

Assignment ITS 323

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To

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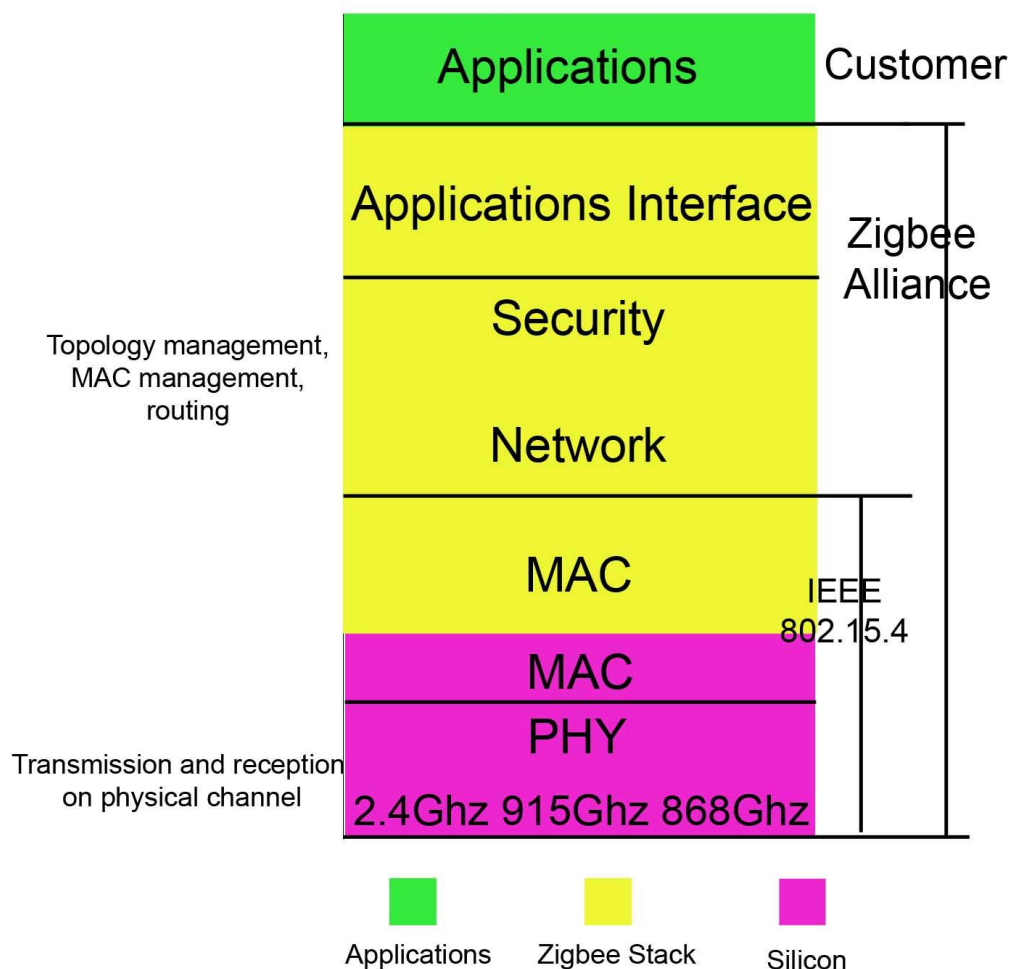
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ZigBee			100%
Bluetooth	33.33%	33.33%	33.33%
WLAN	100%		
Wimax		100%	

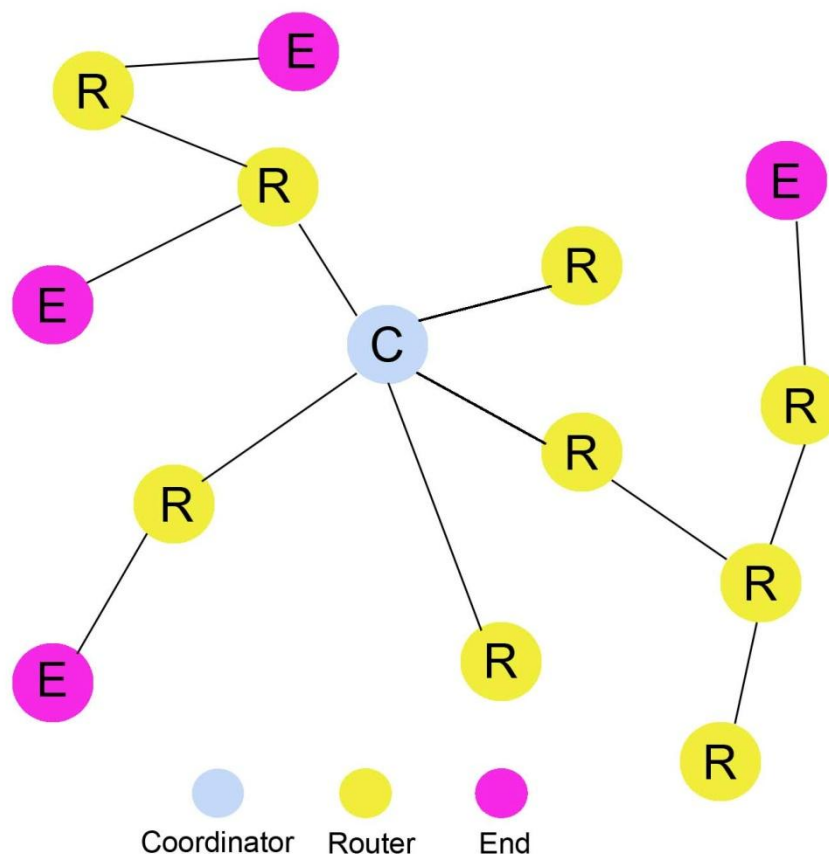
What is Zigbee?

Zigbee is a wireless communication based on the IEEE 802.15.4-2003 standard for wireless home area networks (WHANs) with low data rate, low cost and consume low power which is it can be use for over months or years. Because of this advantages point of zigbee it wildly used for Wireless Sensor Network, this system can be use in indoor or outdoor can bear sun or rain and monitoring applications.

