Introduction to Data Communications

ITS 323

Wireless Technologies

(Zigbee, Bluetooth, Wireless LAN and WiMax)

Assistant Professor Dr. Steven Gordon

=)

By

Thammachart Tula 5122800568

Jinnawat Pinchai 5122790728

Chattanon Saekow 5122792864

Introduction

Computer technology is showing up everywhere in our daily lives in the form of wireless network-based products for consumer use. Activities such as using a mobile phone to remotely access your home security or audio/visual systems, getting information about the status of your car directly from the manufacturer while driving, using the smart card in your phone for storing personal information or to make secure transactions, or networking wireless home appliances will soon be as normal as driving a car or making a telephone call.

Therefore we aim to study about them.

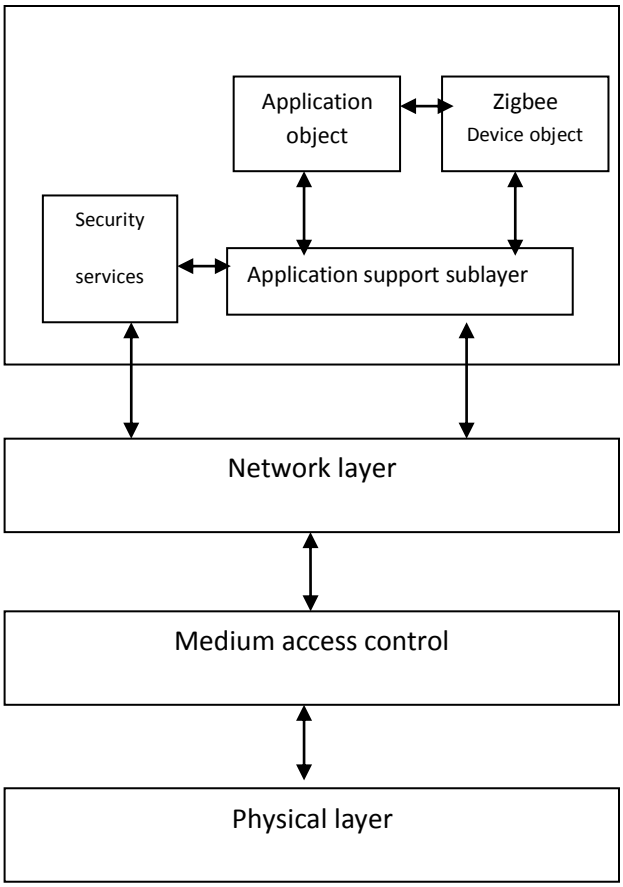
Index

Participation

	Thammachart	Jinnawat	Chattanon
Zigbee	70%	20%	10%
Bluetooth	10%	10%	80%
Wireless LAN	45%	45%	10%
WiMax	20%	70%	10%

Zigbee

Zigbee protocol architecture



Protocols and standards

Zigbee uses IEEE 802.15.4 as its standard which designates the physical layer.

Zigbee protocols are built upon algorithmic research for making a low-speed ad-network of nodes automatically. They support beacon and non-beacon enabled networks. To decrease the power use, they lessen the time the radio is on. In beacon enabled networks nodes are active when beacon is being transferred and in non-beacon enabled networks some devices are always active but some may be dormant.

Standard organizations: Zigbee Alliance

Data transmission

Zigbee uses Direct Sequence Spread Spectrum(DSSS) which divides the 2.4 GHz spectrum into 16 channels or 10 channels in the 915 MHz spectrum and 1 channel in the European 868 MHz spectrum.

Transmission media

The 802.15.4 standard indicates a minimum receiver threshold of -85 dBm for 2.4 GHz radios and -92 dBm for 900 MHz radios.

In the air, data rate is 250 kbps per channel in the 2.4 GHz band, 40 kbps per channel in the 915 MHz band, and 20 kbps in the 868 MHz band. Transmission range is between 10 and 75 meters. The maximum output power of the radios is generally 0 dBm (1 mW).

