Report on

Wireless Communication Technologies

Prepared for

ITS323 Introduction to Data Communications

Submitted to

Dr. Steve Gordon

Prepared by

1. Ms. Dolchanok Chaprasith #5122792823
2. Ms. Jirapa Jenchaimahakoon #5122800584
3. Ms. Ramon Sintateeyakorn #5122800683

Submitted on

8th September 2010

Semester 1/2010

Contents

1 Table of Participation

Section	#5122792823	#5122800584	#5122800683
2	-	100	-
3	-	50	50
4	50	-	50
5	100	-	-
6	33	33	33

Table 1: Table of participation

2 ZigBee

ZigBee is a wireless technology for a home area network based on the IEEE 802.15.4-2003 standard, which specifies the physical and the data link layer of the Open Systems for Interconnection (OSI) protocol architecture, as shown in Figure 1, in a Wireless Personal Area Network (WPAN).

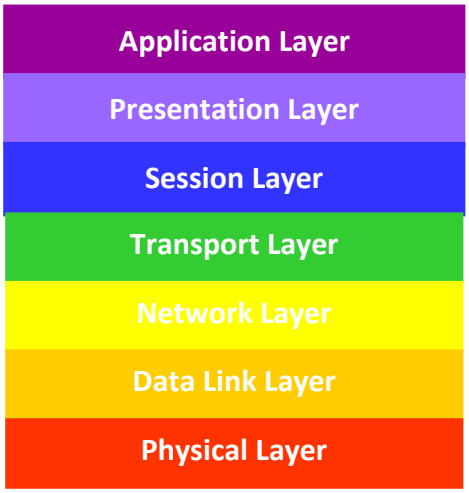

Figure 1: OSI 7-Layer Model

The standard sets the operating frequency to be 2.4 GHz, 915 MHz, and 868 MHz for worldwide use, North America and Europe, respectively, with the data rates of 250 kb/s, 40 kb/s and 20kb/s at the maximum. However, due to overheads and other limiting factors, the actual values are approximately half of those. Although networks operating at 2.4 GHz have the highest data rate, they are susceptible to interference (electromagnetic interference) from other networks, e.g. Bluetooth, operating at the same frequency.

ZigBee uses direct-sequence spread spectrum (DSSS), which is one of the methods of modulation for signal transmission over the air. In DSSS, the original data is combined with a noise signal, i.e. a higher data-rate sequence, to increase the frequency band of the resulting signal. This helps avoiding signal interference and enables recovery from transmission errors.

ZigBee has a transmission range of around 10 to 75 metres and a transmit power of -3 to 0 dBm. Receive thresholds vary with the operating frequency. 2.4 GHz devices have -85 dBm of receiver sensitivity at minimum. 915 MHz and 868 MHz devices have -92 dBm of receiver sensitivity. Lower receiver sensitivity corresponds to higher transmit power and range. Therefore, 915 MHz and 868 MHz devices are better than 2.4 GHz in this aspect.

Offset quadrature phase-shift keying (OQPSK) modulation is used in the 2.4 GHz band. Binary phase-shift keying (BPSK) modulation is used in the 915 and 868 bands. OQPSK modulation is pretty much the same as quadrature phase-shift keying (QPSK) modulation except that the phase change is limited to no more than 90 degrees at a time. This helps improve the quality of the signal by avoiding large amplitude fluctuations.

Like many other networks under the IEEE 802.15.4 standard, ZigBee uses forward error correction (FEC), which is deemed to be the most efficient technique in terms of performance for ZigBee applications in real life.

ZigBee is intended for radio-frequency (RF) applications that require low data rate and long battery life. The applications include home automation like sensors and smart lighting, building automation, patient monitoring, and security. ZigBee is widely used in Americas, Europe, Middle East, Africa, and Japan.

ZigBee devices have three different types: ZigBee Coordinator (ZC), ZigBee Router (ZR) and ZigBee End Device (ZED). Generally, all three are needed to set up ZigBee network. ZigBee hardware cost can range from $3 to $49.

3 Bluetooth

Bluetooth is a wireless technology that provides means of communication between electronic devices, such as computers and telephones. Bluetooth devices are controlled by standards specified by the Bluetooth Special Interest Group (SIG).