Zigbee international standard defined by ZigBee Alliance. ZigBee devices are required to used in IEEE 802.15.4-2003 standard. The standard specifies the lower protocol layers—the physical layer (PHY), and the media access control (MAC) portion of the data link layer (DLL).



Zigbee used mesh,star and cluster tree topology and example is star topology required one coordinator in one network. Zigbee nodes defines in three types of nodes Coordinator, Router and end device



Coordinator is the most important node of this three node types. It can store information about network

Routers act as intermediate nodes, relaying data from other devices.

End devices can be use low power. They have function to able to talk to their parent nodes but they can't relay data from other device.

The data rate of zigbee is 25kbps and can up to 250kbps in 3 standard frequency, which is 2.4Ghz for 250kbps with 16 channels in worldwide, 915Ghz with 10 channels for 40kbps in America and 868Ghz for 20kbps with 1 channel in Europe. See on below table

Frequency	Coverage	Data rate	Channels
2.4Ghz	Worldwide	250kbps	16
915Ghz	America	40kbps	10
868Ghz	Europe	20kbps	1

Transmission and receive current in zigbee are depend on devices such as XBee-PRO 802.15.4+XBee Socket have Transmit current: 215 mA Receive current: 55 mA, XBee-PRO 2.5 have transmit power at 50 mW (+17 dBm) / Int'l 10 mW (+10 dBm) and have Transmit Current 295 mA Receive Current 45 mA.

Antenna Options Chip, Wire Whip, U.FL, RPSMA.

Zigbee have range about 70-300m.

Signal Encoding Techniques: The radios use direct-sequence spread spectrum coding, which is managed by the digital stream into the modulator.

Zigbee used re-transmission when it has error.

Zigbee with applications: Zigbee are very useful used in many applications and the applications required the low data rate and low power consumption and of course, it should not expensive. Here are the applications using zigbee.

Home Automation – Home Automation network, this network can easily installed by homeowner. The zigbee home automation network are focused on real time control devices, which mean that when you pressed the button devices that you expected to work will work such as you pressed button on remote control light will turn on, lower blinds when you want to watch movie or sleep, or you set another button to “outside” mode when you pressed it, air condition TV light will turn off.

Health care – This application can be used by many devices such as blood pressure meter. It measures a patient's blood pressure. The expected frequency of measurement is several times a day.

Insulin pump does inject insulin to a patient, via tube. Health and fitness devices such as cardiovascular fitness and activity monitor measure physical action of the body and calculate and show on monitor, step counter measures walking distance.

Telecom Applications – Telecom Applications network, users expect to see the result of but they do across network quickly by using this application.

Devices that use this network are mobile phones. Samples of this application are mobile payment service, mobile monitoring and control, chatting network, voice over zigbee network etc.

Usage

Advantage points of zigbee are low cost and consume low power. In my opinion I think zigbee has been used worldwide and is used in Thailand also.

Cost

Cost of zigbee transceiver is approximately starting at 3\$. XBee-PRO 802.15.4+XBee Socket can transmit and receive data in 2.4GHz cost approximately 2100B.

What is Bluetooth?

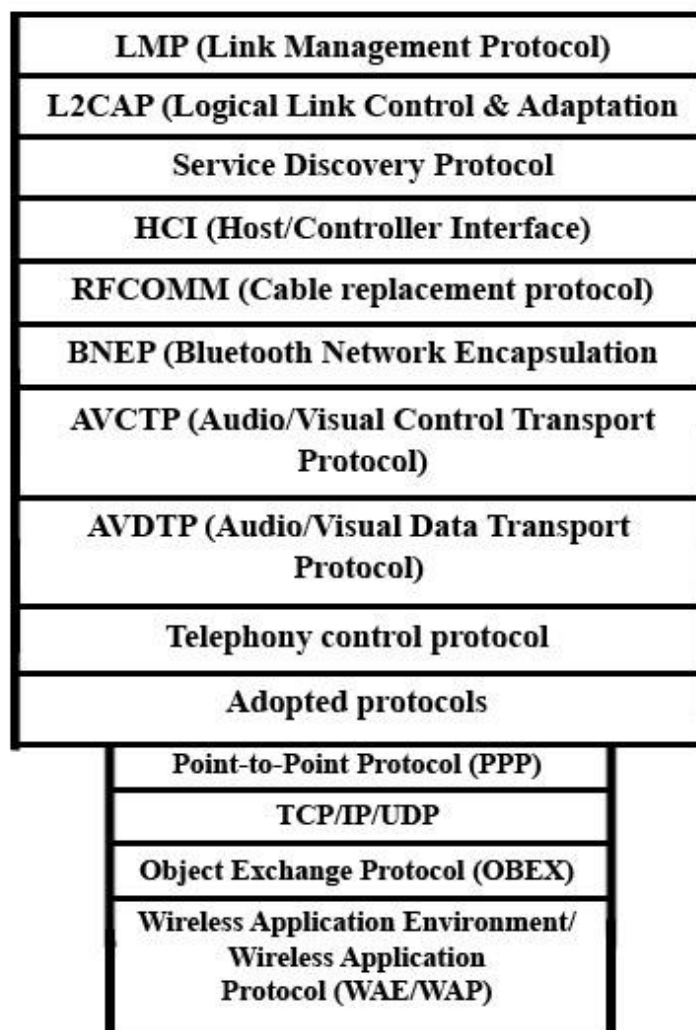
Bluetooth is a wireless technology that exchange data in short distance.

Bluetooth focused on

- Cable replace- Replace all wires.
- Ad hoc networking- Can connect with system any time you want.
- Data/voice access point- Transmit and receive data or voice from server.

The objective of Bluetooth are low cost implementation, small implementation size, low power consumption, robust, high quality data & voice transfer and Open global standard

Bluetooth protocol stack



- **LMP (Link Management Protocol)**- This protocol used for control the radio link between two devices.

- **L2CAP (Logical Link Control & Adaptation Protocol)**- Used for multiplex the connection between two devices by using different higher level protocols.

In Basic mode, L2CAP configurable up to 64kB, with 672 bytes as the default MTU, and 48 bytes as the minimum in MTU.

