

# **Network Interface Standards**

# Network communication

- Ethernet
- 802.11 (Wifi)
- IrDA
- Bluetooth
- Zigbee
- Cellular communication

# Network topology

- Bus
- Ring
- Star
- Point-to-point

# Ethernet

- Inventor of Ethernet LAN: Robert Metcalfe
- About one-third of LANs in the world is Ethernet LAN
- Ethernet is a protocol for local area network of computer, workstations, and devices
- A data transmission is fragment in a frame
- Each frame has a header likes in a packet
- Bus topology
- Open system (allow equipments of different specification)
- Each device listens to the channel, if it is idle, then transmit, else wait.

# Networking

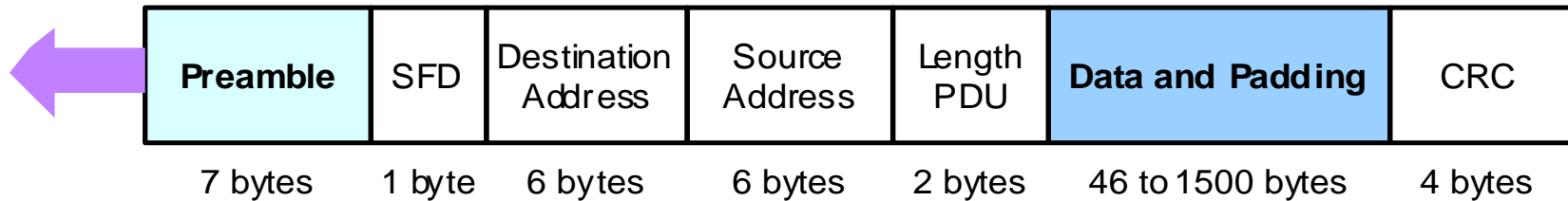
- Ethernet Frames
- Ethernet LAN
- The TCP/IP Protocol Suite
- Software APIs for networking

# Network Interfaces

- Ethernet is the most widely used network interface
- Details found in IEEE Standard 802.3
- Data is transferred in Ethernet Packets (Frames)
- Data rates: 10Mbps, 100Mbps, and now 1Gbps
- Low-cost Ethernet controller chips are used
  - Often attaches directly to a PCI bus
- Original Idea: each network device is assigned a unique 48-bit address by the manufacturer (MAC address)

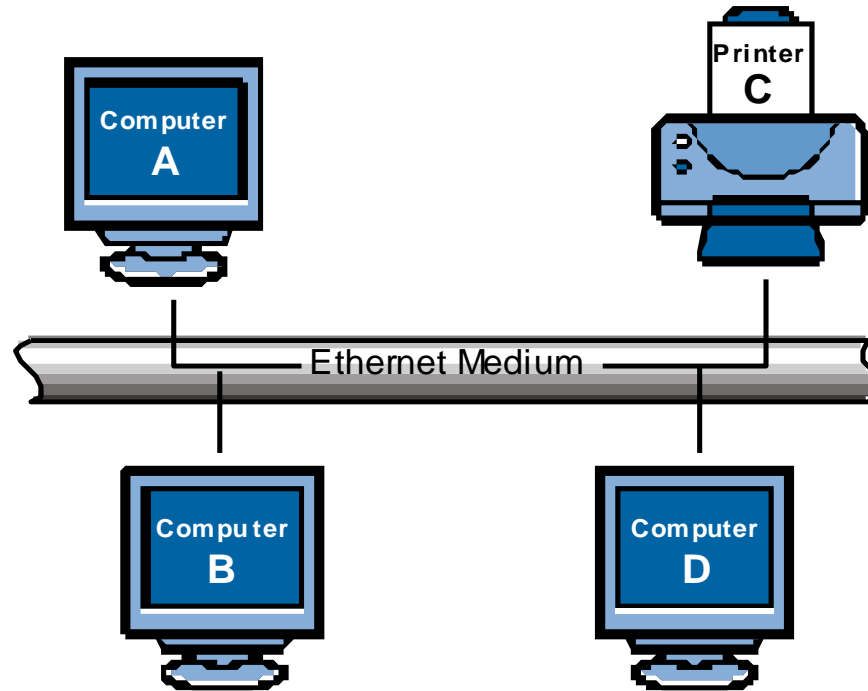
# An Ethernet Frame

Preamble 56 bits of alternating 1s and 0s.  
SFD Start field delimiter, flag (10101011)