Signal Encoding

The radios use DSSS coding, which is managed by the digital stream into the modulator. BPSK is used in the 868 and 915 MHz bands, and OQPSK symbol is used in the 2.4 GHz band.

Applications

Zigbee protocols aim to use in embedded applications which need low data rates and power consumption. Moreover, these applications are inexpensive to be constructed or made up and the devices which are to be used should have a battery life of at least two years to get Zigbee certification.

Here are some typical applications of Zigbee :

1. Home Control : e.g. light control, temperature control
2. Home Security : e.g. intruder warning
3. Home Awareness : e.g. water sensors, power sensors, smoke and fire detectors
4. Mobile Services : e.g. m-payment, m-monitoring and control
5. Industrial Plant : e.g. process control, asset management, environmental management

Device types

1. Zigbee Coordinator (ZC) : It is the most important device because each network must have one ZC. It creates the root of network tree and may be build connections with other networks.
2. Zigbee Router (ZR) : It passes on the data from other devices as well as runs an application function.
3. Zigbee End Device (ZED) : It communicates with its parent node (either ZC or ZR) and cannot relay data from other devices.

Usage

The applications of Zigbee are not being used in Thailand vastly because although the cost is inexpensive for some people but Thailand is still a developing country which most of its citizens cannot afford to have this wireless technology. In addition, the installation can be complicated and also there are some technologies that still not out-of-date and workable.

Bluetooth

Bluetooth is the technology for exchanging data with a short distance using short wave length radio. Bluetooth use a radio technology called frequency-hopping spread spectrum (FHSS) to create the personal space for exchanging the data or so called PANs (Personal Area Networks). Bluetooth technology operates in the unlicensed industrial, scientific and medical or, so called ISM band at 2.4 -2.48 GHz.

-Aims of producing Bluetooth devices are low cost implementation, small implementation size, low power consumption, robustness, high quality data and voice transfer.

In order to connect with Bluetooth, we must have the Bluetooth radio, link controller, link manager and, host (can be any devices such as computer or telephone). Bluetooth can connect up to 8 devices at the same time.

While connected, the system will have a master-slave structure. It will send the data in the packet. Each packet will include 3 small parts. There are access code, header, and, payload. For access code and header, they have the fixed bit number of 72 and 54 respectively. While payload is depending on the work, the size is ranged from 0 – 2745 bits.

Two types of connection for Bluetooth

Synchronous Connection Oriented (SCO), or Asynchronous Connection Less (ACL).

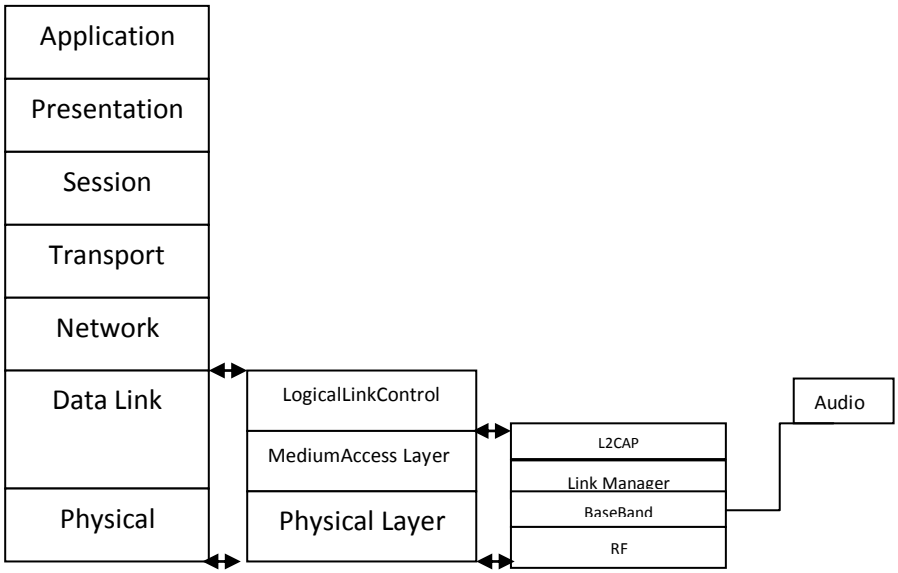
- The synchronous connection oriented channels are used for voice transfer by reserving slots, they are balance between the master and slave. It allows the maximum of three in a piconet. A slave can control two originating from different masters.
- The asynchronous connection-less, these links may be used for data transfer applications, which do not require a synchronous link. The ACL is point-to-multipoint link between the master and all the slaves participating in the piconet.