In Retransmission & Flow Control modes, L2CAP can be configured for reliable per channel by performing retransmissions and CRC checks.

Enhanced Retransmission Mode (ERTM): The improve version of original retransmission mode.

Streaming Mode (SM): This mode has no retransmission or flow control
Reliability in any of these modes is optionally.

- **Service Discovery Protocol**- SDP allows a devices to discover the other devices such as you want to connect mobile phone and Bluetooth headset . SDP will determine which Bluetooth profiles (headset profile, hands free profile) and the protocol multiplexer will connect with.

- **HCI (Host/Controller Interface)**- HCI control the Host (PC,OS) and controller(Chip IC inside hardware) to transfer the same command and same packet event if both of source and destination are different hardware. Before transmission ,their command and packet is changed to match each other. They are implemented on USB(In PCs) and UART(in mobile phone).

- **RFCOMM (Cable replacement protocol)**- RFCOMM stands for Radio frequency communications. RFCOMM is normally implemented on most of the operation system (depend on device) .It makes the application can find their port in order to communicate and send data quicker.

- **BNEP (Bluetooth Network Encapsulation Protocol)**- Main purpose of this protocol is the transmission of IP packets in the Personal Area Networking Profile.

- **AVCTP (Audio/Visual Control Transport Protocol)**- Used by the remote to transfer AV/C commands over an L2CAP channel. The buttons on remote on music player use this protocol to control music.
- **AVDTP (Audio/Visual Data Transport Protocol)**- This protocol do stream music to stereo headsets over an L2CAP channel.
- **Telephony control protocol**-Telephony control protocol-binary (TCS BIN) is defines the call control signaling for the voice and data calls between Bluetooth devices.
- **Adopted protocols**- The adopted protocols are standards that define the different organization produce the same standard embedded in the device and incorporate (at the middle of stack) into protocol stack
It include:

Point-to-Point Protocol (PPP)- 1 transmission to 1 receiver only.

TCP/IP/UDP- Foundation Protocols for TCP/IP protocol suite

Object Exchange Protocol (OBEX) - It is a layer for exchanging of object.

Wireless Application Environment/Wireless Application Protocol (WAE/WAP)
- WAP is an open standard for mobile users access to services.

Bluetooth operates at 2.4Ghz but it can separate depend on what country such as Europe and America 2.4 – 2.4835Ghz separate in 79 channels, will use this channel for transmit or receive data 1600 times per 1second In Japan used 2.402 – 2.480Ghz separate in 23 channels. Distance of Bluetooth is about 5-10m. Data rate of Bluetooth is 1Mbps

Standard Organisations for Bluetooth is IEEE (Institute of Electrical and Electronics Engineers).

Standard is IEEE 802. There are many types of IEEE 802.

Types of IEEE 802

IEEE	Modulation	Data rate(Mb/s)	Freq. (GHz)	Approximate indoor range
IEEE Standard 802.15.1 Version 1.2	FHSS	1	2.45	33 feet
IEEE Standard 802.15.1 (Bluetooth 2.0)	FHSS	1,2	2.45	33 feet
IEEE 802.11	FHSS	1,2	2.4	66 feet

Data Transmission spectrum

Frequency-hopping spread spectrum (FHSS) is used in Bluetooth. It is used in military to prevent from being monitored or blocked by enemy then it is adapt to use in wireless. It is a method of transmitting radio signals. It rapidly switches a carrier among many frequency channels.

Basic algorithm

1. The initiating party sends a request through a control channel.
2. The receiving party sends a number back.
3. The initiating party uses the number to calculate the sequence of frequencies that need to use.
4. The initiating party sends signal through the first frequency then acknowledge to the receiving party that the sequence was correct or not.

Transmission Media

Bluetooth transmission Media is unguided media. Bluetooth transmission at frequency 2.45 GHz needed bandwidth more than 100 MHz so there are not many types of antenna that are used.

Example of antennas

-Wire Monopole is a simple wire and provides good performance and high efficiency.

-PIFA—The Printed Inverted F Antenna is similar to the wire monopole. The PIFA Antenna compose with copper and copper plate

-Helix is coiled around a central core.

-Ceramic chip antenna is the smallest types of antennas. Ceramic Dielectric Antenna and copper are installed in Ceramic antenna

Antenna Type	Performance	Cost
PIFA	Small bandwidth and reduced efficiency	Low
Helix	Good bandwidth and efficiency	High
Ceramic	Small bandwidth and reduced efficiency	Medium

* Ceramic chip antenna is a popular antenna type.

Brand & Model	Transmitted Power in dBm	Antenna Gain in dBi
Linksys USBBT100	13-17 dBm	1.2 dBi
DLINK DBT-120	4 dBm	1.1 dBi

SIGNAL ENCODING TECHNIQUE

Bluetooth combines GFSK (Gaussian frequency-shift keying) and PSK (Phase shift keying) modulation (changing) to generate a new wave form. There is a Gaussian Filter reside in the GFSK that make each pulse smoother .It is a special way to reduce spectral width called pulse shaping. It is a sub technique to change the transmitted pulsed better and to be suited to the communication channel.

Bluetooth use technique FEC (forward error correction) and ARQ (Automatic repeat-request) to retransmit the error frame. There are 3 type of ARQ- It depend on the organization to choose which type of ARQ embedded in the device at the layer stack will adapt the frame and match to the destination

Devices

Bluetooth have been used by many devices

Mobile phone and smalltalk- if you used smalltalk with wire you cannot move or doing something freely but if you use Bluetooth smalltalk you can do anything freely by using your two hands such as drive car.

