The Comparison of Wireless LAN, Bluetooth®, ZigBee®, and WiMAX

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Table of Participations

Section/Task	Ratinan L.	Tattananan N.
Introduction	100%	0%
Protocol Architecture	50%	50%
Data Transmission	20%	80%
Transmission Media	10%	90%
Signal Encoding Techniques	20%	80%
Error Controls	60%	40%
Applications and Usages	90%	10%

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1 INTRODUCTION

The technologies for data communication in local and metropolitan area networks (LANs and MANs) have been standardized by Institute of Electrical and Electronics Engineers (IEEE). Both wired and wireless technologies are considered as a medium for such communication. The following table 1.1 shows the list of IEEE 802 standards.

Standard	Descriptions
802.1	Bridging
802.2	Logical Link
802.3	Ethernet
802.4	Token Bus
802.5	Token Ring
802.6	Distributed Queue Dual Bus (DQDB)
802.7	Broadband LAN Practices
802.8	Fiber Optic Practices
802.9	Integrated Service LAN (ISLAN)
802.10	Interoperable LAN Security
802.11	Wi-Fi, Wireless Local Area Network (Wireless LAN)
802.12	Demand Priority
802.14	Cable Modem
802.15	Wireless Personal Area Network
802.15.1	Bluetooth
802.15.3b	UWB
802.15.4	ZigBee
802.15.5	Mesh Network
802.16	Wireless Metropolitan Area Network: WiMAX
802.16.1	Local Multipoint Distribution Service
802.17	Resilient Packet Ring
802.18	Radio Regulatory TAG
802.19	Coexistence TAG
802.20	Mobile Broadband Wireless Access
802.21	Media Independent Handoff
802.22	Wireless Regional Area Network
802.23	Emergency Service Working Group

Table 1.1 Selected IEEE 802 Standards

The standards selected to be explained in this report are:

1. IEEE 802.11 Wireless Local Area Network (Wireless LAN),
2. IEEE 802.15.1 Bluetooth,
3. IEEE 802.15.4 ZigBee, and
4. IEEE 802.16 WiMAX.

Figure 1.1 Wi-Fi™ Logo

Wireless local area network (Wireless LAN) is the most popular access way to the internet. Usually referred to as Wi-Fi, Wireless LAN links several devices together. For the internet access, the access point links together end users' devices and the wired network which connects to the internet. Other than the internet, wireless LAN can be used in many different ways within such small area like an organization or a house. Wi-Fi, the trademark that manufacturers use to mark the products those fall in Wireless LAN class, become well-known since the internet demand increases.

Figure 1.2 Bluetooth® Logo

Bluetooth was created by Ericsson in 1994. It falls in personal area network (PAN) class so it is given an IEEE 802.15's standard. Bluetooth is the technology to connect two or more devices together within a short distance. Mostly seen installed in cellular phones, Bluetooth, in fact, can be used in any devices from fixed to mobile for short-time and safe connection. Commonly known as a standard way to send media files between mobile phones and personal computers.

Figure 1.3 ZigBee® Logo

ZigBee is the technology that falls in the wireless home area network (WHAN) class. Designed to be cheaper than other wireless PAN (WPAN) technologies like Bluetooth, ZigBee is simpler and uses less power to operate. The main characteristic of ZigBee is that it is developed for

everyday devices to be connected together to perform tasks intelligently, such as remote monitoring and control applications.

WiMAX is a new technology which is created for long distance networks across cities and last mile accesses. As a new technology, WiMAX is one possible replacement of several older technologies that are mainly used nowadays, including CDMA and GSM, and is considered a backhaul for the 4G networks also.

Protocol architectures, data transmissions, transmission media, signal encoding techniques, error controls, applications, usages, and costs will be covered in this report.

2 PROTOCOL ARCHITECTURES

Since the four technologies to be discussed in this report are wireless technologies. Then the physical layer of all four technologies is made for transmitting information through the air. These technologies deal with two lowest layers of the stack: data link and physical layers.

The data link layer is divided into two sub-layers, which are logical link control layer and media access control (MAC) layer. Logical link control (LLC) layer deals with multiplexing and flow control. Media access control layer works to assure that the access to media or such information transmitted will not interfered with each other.