Layer protocol architecture of Bluetooth differs from devices to devices, but compulsory protocols are Link Management Protocol (LMP), Logical Link Control and Adaptation Protocol (L2CAP), and Service Discovery Protocol (SDP). LMP is used to control and maintain the connectivity between two devices. L2CAP is used to multiplex logical connections so that devices using different upper layer protocols can communicate. SDP is used for detection of other devices and services offered by them.

Bluetooth has low power consumption with short communicating distance, but does not require a line-of-sight. Depending on the versions of Bluetooth, the devices may have data rates of 1Mb/2, 3Mb/s, or 24Mb/s. Bluetooth devices operate at the frequency of 2.4 GHz.

Bluetooth uses frequency-hopping spread spectrum (FHSS), which is a method of radio signal modulation that relies on the use of signal-to-noise ratio as seen in DSSS used in ZigBee. The signal frequency will be repeatedly switched throughout the transmission using a random sequence. This helps avoiding signal interference, increases bandwidth utilisation, and provides some security measures against the third person.

Bluetooth uses a broadcast communication system with a transmission range of approximately 1 metre for a transmit power of 1 dBm, 10 metres for 4 dBm, and 100 metres for 20 dBm. The receive threshold is around -93 dBm.

Bluetooth uses Gaussian frequency shift keying (GFSK) modulation, which is a type of frequency shift keying (FSK) modulation with an addition of a Gaussian filter to smoothen the signals. GFSK is more efficient than FSK in terms of spectrum.

There are three types of error correction schemes used in Bluetooth systems: 1/3 rate forward error correction (FEC), 2/3 rate FEC, and automatic repeat request (ARQ). FEC can be more efficient when there are a lot of errors as FEC reduces the number of retransmissions. Otherwise, FEC just introduces more overhead and reduces the throughput.

Bluetooth technology is implemented in many electronic devices, for examples, telephones, game consoles, computers, headsets, etc. Bluetooth is available widely in most countries, including Thailand, partly because many international brands have adopted this technology.

Bluetooth chips are required to enable the use of this technology in devices. The chips cost approximately $4 but the cost of using Bluetooth is free. Therefore, what the users has to pay is the cost of the actual product with Bluetooth technology.

4 Wireless LAN

Wireless LAN or Wireless Local Area Network is a wireless technology that offers mobility to the users. In other words, the users are able to move within a specific area while stay connected to the network. This explains the proportionality between the popularities of laptop computers and wireless LAN. Wireless LAN is controlled under IEEE 802.11 standard, which specifies the physical and the data link layer of the OSI 7-layer protocol architecture.

The operating frequency of wireless LAN is 2.4 GHz, 3.6 GHz and 5 GHz with the data rates varying from 11 Mb/s up to 54 Mb/s. The frequency band of 5 GHz is recommended since 2.4 GHz band is slightly occupied by other technologies. However, the high frequency leads to inability of the signal to go through obstacles.

Wireless LAN uses two signal modulation techniques, which are spread spectrum similar to the one used in Bluetooth, and orthogonal frequency-division multiplexing (OFDM) as used in WiMax.

The antenna in wireless LAN is omni-directional with a transmit power of 0 dBm to 30 dBm with a receive threshold of around -74 dBm. The receiver has to be sensitive to low power signals considering that the signals fade over the distance. The transmission range is approximately 70 metres and can be up to 250 metres when there is a line-of-sight.

Wireless LAN uses turbo product code (TPC), which is a powerful variant of forward error correction (FEC) technique. TPC is very efficient in terms of performance compared to other FEC techniques. It works with arrays of data, where the rows of the arrays are encoded with a certain code to provide security.

Wireless LAN is extremely popular in Thailand and worldwide. It is used for setting up a network for internet access over a specific area, especially at home, company, building, or university. To be able to use this technology, a router is needed. Generally, one can cost around $90 or more.

5 WiMax

WiMax, or Worldwide Interoperability for Microwave Access, is a wireless technology that is developed from the concepts of wireless LAN and Wi-Fi based on the IEEE 802.16 standard, which specifies the physical and the data link layer of the OSI 7-layer protocol architecture.

The standard sets the operating frequency to be 2 GHz up to 11 GHz with the maximum data rate of 75 Mb/s and the specified bandwidth of 20 MHz, 25 MHz and 28 MHz. The operation frequency would be higher if there is a line-of-sight.

WiMax uses orthogonal frequency-division multiplexing (OFDM), which is a variant of frequency-division multiplexing (FDM), as a method of signal modulation. In OFDM, the data is separated into multiple channels with each being modulated with other modulation schemes like quadrature amplitude modulation or phase-shift keying.