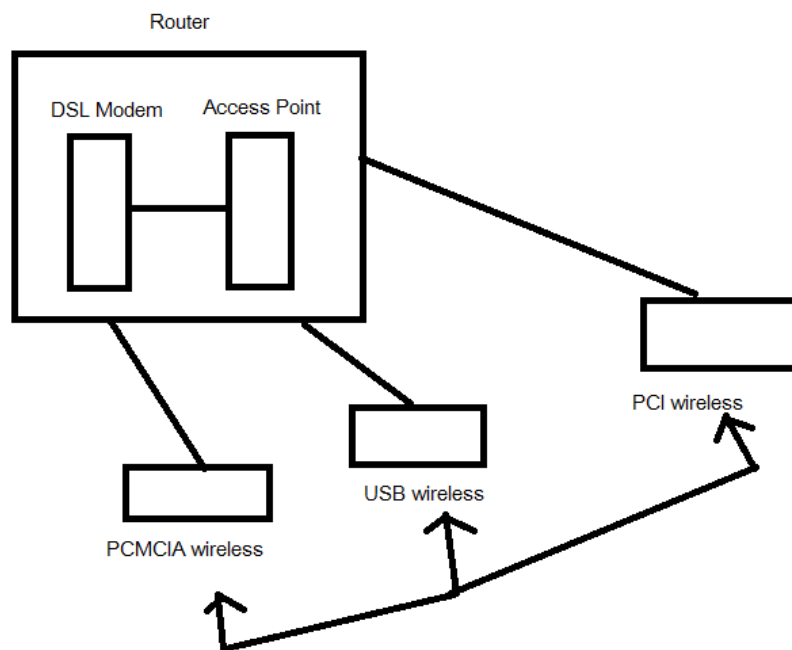
Keyless – This technology used Bluetooth instead of using button. Example when you park your car finished you no need to lock your car, you can walk out and when signal of key and car are disconnected your car will lock itself automatically. Mercedes-Benz SLR is the example that used this technology.

Mouse and Keyboard- Mouse and keyboard are another example of Bluetooth. You no need to aware any wire anymore. They are much more comfortable to use to carry.

Bluetooth are used in worldwide in everywhere also in Thailand. In Thailand we used Bluetooth widely for send and receive data via notebook, mobile phone etc.

Cost of product used Bluetooth depend on what product it is. Smalltalk are starting at 300B to 2000B and so on. Keyboard and mouse that made by apple are around 2300B.

Wireless Local Area Network (WLAN)



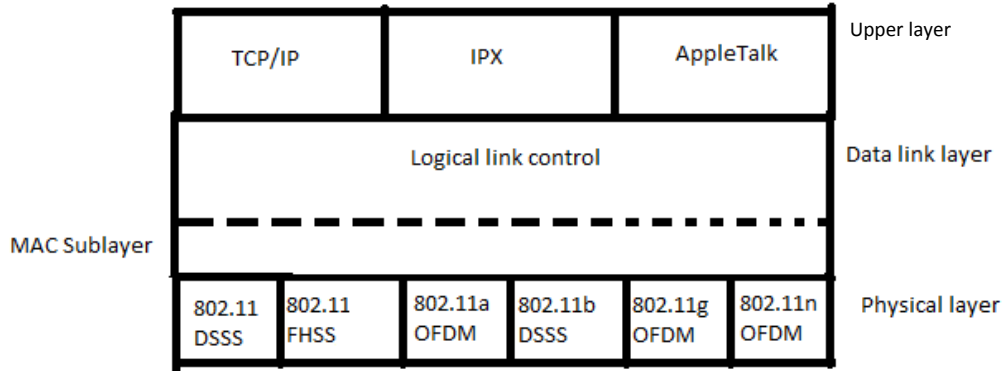
Devices are connected through an access point to the internet. There are many devices to connect together by wireless method. Many devices connect together to form a network. Wireless signal travels in radio frequency. Users can find a signal inside the area that router signal are covered. In Thailand we are allowed to use free radio frequency at 2.4 and 5 GHz. Users can connect to the internet very easy.

Protocol Architectures

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

CSMA/CA is used in wireless computer network. It is used in 802.11 based wireless LANs. CSMA/CA modulation technique is used to transmit the data between nodes. If the node wishes to transmit data, it need to first listen to the channel. If the channel is said "idle," then the node is allowed the transmission process. If the channel is said "busy," the node postpones its transmission for a random period of time.

IEEE 802.11 Protocol Stack



TCP/IP (Internet Protocol Suite)

TCP/IP consists of Application, Transport, Network, Data Link and Physical layer.

IPX Internetwork Packet Exchange

The IPX network address is similar to concept of the IP address. The address of IPX has the same meaning as the bits of IP address. Range of IPX address is 0x1 - 0xFFFFFFFF (assigned a unique 32-bit hexadecimal address). IPX routing table are similar to IP routing tables.

Apple Talk (Used in Mac OS)

Apple talk is a protocol for networking computers which developed by Apple. Datagram of Apple talk delivery protocol is similar to the Network layer.

Apple talk consists of Application, Presentation, Session, Transport, Network, Data Link and Physical layer.

MAC Media Access Control

MAC is a sub-layer of data link layer. MAC provides the channel access control. This makes several stations connected to share the same physical medium. Examples of shared physical media are bus networks, ring networks, hub networks, wireless networks and half-duplex point-to-point links. MAC is not required in full-duplex network but for compatibility reasons full-duplex is often available in the equipment.

Standard Organisations for wireless LAN is IEEE (Institute of Electrical and Electronics Engineers).

Standard of wireless is IEEE 802.11. There are many types of IEEE 802.11

Types of IEEE 802.11

IEEE	Modulation	Data rate(Mb/s)	Freq. (GHz)	Bandwidth (MHz)	Approximate indoor range
IEEE 802.11	FHSS or DSSS	1,2	2.4	20	66 feet
IEEE 802.11b	DSSS	1, 2, 5.5, 11	2.4	20	100-150 feet
IEEE 802.11a	OFDM	6, 9, 12, 18, 24, 36, 48, 54	5	20	25-75 feet
IEEE 802.11g	OFDM&DSSS	1, 2, 6, 9, 12, 18, 24, 36, 48, 54	2.4	20	100-150 feet
IEEE 802.11n	OFDM	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2	2.4	20	250 feet
IEEE 802.11n	OFDM	15, 30, 45, 60, 90, 120, 135, 150,200	5	40	250 feet

New Feature of IEEE 802.11n

IEEE 802.11n uses a new technology that called MIMO (multiple-input multiple-output). MIMO, there are many antennas to transmit and receive the signal

OFDM is Orthogonal frequency-division multiplexing (will be explained in Data Transmission spectrum)

DSSS is direct-sequence spread spectrum (will be explained in Data Transmission spectrum)

Data Transmission spectrum

There are many technologies that have been used to transmit data in Wireless LAN.

