then, FEC will warn the sender with that error.

Error Correction

After the error detection by FEC, it will warn the sender to add error-correcting code, which is the error data. Then, after the receiver is received and recognized the error, they will correct error without additional data.

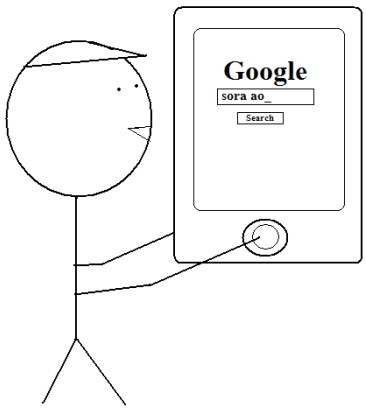
ARQ

If many errors occur and FEC cannot correct this error, Automatic Repeat Request (ARQ) will be run. ARQ will send some request to transmitter for retransmit again. Then, it will use Hybrid Automatic Retransmission Request (HARQ) for error correction. The HARQ implements in both Forward error correction (FEC) and error detection using the ARQ error-control method.

Other Issues of WiMax

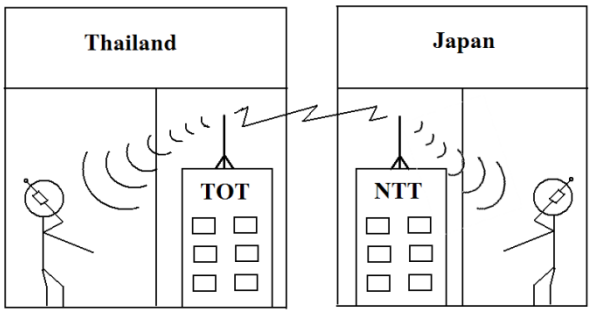
Application

Broadband These technologies are provide the transmission of signal, especially in greater bandwidth and frequency. So, they can transmit more data or signal than some standards. We can see this technologies implement in mobile broadband or at-home broadband connectivity across whole cities or countries. For example, a SIIT student is using internet access by their Nokia mobile phone.



Backhaul

These technologies are provide the transmission, from the phone in the network to the phone outside the network. In detail, during communicating in sub-network, the transmission between the cell tower in the sub-network and the outside are used a backhaul link. For example, a SIIT student phone is sending a picture to their friend phones in Japan.



Usage

In Thailand, many people, especially for modern students and businessman are using these technologies, in the sense of while they using their mobile. In advance, other countries outside Thailand, it is still used these technologies to provided their citizen with the mobile phone communication.

Costs

Since these technologies is using the modernize technologies and can transmitting more data and have greater bandwidth, which cause the costs of WiMax transmission become very expensive. However, the chipset hardware price is very low, but we cannot use it. For nearby cost, the organization (user groups) have to pay for hardware, especially the cell tower which cause very expensive, approximately USD 120 - 160.

Section 2 (Technologies Comparison)

Protocol Architecture

	ZigBee	Bluetooth	Wireless LAN	WiMax
Protocol Architecture	Implemented in additional stack which is Application Interfaces. There is a sub-layer which is ZigBee Device Object, which has Application Framework as its sub-layer.	Implemented in physical and MAC layer. There are 3 sub-layers for the MAC layer which are Logical Link Control and adaption Sub-Layer, Human Computer Interaction Sub-Layer and Link Manager Sub-Layer. There are 2 sub-layers for the physical layer which are Baseband Sub-Layer and Radio Frequency Sub-Layer.	Implemented in the data link layer. There are 3 sub-layers for the data link layer which are Logical Link Control, Bridging and Media-Access. The additional two sub-layers are concerned, when the network is used.	Implemented in physical and data link layer. There are 3 sub-layers for the data link layer which are Service Specific Convergence Sub-Layer, MAC Sub-Layer and Security Sub-Layer. There is a sub-layer for the physical layer which is Transmission Convergence Sub-Layer.
Standards	IEEE 802.15.4	IEEE 802.15 IEEE 802.15.1 IEEE 802.15.2 IEEE 802.15.3 IEEE 802.15.4	IEEE 802.11 IEEE 802.11a IEEE 802.11b IEEE 802.11g IEEE 802.11n	IEEE 802.16 IEEE 802.16d IEEE 802.16e
Standard Organization	The Institute of Electrical and Electronics Engineers (IEEE)	The Institute of Electrical and Electronics Engineers (IEEE)	The Institute of Electrical and Electronics Engineers (IEEE)	The Institute of Electrical and Electronics Engineers (IEEE), WiMax Forum