Bluetooth protocol architecture

The links are created on the basis of master and slaves structure. Master can connect with 7 slaves at the same time. These form a small network called Piconet while slave can become the master at any time.

While connected, the data can be transferred between master and any other devices. **Piconets** can be **setup to interact** with other Piconets to form larger networks called **Scatternets**. Scatternets allow the master in one Piconet to operate as a slave in another Piconet. the use of Scatternets requires synchronization (and sharing of data transmission Bandwidth)

Bluetooth Protocol Stack



Bluetooth is defined as a layer protocol architecture consisting of core protocols, cable replacement protocols, telephony control protocols, and adopted protocols

Bluetooth Core Protocol

-Base band and link control – these two are used for connecting all Bluetooth equipment together.

-Audio – it is directly connected to base band and it used for detecting the voice data.

-Link Manager Protocol (LMP) – it is used for checking the packets of data which receive from the base band.

-Logical Link Control and Adaptation Protocol (L2CAP) – it is to check the correctness of data from each packet.

-Service Discovery Protocol (SDP) – allows a device to discover services supported by other devices

Standard Organization: Bluetooth special Interest group

Cable Replacement Protocol

-RFCOMM – its main purpose is the provide emulation over L2CAP protocol.

Telephony Protocol

-Telephony Control Protocol-Binary (TCS-BIN) - Used to setup and control speech and data calls between Bluetooth devices.

Adopted Protocol

-OBEX (Object Exchange) – it is used for exchanging the object

-Point to point protocol (PPP)

- Internet standard protocol for transporting IP datagrams over a point-to-point link.

Error Correction

Three types of error correction are implemented in Bluetooth systems,

-1/3 rate forward error correction (FEC) – using headers and packets and decide whether the received data is 0 or 1.

-2/3 rate FEC - using hamming distance algorithm.

-Automatic repeat-request (ARQ)

-A CRC (cyclic redundancy check) code is added to each packet and used by the receiver to decide whether or not the packet has arrived error free

-The purpose of the FEC scheme on the data payload is to reduce the number of re-transmissions.

-The ARQ-scheme – packets are retransmitted till an ACK is received (or timeout is exceeded)

Data Transmission

-Data rate

Bluetooth version 1.2 = 1 Mbit/sec

Bluetooth version 2.0 + EDR = 3 Mbit/sec

Bluetooth version 3.0 + HS = 24 Mbit/sec

Bluetooth is a standard communications protocol primarily designed for low power consumption.

Transmission power

We can classify the Bluetooth into 3 classes of transmission power.

Class 1 = maximum permitted power of 20 dBm transmit in the range of 100 meters
Class 2 = maximum permitted power of 4 dBm transmit in the range of 10 meters
Class 3 = maximum permitted power of 0 dBm transmit in the range of 1 meter

Signal encoding techniques

For Bluetooth, the pulse code modulation (PCM) and Continuous Variable Slope Delta Modulation(CVSD) are used. They receive analog data and encode them into digital signal. For CVSD, it determines whether the result of data is lower or higher than the average data, if it higher the output of the air interface will equal to one. On the other hand, it will return 0 or -1.

Cost of Bluetooth

Bluetooth devices use low-cost transceiver microchips, so that the cost of manufacturing Bluetooth is quite low. Bluetooth chips are estimated to cost around 4$US to manufacture. Therefore, the prices of consumer Bluetooth devices are low.