Upper Layers	
Data Link Layer	IEEE 802.2
	IEEE 802.11 MAC with Carrier Sense Multiple Access With Collision Avoidance (CSMA/CA) protocol
Physical Layer	Frequency Hopping Spread Spectrum Direct Sequence Spread Spectrum Infrared

Figure 2.1 Wireless LAN's Stack

Applications and User Interface	
L2CAP Layer	L2CAP Resource Manager Channel Manager
Host Control Interface (⩚ Host | ⩛ Module)	
Link Manager Layer	Link Manager
Baseband Layer	Baseband Resource Manager
	Link Controller
Radio Layer	RF: medium interface

Figure 2.2 Bluetooth's Stack

Upper Layers	
Data Link Layer	IEEE 802.15.4 MAC
Physical Layer	IEEE 802.15.4: 868/915 MHz PHY / 2400 MHz PHY

Figure 2.3 ZigBee's Stack

Upper Layers	
Data Link Layer	MAC Convergence Sub-Layer
	IEEE 802.16 MAC
	MAC Privacy Sub-Layer for authentication and encryption
Physical Layer	IEEE 802.16

Figure 2.4 WiMAX's Stack

The topology for Wireless LAN and WiMAX is star network. ZigBee uses several topologies. The full function devices (FFC) in the network are connected by using mesh or cluster tree topology, and also connected somehow to the coordinator which acts as the big boss. FFC is then linked to reduced function devices (RFC) only by using star topology. Bluetooth is peer-to-peer since it is the technology for sending files between several devices in the short distance.

3 DATA TRANSMISSIONS

The four technologies use different transmission techniques to transmit such information. Each version of such technology is different as well as the technologies improve. The table below illustrates such information for the four technologies.

Technology	Version	Frequency	Bandwidth	Data rate
Wireless LAN (802.11)	b (1999)	2.4-2.5 GHz	20 MHz	1 Mbit/s per stream
	g (2003)	2.4-2.5 GHz	20 MHz	1 Mbit/s per stream
	n (2009)	2.4-2.5 / 5 GHz	20 / 40 MHz	7.2 / 15 Mbit/s per stream
Bluetooth (802.15.1)	1.2	2.402-2.480 GHz	1 MHz	1 Mbit/s
	2.1			3 Mbit/s
	3.0			24 Mbit/s
ZigBee (802.15.4)		868 MHz (Europe) 915 MHz (USA and Australia) 2.4 GHz (most other jurisdictions)	5 MHz (for 2.4GHz frequency)	250kbit/s per channel (2.4GHZ) 40 kbit/s per channel (915 MHz) 20 kbit/s per channel (868 MHz)
WiMAX (802.16)		2 - 66 GHz (only first few GHz are currently assigned)	Scalable b/w 1.25, 5, 10, or 20 MHz	Depends on distance and bandwidth used.*

Table 3.1 Frequencies, bandwidths, and data rates of all four technologies

* According to the new standard, 802.16m, its data rate will be 1 Gbit/s, fixed rate.

The frequencies of all four technologies are approximately equal, except for European and American ZigBee. WiMAX, at the moment, only uses low frequencies. The bandwidth of ZigBee is very low, but Bluetooth's is even lower. These two technologies are mostly used in short distance, personal and home area network, so this low bandwidth is good to go.

WiMAX technology is the strangest one because of its characteristic that it can vary it frequency for the benefit of transmitting data in long distance. Thus the data rate is lower and lower when the distance increases. This is the trade-off. WiMAX offers long-distance transmission but the data rate gets lower and lower. While another technologies offers only short-distance transmission, but the data rate is higher. Anyway, WiMAX will be much better when the 1 Gbit/s fixed rate version available for us.

4 TRANSMISSION MEDIA

The information for the four technologies is described in the table below.

	Transmit power (dBm)	Minimum receive threshold (dBm)	Antenna gain (dBi)	Outdoor range (m)	Indoor range (m)
Wireless LAN	22.5	-77	2.14 (Typically)	140 (802.11b, g) 150 (802.11n)	38 (802.11b, g) 70 (802.11n)
Bluetooth	0, 4, 20	-70	3 and above	0.1, 10, 100 (depends on power class used)	
ZigBee	-3	-85 (2.4 GHz) -92 (868/915 MHz)	3-5	-	100
WiMAX	43 (station) 23 (mobile)	Depends on distance and bandwidth used.	3 (indoor) 8 and above (outdoor)	50,000	

Table 4.1 Transmission Media

The numbers shows highly their characteristics. Wireless LAN's antenna gain is very low because the antenna is designed to be isotropic. Bluetooth's range is not very high because normally it is designed for using to transmit in short-distance. We normally see people using Bluetooth tries to put two devices, receiver and transmitter, closer and closer to each other. ZigBee's range is a little bit too high to be used in a house, but it is reasonable because it is designed for commercial and industrial used as well. And since it tries to reduce the energy requirement, ZigBee requires lower cost. WiMAX uses high power to transmit, 43 dBm for station, because it is designed for long-distance transmission across city. Thus it is more expensive and the outdoor antenna is very directional.