Spread-spectrum (DSSS, FHSS)

Spread-spectrum generates a signal in a particular bandwidth and spread in the frequency domain. This makes a signal with a wider bandwidth. Spread-spectrum's techniques are direct sequence and frequency hopping, which can be used for multiple accesses. Forms of Spread spectrum are combined of **Frequency-hopping spread spectrum (FHSS) and direct-sequence spread spectrum (DSSS)**. These techniques use pseudorandom number sequences which is created by pseudorandom number generators to determine *and* control the spreading pattern of the signal across the bandwidth.

Frequency-hopping spread spectrum (FHSS) is used in military to prevent from being monitored or blocked by enemy then it is adapt to use in wireless. It is a method of transmitting radio signals. It rapidly switches a carrier among many frequency channels.

Basic algorithm

1. The initiating party sends a request through a control channel.
2. The receiving party sends a number back.
3. The initiating party uses the number to calculate the sequence of frequencies that need to use.
4. The initiating party sends signal through the first frequency then acknowledge to the receiving party that the sequence was correct or not.

Direct-sequence spread spectrum (DSSS) is spread spectrum technologies which the transmitting signal uses more bandwidth than the signal that is

being modulated. DSSS gives the highest throughput for the nodes on a network when used with CSMA/CA and the IEEE 802.11.

How to transmit data

DSSS transmits data by a noise signal. This noise signal is a pseudorandom sequence of 1 and -1. White noise is similar to an audio recording of "static". This noise signal can be used to reform the original data at the receiving end, by multiplying the same pseudorandom sequence (because $1 \times 1 = 1$, and $-1 \times -1 = 1$).

OFDM (Orthogonal frequency-division multiplexing)

OFDM is a technique to transmit large amounts of digital data on a radio wave. Each signal travels in own frequency range (carrier). OFDM use concept of multiple subcarriers in a single carrier modulation by using the same single channel. The data rate in the channel is divided between the many subcarriers. Many carriers are spaced apart at right frequencies. This spacing provides the "orthogonality" for this technique it prevents the demodulators from seeing frequencies other than their own. Another name of OFDM is multi-carrier.

Data Transmission	Advantage	Disadvantage
FHSS	<ul style="list-style-type: none"> -Highly resistant to narrowband - Difficult to intercept - Share a frequency band with many types of conventional transmissions 	<ul style="list-style-type: none"> -Slower than DSSS -Multi-user interference possible
DSSS	<ul style="list-style-type: none"> -Resistance to intended or unintended jamming -Share a single channel with many users - Reduced signal noise level 	<ul style="list-style-type: none"> -Expensive receivers - Near-far problem causes reduced performance -Complex Implementation

OFDM	<ul style="list-style-type: none"> -Low sensitivity to time synchronization errors -Easy to adapt to severe channel without complex equalization - High spectral efficiency - Multi-carrier 	<ul style="list-style-type: none"> -Sensitive to Doppler shift -Sensitive to frequency synchronization problems
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Transmission Media

Wireless's transmission Media is unguided media. There are 2 types of antenna for Wireless transmission **Omni Directional Antenna** and **Directional Antenna**.

Omni Directional Antenna, Signal is spread in 360 degree. It is suitable for mobile device which is not fixed direction. They are usually found in Router, PCI wireless card and Access Point. Example Dipole Antenna (mostly stick shape).

Directional Antenna, Signal is sent in exact direction. Range is longer than Omni Directional Antenna but if receiver is not in right direction, it will not get any signal. Example Sector Antenna, Yagi Antenna, Grid Antenna, Solid Dish Antenna. They are usually found in Wireless Bridge.

Some example of Router Specifications

Brand & Model	Transmitted Power in dBm	Antenna Gain in dBi
Linksys WRT120N	802.11b: 21 +- 2 dBm 802.11g: 18 +- 2 dBm 802.11n: 16 +- 2 dBm	2.0
Linksys WRT160NL	802.11g: 15 +/- 1.5 dBm 802.11b: 19 +/- 1.5 dBm	1.8

Signal Encoding Techniques

Wireless needs to transmit digital data but for traveling in radio frequency, wireless use analog signals to transmit. To transform digital data to analog signals Wireless use Phase shift Keying (PSK) technique. Phase shift Keying (PSK) is used in IEEE 802.11 for Signal Encoding.

Errors error detection, error correction, ARQ

Cyclic Redundancy Check (CRC) technique is used to detect error in wireless LAN. CRC detects error of raw computer data changing by any accident. A CRC calculates binary sequence for each block of data and stores them. When a block is read the device will recalculate binary sequence again. If the recalculation is not matched with original calculation binary sequence, the block will send an error and the device need to send request again otherwise the data is assumed to be error.

Wireless LAN use Forward Error Correction (FEC) technique to allows the receiver to detect and correct errors. Forward Error Correction does not need to retransmit the data when error is detected.

Wireless LAN uses Stop-and-Wait ARQ technique for error control.

Application

Nowadays Wireless LAN technology is usually found in every place. It will come in form of WI-FI or Hot spot. It is used in mostly everywhere for example university, company, shopping mall and home. Wireless LAN technology is usually found in laptop, cell phone and Desktop. Nowadays in laptop and cell phone are already installed with Wireless card but for Desktop you may need to install PCI Wireless card or USB Wireless card. The small network the equipment that needed is ADSL, Access Point and Wireless adapters (Wireless card). People may use Wireless LAN technology to access to the internet or send some data to anywhere for example Wireless LAN technology is applied in restaurant to use PDA to order some food to the kitchen. Wireless LAN technology is applied in coffee shop so people can relax with drinking coffee and access to the internet.

Usage

Wireless LAN technology is found in everywhere in Thailand but for some countryside Wireless LAN technology has not been used because Wireless LAN technology need some knowledge and cost. Wireless LAN technology is usually found all over the world.