Data Transmission

	ZigBee	Bluetooth	Wireless LAN	WiMax
Spectrum (GHz)	IEEE 802.15.4: **2.4**	IEEE 802.15: **2.4** IEEE 802.15.1: **2.4** IEEE 802.15.2: **2.4** IEEE 802.15.3: **2.4** IEEE 802.15.4: **2.4**	IEEE 802.11: **2.4** IEEE 802.11a: **5.3/5.8** IEEE 802.11b: **5.3/5.8** IEEE 802.11g: **5.3/5.8** IEEE 802.11n: **5.3/5.8**	IEEE 802.16: **66** IEEE 802.16d: **11** IEEE 802.16e: **6**
Frequency (GHz)	IEEE 802.15.4: **2.4**	IEEE 802.15: **2.4** IEEE 802.15.1: **2.4** IEEE 802.15.2: **2.4** IEEE 802.15.3: **2.4** IEEE 802.15.4: **2.4**	IEEE 802.11: **2.4** IEEE 802.11a: **3.7/5** IEEE 802.11b: **2.4** IEEE 802.11g: **2.4** IEEE 802.11n: **2.4/5**	IEEE 802.16: **11** IEEE 802.16d: **11** IEEE 802.16e: **6**
Bandwidth (MHz)	IEEE 802.15.4: **0.25**	IEEE 802.15: **1** IEEE 802.15.1: **1** IEEE 802.15.2: **1** IEEE 802.15.3: **0.25** IEEE 802.15.4: **1**	IEEE 802.11: **20** IEEE 802.11a: **20** IEEE 802.11b: **20** IEEE 802.11g: **20** IEEE 802.11n: **20/40**	IEEE 802.16: **28** IEEE 802.16d: **20** IEEE 802.16e: **20**
Data Rate (Mb/s)	IEEE 802.15.4: **0.25**	IEEE 802.15: **1-3** IEEE 802.15.1: **1-3** IEEE 802.15.2: **>20** IEEE 802.15.3: **0.25** IEEE 802.15.4: **1-3**	IEEE 802.11: **2** IEEE 802.11a: **54** IEEE 802.11b: **11** IEEE 802.11g: **54** IEEE 802.11n: **72.2/150**	IEEE 802.16: **134** IEEE 802.16d: **75** IEEE 802.16e: **15**