5 SIGNAL ENCODING TECHNIQUES

For Wireless LAN, as of IEEE 802.11n-2009 standard, the signal encoding technique used is the one called orthogonal frequency-division multiplexing (OFDM). The OFDM is used as a digital multi-carrier modulation method. ODFM uses multiple sub-carriers to carry data for multiple data channels multiplexed by the scheme. Each data channel may use any conventional modulation scheme, though DQPSK has proven to be one of the more popular choices for ODFM sub-carriers encoding. OFDM electronic implementations also include Fast Fourier transform algorithm and forward error correction.

Bluetooth's technique is differential quadrature phase-shift keying (DQPSK), the differentiated version of quadrature phase-shift keying technique (QPSK). QPSK is a version of PSK that uses four signal symbols by coding two bits in the form of equispaced angular phases of the four quadrants of a circle. This is an advantage over normal Binary PSK, thus QPSK handles double data rate in the same bandwidth. Older version of Bluetooth also use Gaussian frequency shift-keying (GFSK), which is based on the equation of the Gaussian bell curve.

WiMAX uses scalable orthogonal frequency-division multiple access (SOFDMA). It is even more complex, because this technique is a multi-users version of OFDM, which by itself is already a multiplexing scheme. SOFDMA is used by WiMAX because it is needed for WiMAX to achieve its long-range interoperability between much greater numbers of users.

ZigBee, unlike the other three technologies, uses Direct-sequence spread spectrum (DSSS), which is a form of spread-spectrum modulation techniques, which make use of carrier signal's spectrum over the full bandwidth of the device (in this case is 5 MHz), rather than using multiple channels. DSSS transmitter pseudo-randomize phase-modulation of a sine wave to make the transmission appear to be like noises, while the receiver knows the generating seed numbers in advance so it can understand the noise-like transmission. This has the advantage of being resistant to jamming and interception.

All of the techniques use analog signal for transmission over the medium.

6 ERROR CONTROLS

Wireless LAN uses cyclic redundancy check (CRC) for detecting errors when receiving such transmissions. Forward error correction (FEC) is the IEEE 802.11b standard for correcting the data because data correction is much more efficient than retransmitting. Reed Solomon Code and Turbo Code are used as approaches for FEC implementation.

Bluetooth uses CRC for error detection and performs three error correction schemes, which are 1/3 rate FEC, 2/3 rate FEC, and, if necessary, ARQ. This technology provides two error corrections methods to play their role for reducing retransmission rate.

ZigBee error correction is done in MAC layer. The algorithm is unique version of hybrid-ARQ protocol. Reed Solomon Code is used for detecting errors.

WiMAX detects and corrects errors by using the technique called hybrid automatic repeat request (HARQ), which combines FEC and ARQ error control method together. To be more specific, before the transmission of such data, the transmitter add both error detection code, which can be any kind of code, such like Reed Solomon Code or Turbo Code, and FEC together. In good condition, the error detection and correction is done and the receiver receives correct data, if the condition is bad then, if the error exists, the retransmission request is sent, similar to ARQ.

7 APPLICATIONS AND USAGES

Local area network is the network owned by any private owner to be used for internal communications. The owner can be anyone from a person using personal computer and connecting his/her computer to the internet by his own LAN, to gigantic organization where people transmits and receives data within closed area or to link itself to the internet. Wireless LAN is used for connecting any devices in the LAN by using wireless technology. Devices to be used in the LAN may not be only personal computers, but may be video game consoles, MP3 players, smart phones, printers, and other peripherals as well. Wireless LAN is commonly used around Thailand by people who use laptop. We can find coffee shops, office buildings, and public areas provide wireless signal for public uses in major cities. In Lower Manhattan, wireless signal can be found almost everywhere. In residential areas, Wireless LAN can be found in almost every house dwelled by laptop users, because people likely to pay for wireless router more than connect their computer by twisted pairs.

Bluetooth, recently, is installed in every mobile phone and personal computer. People use this technology for transmitting files from one device to another and disconnect when the transmission is complete. Bluetooth is very popular in teenagers' community in Thailand where entertainment is highly demanded. Teenagers love to take photos and film videos of themselves and transmit to friends by Bluetooth technology installed in their cellphone. Moreover, Bluetooth

can be used for other applications, for example, connecting phone's wireless headset, connecting personal computers to input and output devices such as printers, mice, and keyboards.

The name of ZigBee technology in Thailand is not well-known. ZigBee, mostly, to Thai people is the developing technology for more convenient life. The applications ZigBee does are the controls of every device in the house, monitoring of energy and water usages, and, up to industrial level, as the process control, environmental management, asset management, and so on. The most obvious examples of the use of ZigBee in everyday life are the control of lighting, temperature, and home theater, the detection of smoke and fire, power and water sensors, and healthcare service which benefits to people on chronic disease.

In Thailand, WiMAX technology is not widely used due to the availability and cost. It is too new to be popular. WiMAX transmission is still in trouble in Thailand because of commercial reasons and the cost is still much expensive when compared to Bluetooth and Wireless LAN.

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