Cost

Nowadays Wireless router are very cheap about 1500-4500 Bath depend on the feature, internet broadband is about 599 Bath per Month (6 Mbps by True) and Wireless adapters (Wireless card) is about 500-1500 Bath depend on the feature. The cost is very reasonable because there are many competitions to reduce the cost.

WIMAX

Protocol Architecture

WIMAX Technology Standard is based on IEEE802.16 standard. This IEEE802.16 standard is defined by IEEE (Institute of Electrical and Electronics Engineers). There are 3 types of Using WIMAX Technology.

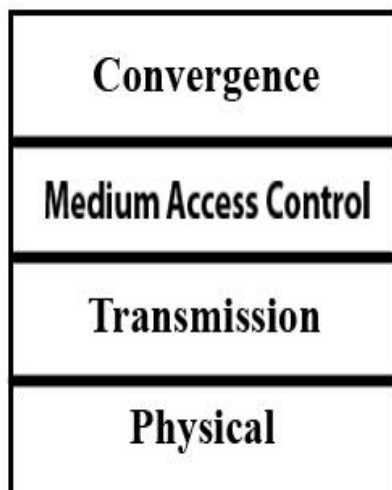
- **Fixed** Users cannot move while transmitting and receiving data due to Multipath Fading (Signal is Interfered by another signal). It is used for permanent receiver station for instance ISP to building, ISP to user's home. Fixed type is based on IEEE 802.16. This type is the beginning of WIMAX technology.

- **Portable** Users can transmit and receive data while move but not fast. This type is quite slower than the fixed type and the area of using this type is narrower. The good point is that the users can use anywhere (Roaming) in the range of area that is provided by ISP. ISP allows user to use this service by checking the profile. This type is based on IEEE802.16a which is inherited from the origin IEEE802.16 standard.

- **Mobility** Users can transmit and receive data while move so fast (in the vehicle). This type is based on IEEE802.16e which is inherited from the above type.

Layered Stacks

The Layered Stacks is composed of Convergence Layer, Medium Access Control Layer, Transmission Layer and Physical Layer as shown below (figure 1).



-Physical layer and Transmission layer

- Signal is encoded or decoded by hardware.
- Bit transmission or reception over medium.

-Medium Access Control layer

- This layer provides sub layer for security in order to encryption

- assemble data into a frame with address and error detection filed on transmission

- the users send their profile to subscriber station in order to entry into the network
- Separate data from a frame and perform address recognition on reception (The address is set at the first time on transmission and this receiver should be able to recognize the address is sent by transmitter in order to communicate)

-Convergence layer

PDU stands for (Protocol data unit).PDU are the sub layer of Convergence layer.

PDU can have several layers depend on what standard. In this technology it depends on IEEE802.16 standard.

For each layer, a unit of data is specified by protocol and consists of protocol-control information.

- Define the QOS (quality of service) for example different users/device can take different speed of data flow depend on the priority.
- Encapsulate PDU (Protocol data unit) framing from Digital Audio, Video Multicast, Internet protocol into 802.16 MAC frame

Data Transmission



Available at 2.3 – 2.7GHz and 4.9 – 6.0GHz

High net throughput, up to 18 Mbps full-duplex

Long range, up to 80 km/50 miles

Point-to-Point and Multiple-Point-to-Point architectures

Advanced OFDM-based air interface

The picture above is the equipment as threshold to distribute signal to the last mile (user).

This picture refers to <http://www.wimax-industry.com/sp/rdw/images/IDU-C-8.jpg>

Spectrum

There are three licensed spectrum 2.3GHz, 2.5 GHz and 3.5 GHz. 2.5 GHz is the most use in the USA. 2.5 is used by the most country in Asia (This spectrum have to be permitted by government of that country before release spectrum for commercial business, marketing and so on).

WIMAX use TDD/FDD (Time-Division Duplexing, Frequency-Division Duplexing) as necessary attribute to drive a proper service to the user .For the fixed profile have spectrum profile 3.5 MHz, 5 MHz. For the mobile have spectrum profile 5 MHz, 8.75 MHz and 10 MHz.

Data rate

Downlink up to 144 Mb/s Upload Link up to 35 Mb/s(Depend on the what type profiles it is and the range). It is expected downlink up to 1 GB/s in the future. The range of service is over 50 Kilometer up to 70 Kilometer.

Bandwidth

WiMAX has a theoretical maximum bandwidth of 75Mbps.

Transmission Media

WIMAX (standard IEEE802.16e for Mobility) uses technique NLOS (Non Line of Sight) to transmits the data across to the receiver antenna.

There are three type of antenna available which are Omnidirectional, Sector and Panel

The formula for NLOS is $PL(d_1, d_2) = PL(d_1) + 10n_j * \log(d_2) - W/2[\text{dB}]$
D1 is the LOS(line of sight) distance from BS (Base station) to the closest street intersection.

D2 is the distance from the intersection to Destination (For example the cross of the street).

W is the width of the street where the BS is located.

NJ is a randomly path loss

PL is the path loss

Since NLOS generates Fresnel zone. The Fresnel zone is look like a ellipsoid. If there is an obstruction near the transmission path .It will reflect to decrease the signal that follow behind the first one. And also the first signal power is decreased by an obstruction. The amount of signal lost depends on obstruction.

In a NLOS link, a signal reaches the receiver through reflections and diffractions. The signals arriving at the receiver consists of components from the direct path, multiple reflected paths and diffracted propagation paths. These signals have different delay spread , and stability relating to the direct path.

The formula for calculating Fresnel radius at any point between the end points of the link is (the green one).

If unobstructed, radio waves will travel in a straight line from the transmitter to the receiver (the red line).

But if there are obstacles near the path, the radio waves reflecting off those objects may arrive out of the line (the red line) and have to use another path. It causes to reduce the signal power. Since it is the wireless transmission without obstruction. The signal get weaker when travel longer.