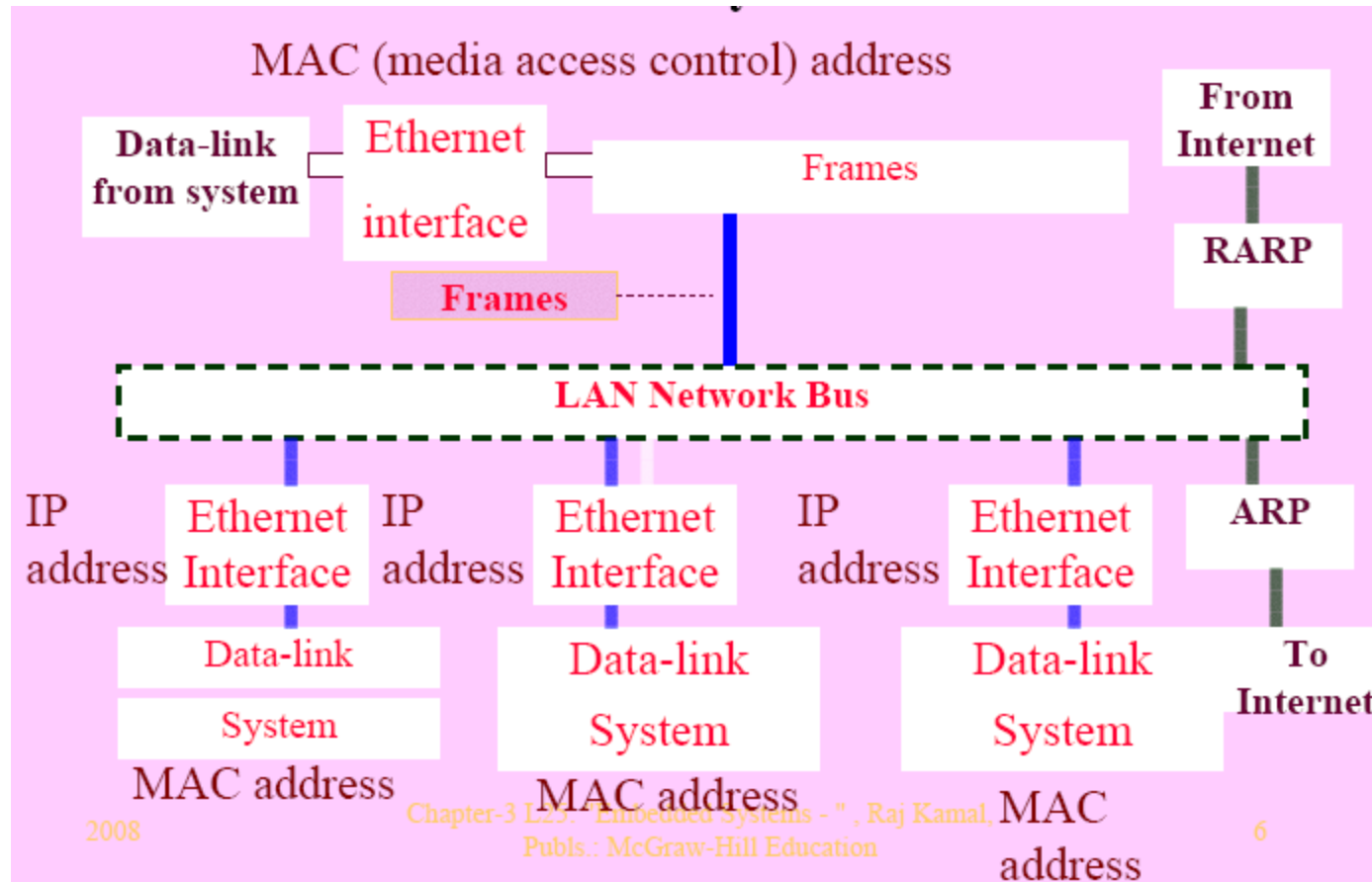
- Preamble - 56-bit start region, denotes the beginning of a Ethernet frame
- SFD - Start Frame Delimiter, 8-bit value marking the end of the preamble
- Destination MAC Address – 48-bit address denoting where data is headed
- Source MAC Address – 48-bit address denoting where data came from
- Length/Type (PDU) - 16-bit sub-protocol label field with length or type
- Data Payload – The data being sent
- CRC (or Frame Check Sequence), a CRC value computed on the entire frame. Used to detect bit errors occurring during transmission.