Usage of Bluetooth

Bluetooth is widely used in most country as because of its low manufacturing cost and, the standard of 2.4GHz spread-spectrum ISM band, which existed in most countries. Especially in Thailand where Bluetooth is very common nowadays to Thai people.

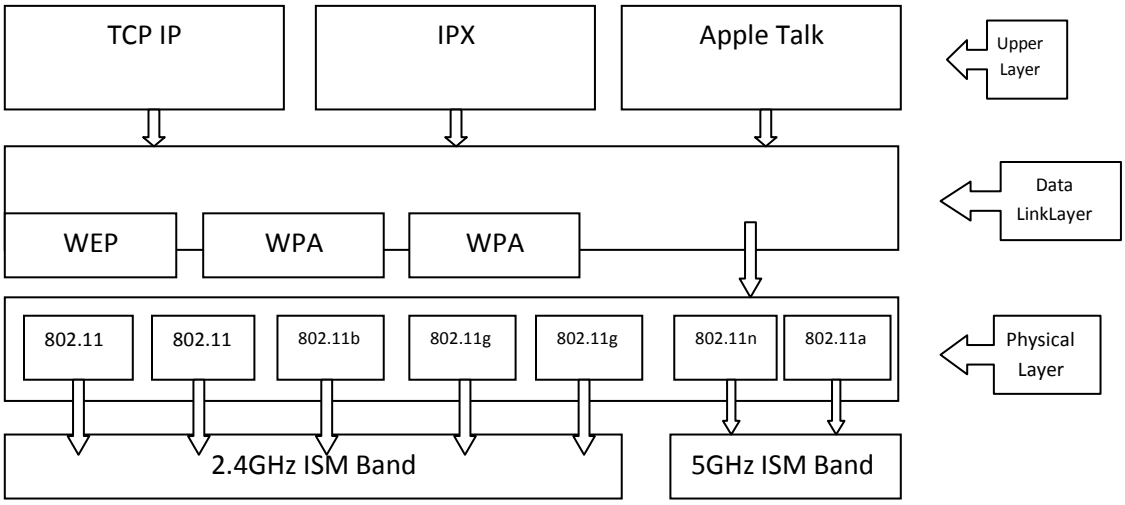
Application of Bluetooth

-The common and the earliest application of Bluetooth is the wireless control between mobile phone and a hands free headset.

-Wireless network connecting between pc and other devices for sharing data or transferring data.

-Bluetooth is used for controlling instead of infrared where is traditionally used.

Wireless-LAN



The Wireless Local Area Network (WLAN) technology is defined by the IEEE 802.11. There are currently four specifications: 802.11, 802.11a, 802.11b, and 802.11g. All four use the Ethernet protocol and CSMA/CA (carrier sense multiple access with collision avoidance instead of CSMA/CD) for path sharing.

Standard Organization: Wi-Fi Alliance

Data transmission

802.11 applies to wireless LANs and provides 1 or 2 Mbps transmission in the 2.4 GHz band using either frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS).

802.11a is an extension to 802.11 that provides up to 54 Mbps in the 5GHz band. 802.11a uses an orthogonal frequency division multiplexing (OFDM) encoding scheme rather than FHSS or DSSS. The 802.11a specification applies to wireless ATM systems and is used in access hubs.

802.11b provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1 Mbps) in the 2.4 GHz band. 802.11b uses only DSSS. 802.11b was an approval to the original 802.11 standard, allowing wireless functionality comparable to Ethernet.

802.11g offers wireless transmission over relatively short distances at 20 - 54 Mbps in the 2.4 GHz band. The 802.11g also uses the OFDM encoding scheme.

Transmission media

Generally, WLAN equipment has an output power of 15 dBm (about 30 mW). Receive threshold changes according to types of receiver. Here are some typical receiver sensitivity values

- Orinocco cards PCMCIA Silver/Gold : 11Mbps => -82 dBm ; 5.5Mbps => -87 dBm; 2Mbps=> -91 dBm; 1Mbps=> -94 dBm.

- CISCO cards Aironet 350: 11Mbps => -85 dBm ; 5.5 Mbps => -89 dBm; 2 Mbps => -91 dBm; 1 Mbps => -94 dBm.