Transmission Media

	ZigBee	Bluetooth	Wireless LAN	WiMax
Transmitted Power (dbM)	IEEE 802.15.4: **10**	IEEE 802.15: **20** IEEE 802.15.1: **20** IEEE 802.15.2: **20** IEEE 802.15.3: **20** IEEE 802.15.4: **20**	IEEE 802.11: **17** IEEE 802.11a: **15** IEEE 802.11b: **18** IEEE 802.11g: **23** IEEE 802.11n: **20**	IEEE 802.16: **43** IEEE 802.16d: **18** IEEE 802.16e: **9**
Received Threshold (dbM)	IEEE 802.15.4: **-20**	IEEE 802.15: **-70** IEEE 802.15.1: **-76** IEEE 802.15.2: **-82** IEEE 802.15.3: **-87** IEEE 802.15.4: **-92**	IEEE 802.11: **-86** IEEE 802.11a: **-54** IEEE 802.11b: **-86** IEEE 802.11g: **-68** IEEE 802.11n: **-65**	IEEE 802.16: **-81.5** IEEE 802.16d: **-86** IEEE 802.16e: **-80**
Antennas	IEEE 802.15.4: **Module, Chip**	IEEE 802.15: **Low-Profile** IEEE 802.15.1: **Single, Dual** IEEE 802.15.2: **Whip** IEEE 802.15.3: **Zard, Flat** IEEE 802.15.4: **Module, Chip**	IEEE 802.11: **Cantenna, Biquad** IEEE 802.11a: **Directional** IEEE 802.11b: **Homebrew** IEEE 802.11g: **Twin** IEEE 802.11n: **MIMO**	IEEE 802.16: **MIMO** IEEE 802.16d: **Adaptive** IEEE 802.16e: **MIMO**
Distance (Meters)	IEEE 802.15.4: **10 – 75**	IEEE 802.15: **10** IEEE 802.15.1: **10** IEEE 802.15.2: **10** IEEE 802.15.3: **10** IEEE 802.15.4: **10**	IEEE 802.11: **20** IEEE 802.11a: **35** IEEE 802.11b: **38** IEEE 802.11g: **38** IEEE 802.11n: **70**	IEEE 802.16: **48,000** IEEE 802.16d: **10** IEEE 802.16e: **5**

Note for Comparison Table of Transmission Media

MIMO = Multiple Input – Multiple Output

Signal Encoding Techniques

	ZigBee	Bluetooth	Wireless LAN	WiMax
Signal Encoding Techniques	IEEE 802.15.4: **O-QPSK, BPSK**	IEEE 802.15: **FSK** IEEE 802.15.1: **DPE** IEEE 802.15.2: **DPC** IEEE 802.15.3: **PLMC** IEEE 802.15.4: **QPSK**	IEEE 802.11: **FSK, PSK, PPM** IEEE 802.11a: **QAM** IEEE 802.11b: **PSK** IEEE 802.11g: **OFDM** IEEE 802.11n: **AAC**	IEEE 802.16: **BPSK, QAM, QPSK** IEEE 802.16d: **BPSK, QAM, QPSK, OFDM** IEEE 802.16e: **OFDM**

Note for Comparison Table of Signal Encoding Technique

PSK	=	Phase Shift Keying
BPSK	=	Binary Phase Shift Keying
QPSK	=	Quadrature Phase-Shift Keying
O-QPSK	=	Offsset-Quadratic Phase Ship Keying
FSK	=	Frequency Shift Keying
DPE	=	Differential Phase Encoding
DPC	=	Dirty Paper Coding
PLMC	=	Physical Layer Modulation and Coding
PPM	=	Pulse-Position Modulation
QAM	=	Quadrature Amplitude Modulation
OFDM	=	Orthogonal Frequency-Division Multiplexing
AAC	=	Asymmetrical Advance Coding

Error

	ZigBee	Bluetooth	Wireless LAN	WiMax
Error Detection	Preamble and Packet Error Detection	Cyclic Redundancy Check	Produce a receive data error signal	Forward Error Correction (FEC)
Error Correction	Retransmission	Forward Error Correction	Fountain codes, resolution adaptive ADC	
ARQ	Hybrid-ARQ	Bluetooth ARQ	The no-ACK (NACK) ARQ	Hybrid-ARQ

Other Issues

	ZigBee	Bluetooth	Wireless LAN	WiMax
Example of Applications	Censors, Automation	Home Network, Bluetooth Headset	Cross-Building, Ad Hoc Network	Broadband, Backhaul
Usage	Thailand: Widely use (especially engineer) Other Countries: Basic Robot	Thailand: Widely use (Bluetooth Headset) Other Countries: provide their data transmission	Thailand: Widely use for short-time comm. Other Countries: Widely use for provide their citizen comm.	Thailand: Widely use (for mobile phone) Other Countries: provide them with Mobile Connection
Costs	Low Costs Chipset: USD 4 Hardware: USD 50 – 70	Low Costs Chipset: USD 4 Hardware: USD 66 - 100	Low Costs Chipset: USD 4 Hardware: USD 60 – 80	High Costs Chipset: USD 4 Hardware: USD 120 – 160

Section 3 (Conclusion)

Wireless Technologies is designed for data transmission over a distance. There are many technologies that involve wireless technologies such as ZigBee, Bluetooth, Wireless LAN, WiMax and many more.