# A Small Ethernet Network





# Ethernet LAN between data link layer



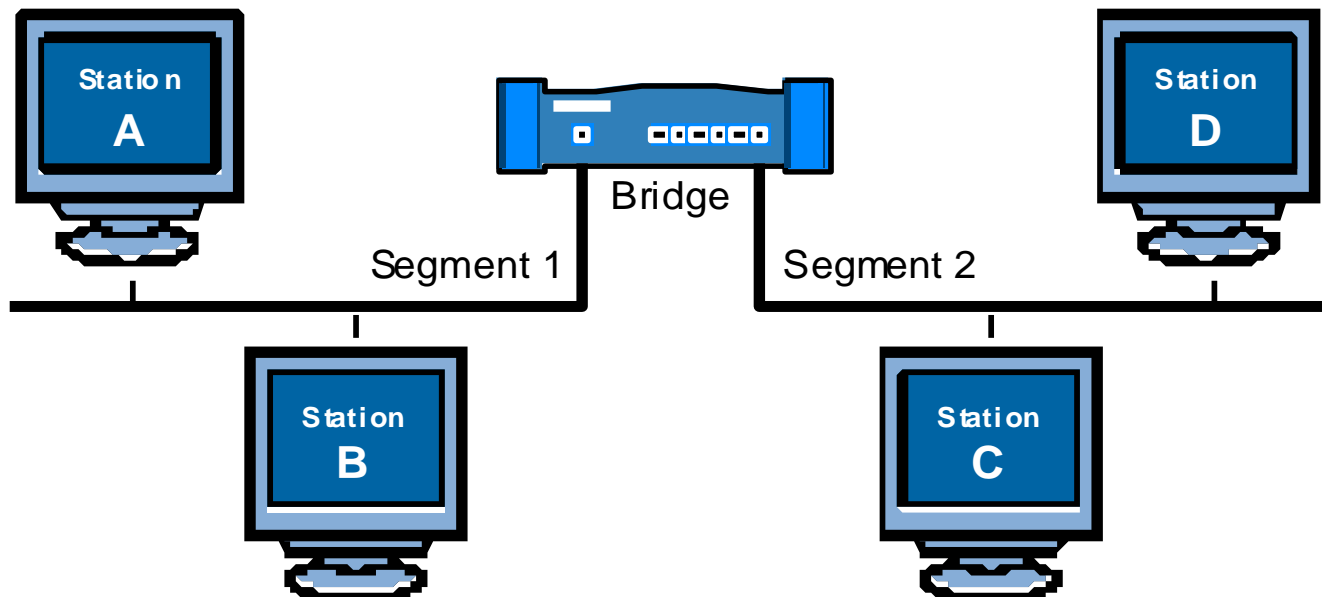
# Ethernet LAN

- Passive, connection based
- Media Access Control (48-bit address) for transmitting and forwarding frames on the same LAN
- Can also use multi-cast addressing
- Outside a LAN, the internet protocol is used

# CSMA/CD

- Carrier sense multiple access with collision detection (CSMA/CD)
- Device waits for medium to be idle
- Device starts transmitting data
- Device Listens to data to detect a collision
- When collision detected, stop and wait for a random amount of time before starting over
- Works a bit different in 1 Gbps Ethernet