Chosen antenna: Sector Antenna

The typical antenna that we are going to describe is Degree Sector Antenna which has frequency of 2.4 GHz - 2.5 GHz, gain of 14 dBi and maximum power 50 watts. It is 5.5 x 21.5 inches long and 5.25 inches deep.

The maximum distance that WLAN can transmit the signal is usually 300 meters. However, occasionally, the distance can be increased but the data may be interrupted by interference signal. Moreover, the signal cannot pass through some kinds of “thick” objects such as buildings, walls and etc. The most efficient distance is ranged from 1-50 meters.

Signal Encoding

The modulation used in IEEE 802.11 has been phase-shift keying (PSK) in the past. The modulation method selected for IEEE 802.11b is known as complementary code keying (CCK), which allows higher data speeds and is less sensitive to multipath-propagation interference. IEEE 802.11a uses a modulation scheme known as orthogonal frequency division multiplexing (OFDM) that makes possible data speeds as high as 54 Mbps, but commonly, communications takes place at 6 Mbps, 12 Mbps, or 24 Mbps.

Errors

An apparatus for detecting errors in a wireless communication channel compose of a receiver (which receives data from the wireless communication channel), a signal strength indication circuit coupled with the receiver which indicates signal strength for a received data stream, and processing resources coupled to the signal strength indication circuit which monitors the received data signal strength to detect abnormalities in the strength of the received data stream, typical of incorrect data.

Moreover, the system includes a signal phase monitoring circuit coupled with the receiver. This circuit indicates phase of the received data stream. Processing resources coupled with the signal phase monitoring circuit, monitor the received data stream phase to detect abnormalities in phase of the received data stream typical of incorrect data.

In addition, the data stream will include data packets that have error detection codes placed within the data packets. Processing resources, coupled with the receiver, are responsive to the error detection codes to detect errors in the data packets. Therefore error detection system based on monitoring the amplitude, and the phase of a received signal, combined with digital CRC detection techniques provides an efficient error detection system, capable of detecting interference early in transmission, allowing more rapid recovery in retries.

Applications

Mobile Workforce : Real-time interaction, instant messaging, paging, voice services, mobile network access, and real-time network access in the office are transforming the business environment.

Education : Once installed Students can access the Internet, email and shared resources from anywhere on a campus .

Temporary Network / Network Extensions : For temporary network installations or extensions to existing wired networks, Wireless LAN relatively quickly and once up and running any future changes are simple.

Moves, Adds and Changes: For network managers, a wireless LAN means less time spent carrying out moves, adds and changes.

Public Areas: As well as providing the Wireless LAN infrastructure needed for wireless connectivity in public areas that allows proprietors to provide chargeable internet sessions at their chosen location.

Usage

WLAN is used all over Thailand especially in schools and universities because it is important for students and others to access to the Internet. Moreover it is often being used in offices and houses also since the installation of WLAN is not complicated.