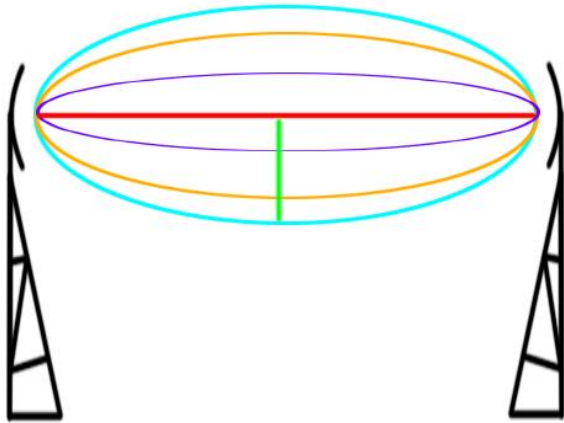
$$FN = \sqrt{\left(n \left(\frac{c}{f}\right) d_1 d_2\right) / (d_1 + d_2)}$$

FN = the nth Fresnel Zone radius in meters

D1 = distance of P from start to end in meters.

D2 = distance of P from end to start in meters.

n = the level of Fresnel zone



The red line is the First level of zone so n will equal to 1.

The purple line is the second level of zone so n will equal to 2.

The green line is the radius of Fresnel zone.

LOS links must be freed from any obstruction because it is the directed line to transmit.

The formula below is to calculate the LOS (IEEE802.16)

We can calculate free space loss by using this formula $P_t/P_r = (4\pi d)^2 / G_t G_r \lambda^2$

Signal Encoding Technique

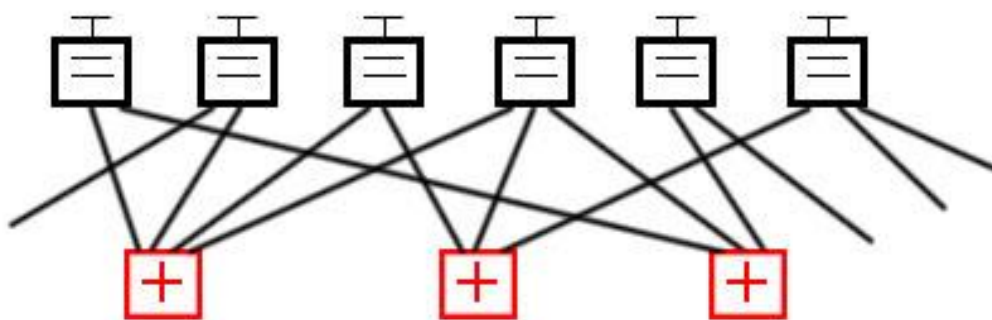
WIMAX uses Quadrature Amplitude Modulation (QAM) technique to whether encode the digital data (bit) into wave form. Modulation means change the original form to other form that is more complex.

QAM is both an analog and a digital modulation (To transform data into waveform) scheme. It brings two analog message signals, or two digital bit streams to the receiver by changing the amplitudes of two carrier(digital and analog) waves using the amplitude-shift keying (ASK) or amplitude modulation (AM). These two waves are in the form of sinusoids (General sine wave function $s(t) = A \sin(2\pi ft + \phi)$). The changed waves are combined, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK) to generate more accurately wave form. QAM is used widely as a modulation scheme for digital telecommunication systems.

Error Detection

Error Correction

Low-density parity-check code



The above picture is called "LDPC GRAPH"

LDPC generate a graph fragment randomly by using Forney's factor graph theory . In this graph, n variable nodes in the top of the graph are connected to the nodes (with sign + inside the box) at the bottom of the graph. The bits of a

valid message, when placed on the 'T' at the top of the graph. It will satisfy condition of the theory. All lines connect to a variable node (with sign '=' inside) have the same value, and all values connecting to a factor node (box with a '+' sign) must be sum to be an event number that be divide by 2 and no remainder left.

Ignore the lines that going out of the picture, there are 8 possible 6-bit strings corresponding to valid codeword (000000, 011001, 110010, 101011, 111100, 100101, 001110, 010111).

This LDPC code represents a 3-bit message .Then this message is encoded to be 6-bit message.

So $n = 6$ $k = 3$.

The parity-check matrix is

$$H = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$

Then put the parity-check matrix H into this form $[-P^t \mid I_{n-k}]$ then perform basic row operation.

$$H = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 \end{bmatrix} \rightarrow H = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix} \rightarrow$$

$$H = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}$$

Suppose the generator matrix is already given as

$$G = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

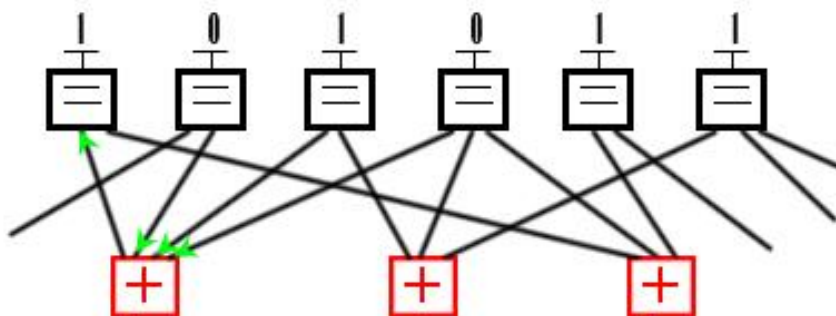
The example is bit-string 101 .In codeword string will be obtained by

$$(101) \cdot \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix} = (101011) = r$$

At the receiver, Receiver must decode the codeword given from transmission.

For example, consider that the valid codeword, 101011, from the example above, is transmitted and receiver get the codeword with the first and fourth bit is gone while transmitting which is ?01?11. Since the transmitted message must be satisfied according to the condition .In this example, the first bit cannot be recovered yet, because all of the line connected to it having more than one unknown bit (?). In order to decode the message. One erased bit must be recovered before recovering another bit. In this example, the second and the third bit are enough. The fourth bit must have been 0, since only a 0 in that position would satisfy the condition ($0+1+0 = 1$ so the leftmost is 1 to satisfy the condition).If the fourth bit is 1. $0+1+1$ it will not satisfy the first bit since the first bit must be one in order to Correct the that error bit.