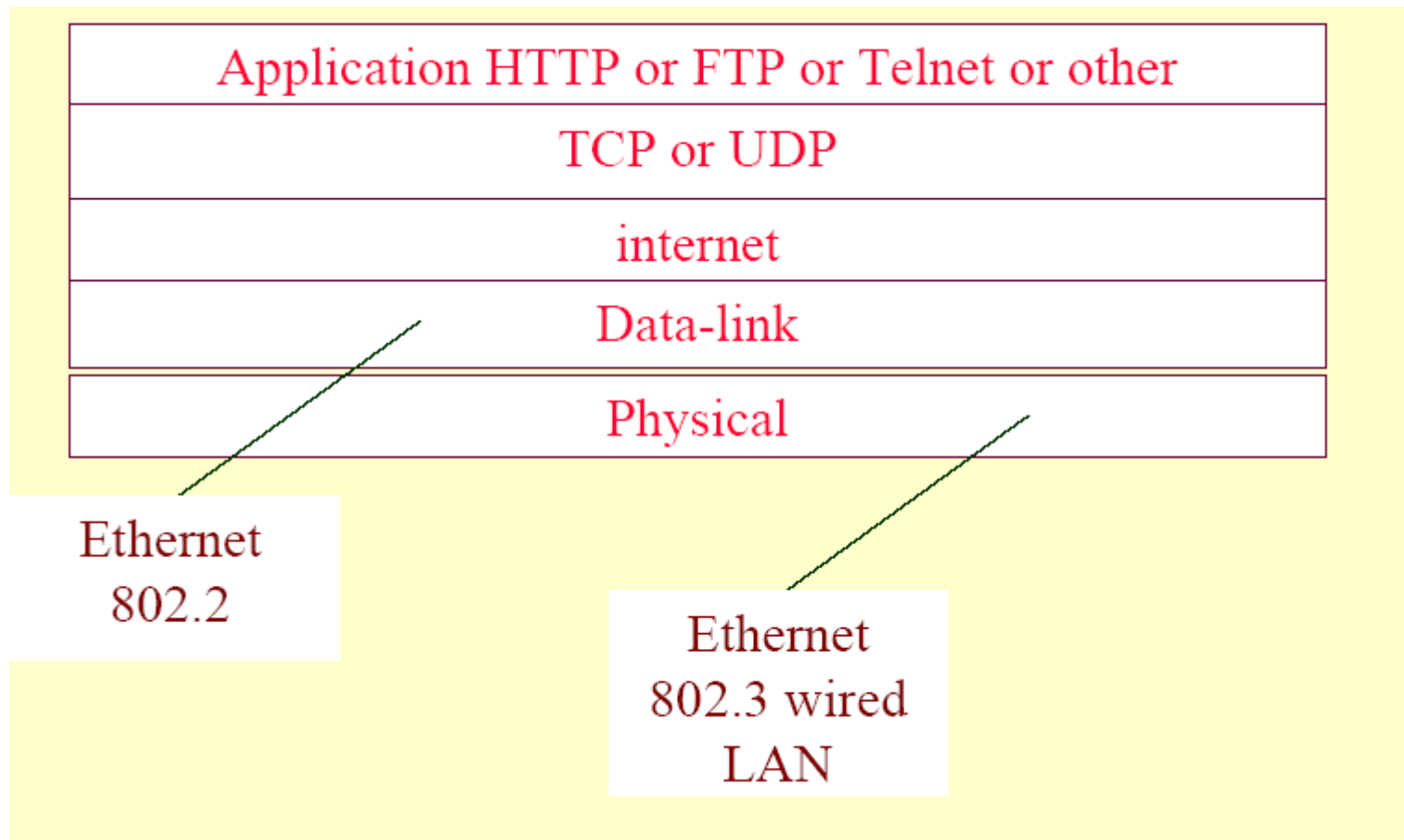
# An Ethernet Bridge Connecting Two Segments