Costs

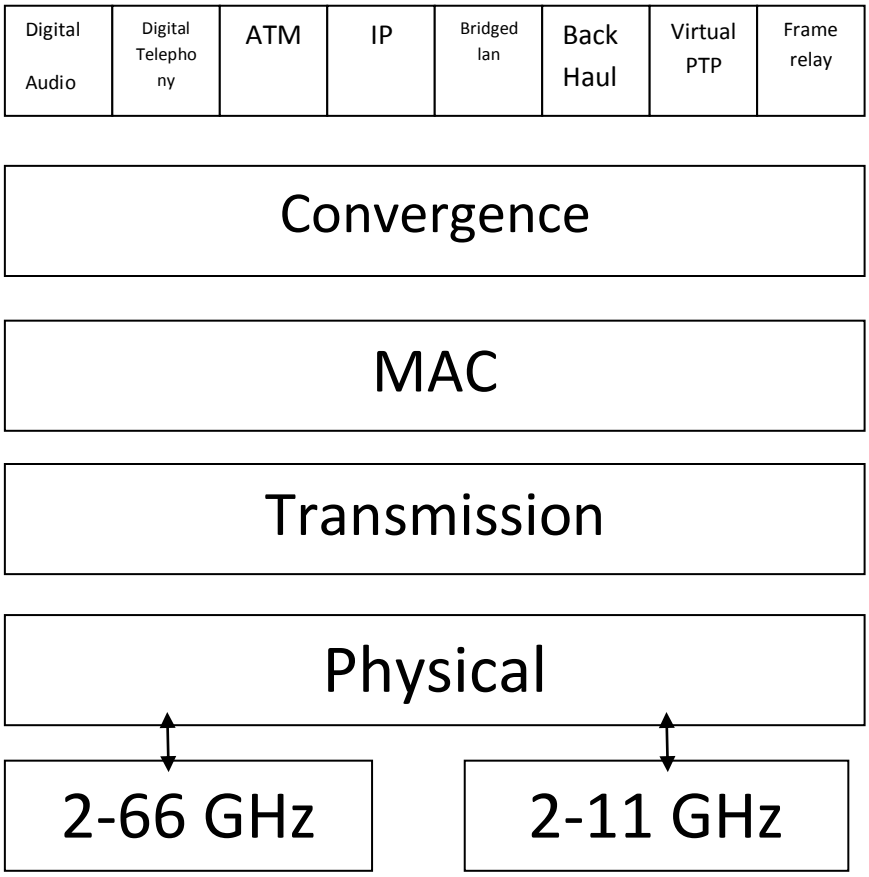
Home modem: $30

Home modem router: $25

USB home modem router: $50

WiMax

Protocol Architecture



IEEE 802.16 Protocol Architecture has 4 layers: Convergence, MAC, Transmission and physical, which can be map to two OSI lowest layers: physical and data link.

Protocol

WiMax used IEEE 802.16 as its base standard which includes two sets of standards: IEEE 802.16d(fixed WiMax) and IEEE 802.16e(mobile WiMax). IEEE 802.16 standards are involved with the air interface between a contributor's transceiver station and a base transceiver station.

The fixed WiMax standard gives fixed, point-to-multipoint(PMP) wireless access service and its product profile utilizes the OFDM 256-FFT (Fast Fourier Transform) system profile. It supports both time division duplex (TDD) and frequency division duplex (FDD) services.

IEEE 802.16e gives mobility features to WiMAX in the 2-11 GHz licensed bands. In addition, it allows for fixed wireless and mobile Non Line of Sight (NLOS) applications fundamentally by improving the OFDMA (Orthogonal Frequency Division Multiple Access).

Standard Organization: WiMAX Forum

Data Transmission

There is no standard spectrum for WiMAX, however the WiMAX forum has published three licensed spectrum profiles 2.3 GHz, 2.5 GHz and 3.5 GHz, in an effort to be standard and decrease cost.

The frequency for IEEE 802.16d is between 2 to 11 GHz and for IEEE 802.16e, it is between 2 to 6 GHz.

The bandwidth of IEEE 802.16d is 20 MHz and for IEEE 802.16e, it is 12 MHz.

The value of data rate of IEEE 802.16d is 75 Mbps and 30 Mbps for IEEE 802.16e.

Transmit media

WiMAX base stations transmit at power levels of +43dBm (20W). A WiMAX mobile station (MS) typically transmits at +23 dBm (200mW). Cellular (CDMA) transmit powers for both the BS and MS are similar to those used in WiMAX. The receiver sensitivity for this wireless technology is between -118 to -30 dBm.

Chosen antenna: Sector antenna (24 3015)

This antenna offers great range and throughput with less energy. It has a gain of 17.5 dBi and a size of 50 x 22 x 4 centimeters.

Distance

WiMAX tower base station can cover up 10Km radius. In theory it suggests to cover a lot more distance than just 10Km, it can reach some where about 50 km (30 miles), but in fact due to certain geographical limitations it goes as far as 10 km approx. 6 mils. Any wireless connecting device for WiMAX will connect to WiMAX network if fallen in to the range.