For the fourth bit we take the third and the sixth node plus to gather to get 10(Since the connecting line is come from third node and sixth node then plus the value to get 10) and put only the 0 (the rightmost bit) at the top of T. Now the fourth bit is recovered.



This result can be validated by multiplying the corrected codeword r by the parity-check matrix H :

$$Z = Hr = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

The resulting codeword r must be vector 0 in order to be validated.

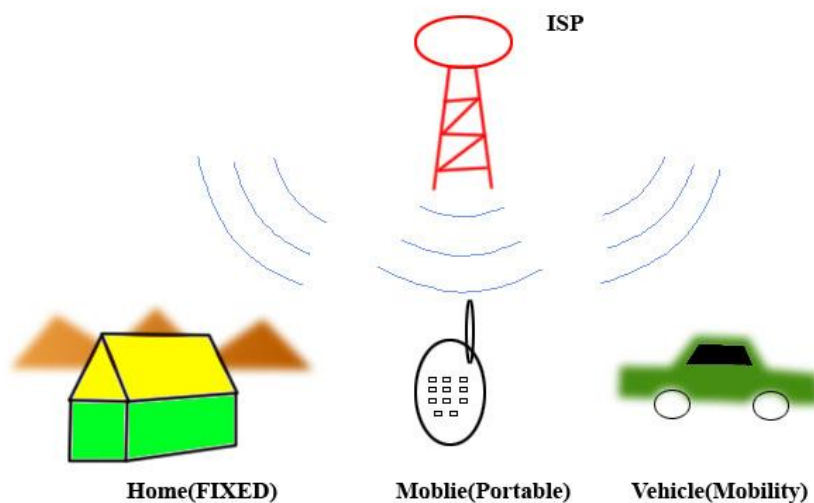
ARQ and error detection

WIMAX use technique Hybrid automatic repeat request (HARQ) is a combination of forward error-correcting coding and error detection using ARQ (cyclic redundancy check).

HARQ composes of two techniques which are ED and FEC .When the coded data block is received, the receiver first decodes the error-correction code. If the channel quality is good enough. All transmission errors should be correctable and the receiver can obtain the correct data block. If the channel quality is bad and not all transmission errors can be corrected, the receiver will detect this situation using the error-detection code then the received coded data block is rejected and a retransmission is requested by the receiver using ARQ technique.

Application

WIMAX technology usually embedded in mobile phone (4g) .WIMAX can use as a internet access provided by ISP. FIX WIMAX is used at home in the town or even if the countryside (So far from the transmit station). This technology reduces the cost but the speed of internet is still stable even if it is a wireless .It is not only the voice can be transferred thought the network. It is including video .WIMAX can transfer a data at real time and respond at real time also.



Usage

WIMAX is being used in

Indonesia and Vietnam. All of these countries are developing country. Thailand is also included but at this moment, it is during of testing this WIMAX technology .A province that has already installed this technology are Nakornratchasima, Korngan, Hardyai and Chingmai .They are tested in countryside because It reduce the cost. ISP does not need to drag the wire across the bad territory to the last mile (user) and its speed of data rate is still good. There is a little interference across the network.

Cost



(These pictures refers to http://www.mrpalm.com/list3.php?cont_id=1447)

The above picture is the mobile phone attached with WIFI technology
(IEEE802.16e standard)
34900 Bath in Thailand.

Comparison Table

Technology	Standard	Frequency	Data rate	usage
Zigbee	IEEE 802.15.4	2.4Ghz 915Ghz 868Ghz	250kbps 40kbps 20kbps	Worldwide America Europe
Bluetooth	IEEE 802.15.1 IEEE 802.11	2.4 – 2.4835Ghz (America) 2.402 – 2.480Ghz (Japan) 2.4	1Mbps 2 Mbps	worldwide
Wireless	IEEE 802.11 IEEE 802.11b IEEE 802.11a IEEE 802.11g IEEE 802.11n	2.4 GHz 2.4 GHz 5 GHz 2.4 GHz 5 GHz	1,2 Mbps 1, 2, 5.5, 11 Mbps 6, 9, 12, 18, 24, 36, 48, 54 Mbps 1, 2, 6, 9, 12, 18, 24, 36, 48, 54 Mbps 15, 30, 45, 60, 90, 120, 135, 150,200 Mbps	worldwide
WiMAX	IEEE 802.16 IEEE 802.16a IEEE 802.16e	10-66 GHz 2-11 GHz 8.5,10 GHz	144Mbps	Developing country ,America, Indonesia, Vietnam, Thailand

Technology	Antenna	distance	Application	Error detection
Zigbee	Chip, Wire Whip, U.FL, RPSMA	70-300m	Home Automation, Health care, Telecom Applications, etc	re-transmission
Bluetooth	Wire, Helix, Ceramic chip antenna	5-10m	Mobile phone and smalltalk, Keyless, Mouse and Keyboard etc	(forward error correction) and ARQ (Automatic repeat-request)
Wireless	Omni Directional Antenna, Directional Antenna	66-250 feet	Home Mobile phone University Restaurant company shopping mall	CRC (Error detection) FEC (error correction) ARQ
WiMAX	Omnidirectional, Sector, Panel	12-80 km	Mobile phone, home, building, country side,	forward error-correction and ARQ (cyclic redundancy check).

	Advantage	Disadvantage
Zigbee	<ul style="list-style-type: none"> -Low cost -Consumed low power -Easy to install 	<ul style="list-style-type: none"> - High performance high cost. - Low data rate - Short range
Bluetooth	<ul style="list-style-type: none"> -Low cost installing - Low cost for equipment -Easy to install -Simple to use 	<ul style="list-style-type: none"> -Short range of transmission -Loss of signal
Wireless-LAN	<ul style="list-style-type: none"> -Low cost installing - Low cost for equipment -Easy to install -Simple to use -Use all over the world 	<ul style="list-style-type: none"> -Short range of transmission -Loss of signal -Not too secure
WiMAX	<ul style="list-style-type: none"> -Transmit data over a long distance up to 80Km. -High speed in short range. 	<ul style="list-style-type: none"> -Speed of transmit will be slower when travel longer. -Expensive cost installing

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