A transmit power of WiMax depends on the types of WiMax stations. WiMax base stations have a transmit power of approximately 43 dBm, while WiMax mobile stations have a transmit power of approximately 23 dBm with the receive threshold of around -92 dBm. WiMax has a transmission range of around 65 kilometres at the maximum. However, due to geographical limitations, this number is expected to be lower in practice.

WiMax uses three kinds of antennas, namely, omni-directional antenna, sector antenna and panel antenna. Omni-directional antenna (in Figure 2) is used for point-to-multipoint configuration which broadcast 360 degrees from the base station. It is good in a situation where there are a lot of subscribers located very close to the base station. This kind of antenna is used in Last Mile application for residential and business subscribers to connect to the base station.

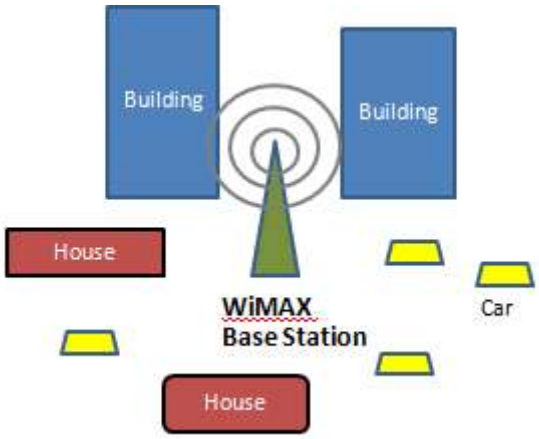

Figure 2: Omni-directional Antenna

Sector antenna (in Figure 3) is a directional antenna focused on a smaller sector which broadcasts 30-90-120 degree. It offers a greater range and throughput with less energy. To use sector antennas to cover a 360-degree service area is better than to use an omni-directional antenna due to the superior performance of sector antennas.

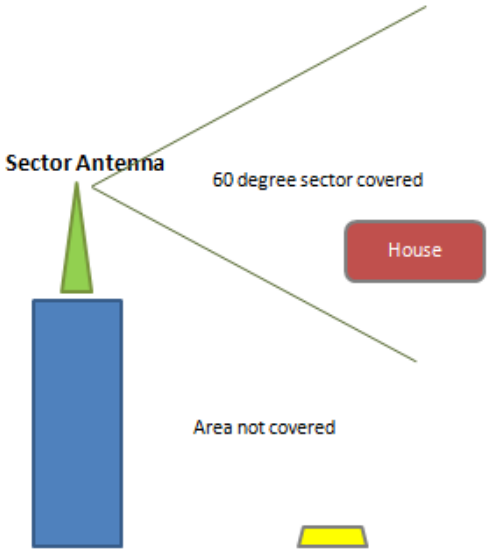

Figure 3: Sector Antenna

Panel antenna (in Figure 4) is most often used for point-to-point applications. It is a directional antenna which provides a powerful connection that is stronger and more stable. Therefore, it is able to send a lot of data with few errors. This kind of antenna is used in Backhaul applications that connect the base stations located across long distance.

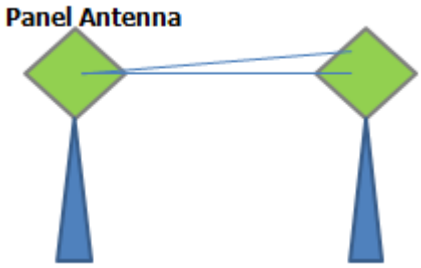

Figure 4: Panel Antenna

Error correction technique implemented in WiMax is FEC with Reed-Solomon (RS) codes, which defines the way to detect and correct symbol errors. It is especially suitable in case of burst errors. Because WiMax uses built-in error correction techniques, the system's signal-to-noise ratio (SNR) is greatly reduced.

WiMax is implemented in many movable devices like laptop computers and, particularly, mobile phones. WiMax is widely used in USA and Asia, including Thailand, mostly in telecommunication. WiMax has high transmission speed and is able to provide wide area coverage and high quality of service capabilities. Also, WiMax is connectable across cities and countries. It is easy to expand the network because there is no need to construct a new cable path. The cost the users of WiMax have to pay is the price of the actual product with WiMax technology.