Signal Encoding

As a standard intended to satisfy needs of next-generation data networks (4G), WiMAX is differentiated by its dynamic burst algorithm modulation adaptive to the physical environment the RF signal travels through. Modulation is selected to be more which means that when the bursts have a high signal strength and a high carrier to noise plus interference ratio (CINR), they are more easily to be decoded by using digital signal processing (DSP). In contrast, working in less desirable environments for RF communication, the system automatically steps down to a more robust mode which means fewer bits per OFDM/SOFDMA symbol; with the advantage that power per bit is higher and therefore simpler accurate signal processing can be performed.

Burst profiles are used inverse to low signal attenuation; meaning throughput between clients and the base station is determined largely by distance. Maximum distance is achieved by the use of the most robust burst setting; that is, the profile with the largest MAC frame allocation trade-off requiring more symbols to be allocated in transmitting a given amount of data than if the client were closer to the base station.

The client's MAC frame and their individual burst profiles are determined as well as the specific time allocation. However, although this is done automatically then the “practical deployment” should avoid high interference and multipath environments. Too much interference causes the network function poorly and can also distort the capability of the network.

The system is complex to deploy as it is necessary to track, not only the signal strength and CINR, how the available frequencies will be assigned. This could lead to cluttered frequencies with slow response times or lost frames.

As a result the system has to be initially designed in consensus with the base station product team to accurately project frequency use, interference, and general product functionality.

Adaptive modulation

There are 4 standard modulation types : BPSK, QPSK, 16-QAM and 64-QAM. In all these 4 types, 64-QAM is the most efficient at transmitting data but the worst at resisting the interference signals. In contrast, BPSK is the most efficient at resisting the interference signals but the worst at transmitting data. Coding rate and modulation play a lot of role about sending data and handle with interference signals according to the conditions of channel. technique is

Errors

Error detection techniques are to reduce the system signal-to-noise ratio obligations. Convolutional Encoding, Strong Reed Solomon FEC, and interleaving algorithms are used to identify and correct errors to correct throughput. These strong error correction techniques assist to recover corrupted frames that may be missed due to frequency selective fading or burst errors. To remove the errors that cannot be corrected by the Forward Error Detection (FEC), Automatic Repeat Request (ARQ) is used by sending the error information again. This improves the Bit Error Rate (BER) performance for a similar maximum level.

Applications

WiMAX can provide wireless broadband Internet access, telephone access services, television service access and mobile telephone services.

The bandwidth and range of WiMAX make it suitable for the following potential applications. They provide:

1. Connectivity across cities and countries through variety devices.
2. Wireless alternative to cable and DSL for "last mile" broadband access.
3. Source of Internet connectivity as part of a business continuity plan.
4. Etc.

Usage

In Thailand WiMax is not being used yet but it is being tested in some provinces and places for future purposes. Sometimes it is used in big events such as national assembly for the governments. In some developed countries, like USA, there are many progresses going on and their citizens are able to use it. The reason for this is that there is nobody in Thailand has gut to invest on WiMax technology due to more than 35% Thai citizens are not interested in it.

Cost

These are the costs of home modem, USB modem and voice adapter that we have taken from a site.

Home modem purchase is $84.99

USB modem purchase is $79.99

Voice adapter is always purchased for $15.00

Comparison

	Data rate	Receiver sensitivity(dBm)	Output power (dBm)	Distance
Zigbee	250 kbps	-85	0	10 -25 meters
Bluetooth	1-24 Mbps	-70	0-20	1-100 meters
WLAN	1-54 Mbps	-100 to -80	15	300 meters
WiMax	75 and 30 Mbps	-118 to -30	23 and 43	10 kilometers

The above table shows how data rate, receiver sensitivity, output power and distance vary from each wireless technology.

References

Websites:

wikipedia.org

javvin.com

specifications.nl

radio-electronics.com

And special thanks to **Dr. Steven Gordon** for giving us hints, clues and information. =)