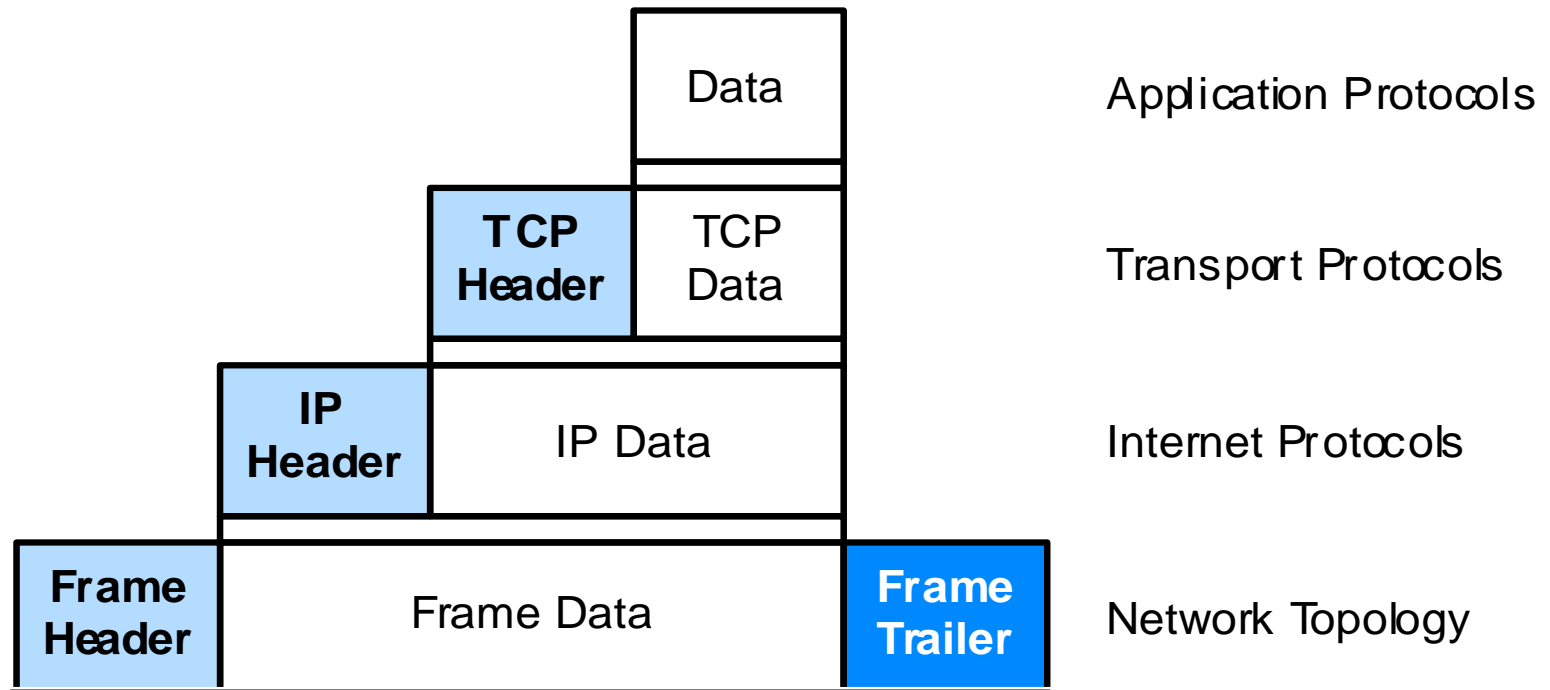
# TCP/IP Protocol

- Application Protocols – HTTP, SMTP, SSH, etc.
- Transport Protocols – TCP, UDP
- Network Communication Protocols – IP
- Network Topology – Ethernet, Wi-Fi, Token Ring, etc.