6 Comparison of Wireless Technologies

ZigBee, Bluetooth, wireless LAN, and WiMax all have their own unique properties that make them suitable for certain applications. OSI 7-layer protocol architecture is used in all of them except for Bluetooth, which uses protocol architecture specified by SIG because of its special method of communication.

ZigBee has the lowest operating frequency while WiMax has the highest. This makes WiMax the best in terms of speed since higher operating frequency corresponds to higher rate of data processing. All of the technologies occupy the frequency band of 2.4 GHz. As a result, the signal is susceptible to interference and so, this frequency band is better avoided. This is not a problem for ZigBee, wireless LAN, and WiMax where alternative frequency bands are available.

WiMax has a slightly longer transmission range of 65 kilometres at the maximum compared to other technologies, while ZigBee and Bluetooth both have the shortest overall. However, this is not a problem for Bluetooth due to its designated function. The receive threshold of each technology is more or less the same. Like the case of the operating frequency, ZigBee has the lowest transmit power while WiMax has the highest. This explains why ZigBee has the lowest transmission range.

The main signal modulation techniques used in ZigBee, Bluetooth, wireless LAN, and WiMax are DSSS and ODFM. In DSSS, the bits are transmitted by spreading them over a frequency band, while in ODFM the bits are split into smaller sections transmitted one at a time. As a result, ODFM can transmit more bits and higher throughput can be achieved compared to DSSS.

All of the technologies use some kinds of forward error correction (FEC) technique. This is because FEC helps avoiding retransmission and therefore, enhances bandwidth. FEC can be combined with other error correction techniques as seen in Bluetooth, where FEC is combined with ARQ, leading to improvement in terms of performance.

Bluetooth and wireless LAN seemed to be the most popular technologies. This is partly due to the adoption of Bluetooth by international organisations. Wireless LAN and WiMax share similar applications. Judging from several features of WiMax as mentioned above, WiMax is superior compared to wireless LAN. The reason wireless LAN is more popular may be due to the fact that WiMax is still a new technology. As for ZigBee, it is less widely used than other technologies probably because of a smaller target market.

7 References

[1] http://www.howstuffworks.com/bluetooth.htm
[2] http://www.bbc.co.uk/webwise/askbruce/articles/connect/bluetooth_2.shtml
[3] http://en.wikipedia.org/wiki/Frequency-hopping_spread_spectrum
[4] http://searchnetworking.techtarget.com/sDefinition/0,,sid7_gci525695,00.html
[5] http://www.palowireless.com/infotooth/knowbase/radio/109.asp
[6] http://www.swedetrack.com/images/bluet08.htm
[7] http://www.bluetomorrow.com/about-bluetooth-technology/general-bluetooth-information/bluetooth-costs.html
[8] http://kb.iu.edu/data/aick.html
[9] http://www.cspro.org
[10] www.wi-fiplanet.com
[11] http://www.pulsewan.com/
[12] http://en.wikipedia.org/
[13] http://en.wikipedia.org/wiki/WiMAX
[14] http://www.wimax.com/general/what-is-wimax
[15] http://www.wifinotes.com/wimax/IEEE-802.16.html
[16] http://en.wikipedia.org/wiki/Wireless_LAN
[17] http://searchmobilecomputing.techtarget.com/definition/wireless-LAN
[18] http://www.cspro.org/component/content/article/3-articles/25
[19] http://www.wi-fiplanet.com/tutorials/article.php/1428941/EIRP-Limitations-for-80211-WLANs.htm|
[20] http://en.wikipedia.org/wiki/ZigBee
[21] http://www.digi.com/technology/rf-articles/wireless-zigbee.jsp
[22] http://www.freescale.com/webapp/sps/site/homepage.jsp?code=802-15-4_HOME
[23] http://www.eetimes.com/design/other/4006430/Home-networking-with-Zigbee
[24] http://www.qsl.net/n9zia/wireless/dsss.html
[25] http://en.wikipedia.org/wiki/Direct_sequence_spread_spectrum
[26] http://searchnetworking.techtarget.com/sDefinition/0,,sid7_gci525721,00.html
[27] http://www.eetimes.com/design/industrial-control/4006666/Picking-the-right-802-15-4-ZigBee-wireless-connection-for-your-embedded-design
[28] http://www.softbaugh.com/downloads/DZ1611_RF_Report.pdf
[29] https://learningnetwork.cisco.com/thread/10626