In term of **protocol architecture**, ZigBee is implemented in additional layer that is Application Interfaces; the advantage is become simpler and made application become efficient. While Bluetooth is used MAC and physical layer to implement their technical devices, that become the advantage of transmission efficient and made the cost become less expensive, as same as Wireless LAN. For WiMax, it used physical and data link layer but the costs still high because of long (wide) transmission distance and that become the advantage/disadvantage of it.

In term of **data transmission**, ZigBee and Bluetooth are used less spectrum, less frequency, less bandwidth and less data rate, the disadvantage: they can transmit the data in short distance and more chance of error, the advantage: the costs are very cheap. For WiMax, it has pretty high spectrum, high frequency, high bandwidth and high data rate, the advantage is, can transmit with the long (wide) distance and can transmitted faster (better) than another technologies. For Wireless LAN, it used fewer spectrums, less frequency that have the advantage of low costs, and can transmit faster because of high bandwidth and high Data Rate.

In term of **transmission media**, since WiMax have high data rate, so it can transmit and receive data in large (long/wide) distance, this become the advantage of it, but the cost is pretty high which is one of the disadvantage of it. For Bluetooth and Wireless LAN, the disadvantage is can transmit lower distance range because of lower transmitted power, as same as ZigBee technology, but the advantage: the costs become low and fewer.

In term of **signal encoding techniques**, each technology has different signal encoding technique. Some technologies have more than more one signal encoding techniques. For example, in ZigBee are used Offsset-Quadratic Phase Ship Keying, the advantage is, it has finite phase which made the encoding scheme become faster, and many more techniques are used. In Bluetooth, it is used Frequency Shift Keying, the advantage is can send-receive-encode up to 300 bits per seconds that is very fast, which becomes the advantage of it, and many more techniques were used. For Wireless LAN, it is use Quadrature Amplitude Modulation, the advantage is, can encoding in both analog and digital data scheme and widely used in the applications with digital data communication, and many techniques are used by Wireless LAN. In WiMax, it is use Binary Phase Shift Keying, it is used finite signals to represent digital data as same as Offsset-Quadratic Phase Shift Keying, that become the advantage of it, and more techniques are used by WiMax.

In term of **errors**, ZigBee and WiMax is used the Hybrid ARQ, it is the combination of both Error Detection and Error Correction, so the manufacture can used this without any implementation in each Error Detection and Error Correction, this become the one of the advantage of ZigBee and WiMax. In Bluetooth, Cyclic Redundancy Check is used for Error Detection, this techniques is designed for short-time error correction which is the advantage of it. For Wireless LAN, Fountain codes is used for error correction, this techniques is designed for limitless encoding, this is widely known as efficient encoding and decoding techniques, so this become the advantage of it.

In term of **other issues**, ZigBee, which is basic techniques, is widely used in engineering module, for example, the construction balance censor in civil engineer, the advantage is, the chipset's costs are cheap. For Bluetooth and Wireless LAN, they are widely used in Thailand, for example, basic networking which can found in all areas in educational, business and residential areas, the advantage is, the costs become lower every day due to widely used. In WiMax, this is the high featured technologies, which is implementing in mobile communication, especially, mobile phone. Since WiMax is the high technology, so the disadvantage is, the costs are higher every day.

To summarize, ZigBee, Bluetooth and Wireless LAN are the low-featured technologies which have low frequency, low bandwidth and low data rate, which can transmitted in short-distance communication but widely used in our today life. While WiMax is the mobile communication technologies, which has high frequency, high data rate and high bandwidth, which can transmit in long (wide) distance, but the costs is pretty high in today market. In Conclusion, different technologies is used different techniques/ features to implement, some are the same. All technologies have advantage and disadvantage of it, so it is widely used in our today life.

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