# TCP/IP



# Network Protocol Layers



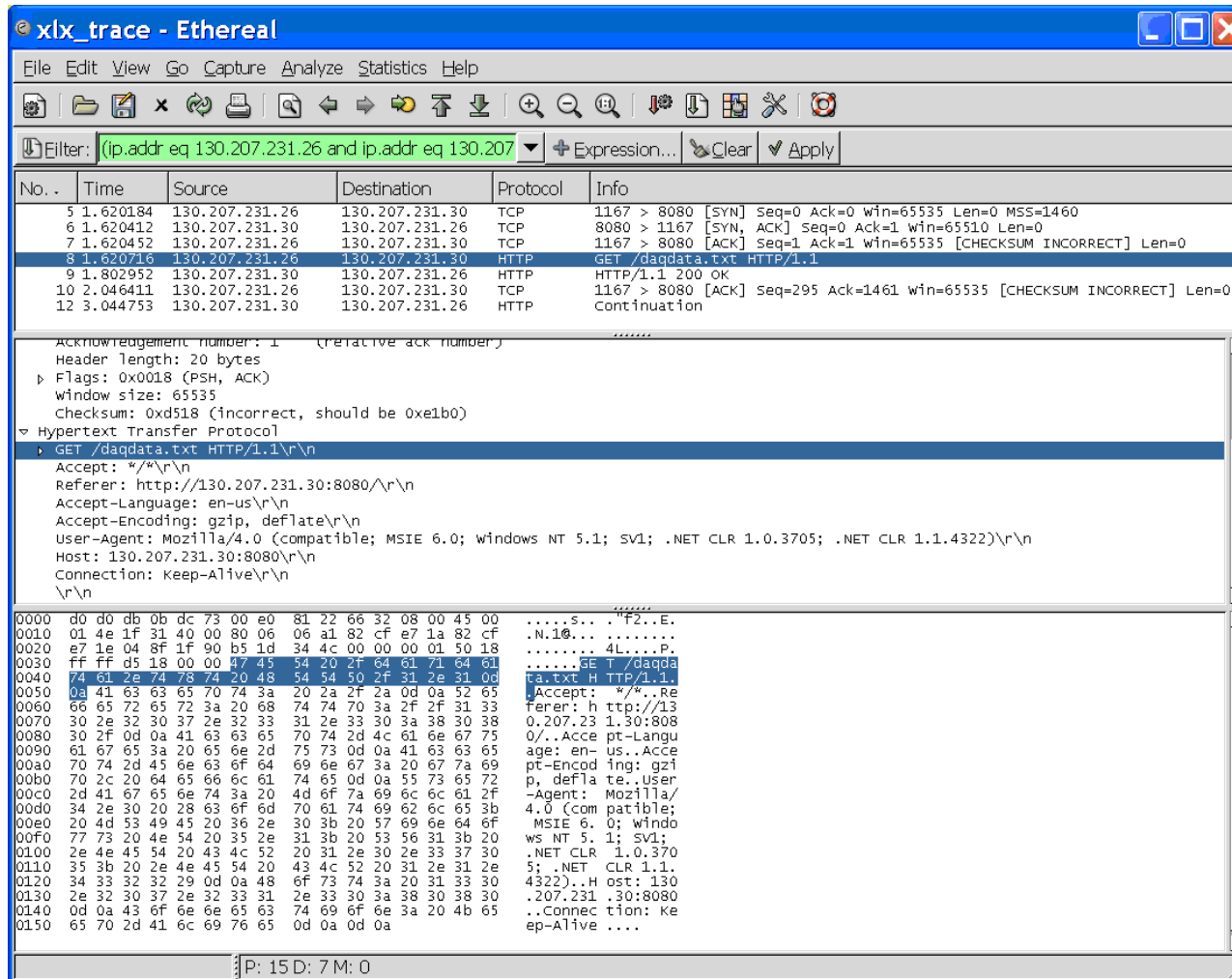
# Network Software Support

- Ethernet controller hardware filters, buffers, sends, and receives Ethernet packets
- Software is still needed to implement protocols
- OS typically provides software to implement the network protocols (TCP/IP, HTTP, FTP, etc.)
- OS may also support networked file systems
- Common network applications (i.e. browser, telnet, ftp) may be provided with OS or available from third parties



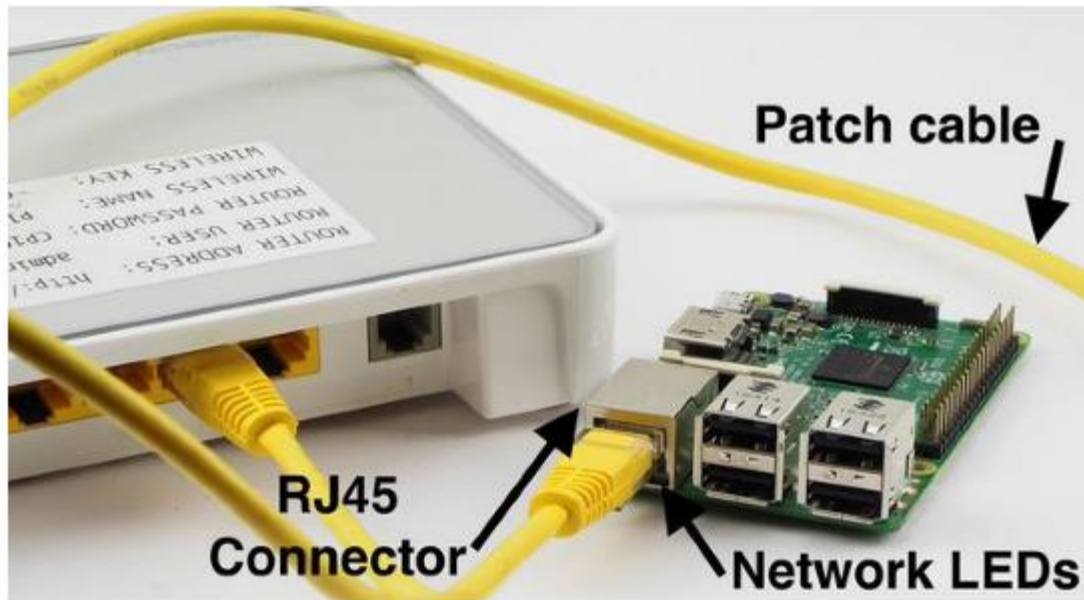
# **Windows Embedded CE Networking Software**

- Includes a TCP/IP Protocol Suite
- Supports sockets model programming interface in Windows Sockets (Winsock)
- Also has some higher level API interfaces such as WinInet & WinHTTP
- Comes with browser & ping applications.



**Figure 4.5** The free Ethereal Network Protocol Analyzer capturing and decoding network traffic on a desktop PC. The PC just loaded a short web page from a remote server (see HTTP packets). ([www.ethereal.com](http://www.ethereal.com))

# Network with Raspberry Pi



# How to connect TCP/IP from Pi

- DHCP (Dynamic Host Configuration Protocol)
- Static IP address

# Check for your IP address

- ifconfig

```
eth0      Link encap:Ethernet  HWaddr b8:27:eb:d5:f4:8f
          inet addr:192.168.1.16  Bcast:192.168.255.255
Mask:255.255.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1114 errors:0 dropped:1 overruns:0 frame:0
          TX packets:1173 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:76957 (75.1 KiB)  TX bytes:479753 (468.5 KiB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:16436  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)
```

```
wlan0      Link encap:Ethernet  HWaddr 00:0f:53:a0:04:57
            inet addr:192.168.1.13  Bcast:192.168.255.255
Mask:255.255.0.0
            UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
            RX packets:38 errors:0 dropped:0 overruns:0 frame:0
            TX packets:28 errors:0 dropped:0 overruns:0 carrier:0
            collisions:0 txqueuelen:1000
            RX bytes:6661 (6.5 KiB)  TX bytes:6377 (6.2 KiB)
```

# Enable DHCP on your hub

The screenshot displays the Huawei HG533 web management interface. The left sidebar contains navigation links: Status, Basic, WAN, LAN, WLAN, ADSL, Advanced, and Maintenance. The main content area is titled 'HG533' and shows the 'Basic > LAN > DHCP' path. The 'DHCP' tab is selected. The 'DHCP Server' section has the 'DHCP server' checkbox checked and circled. Below this, there are input fields for 'Start IP address' (192.168.1.2), 'End IP address' (192.168.1.254), 'Lease duration' (1 day(s), 0 hour(s), 0 minute(s), 0 second(s)), 'DNS Domain', 'Primary DNS server address' (192.168.1.1), and 'Secondary DNS server address'. A 'Submit' button is at the bottom of this section. The 'DHCP Option Pool' section below it shows 'Device type' set to 'STB', 'Option80' set to an empty field, 'Start IP address' (0.0.0.0), 'End IP address' (0.0.0.0), and 'DHCP relay' checkbox unchecked.

**DHCP Server**

DHCP server: ☒ Enable

Start IP address: 192.168.1.2

End IP address: 192.168.1.254

Lease duration: ☐ Permanent lease  
1 day(s) 0 hour(s) 0 minute(s) 0 second(s)

DNS Domain:

Primary DNS server address: 192.168.1.1

Secondary DNS server address:

Submit

**DHCP Option Pool**

Device type: STB

Option80:

Start IP address: 0.0.0.0

End IP address: 0.0.0.0

DHCP relay: ☐ Enable

# Wireless Networking Standards

- Wi-Fi - IEEE Standard 802.11
- Bluetooth - IEEE Standard 802.15.1
- ZigBee - IEEE Standard 802.15.4
- GSM
- Features of each on the next slide



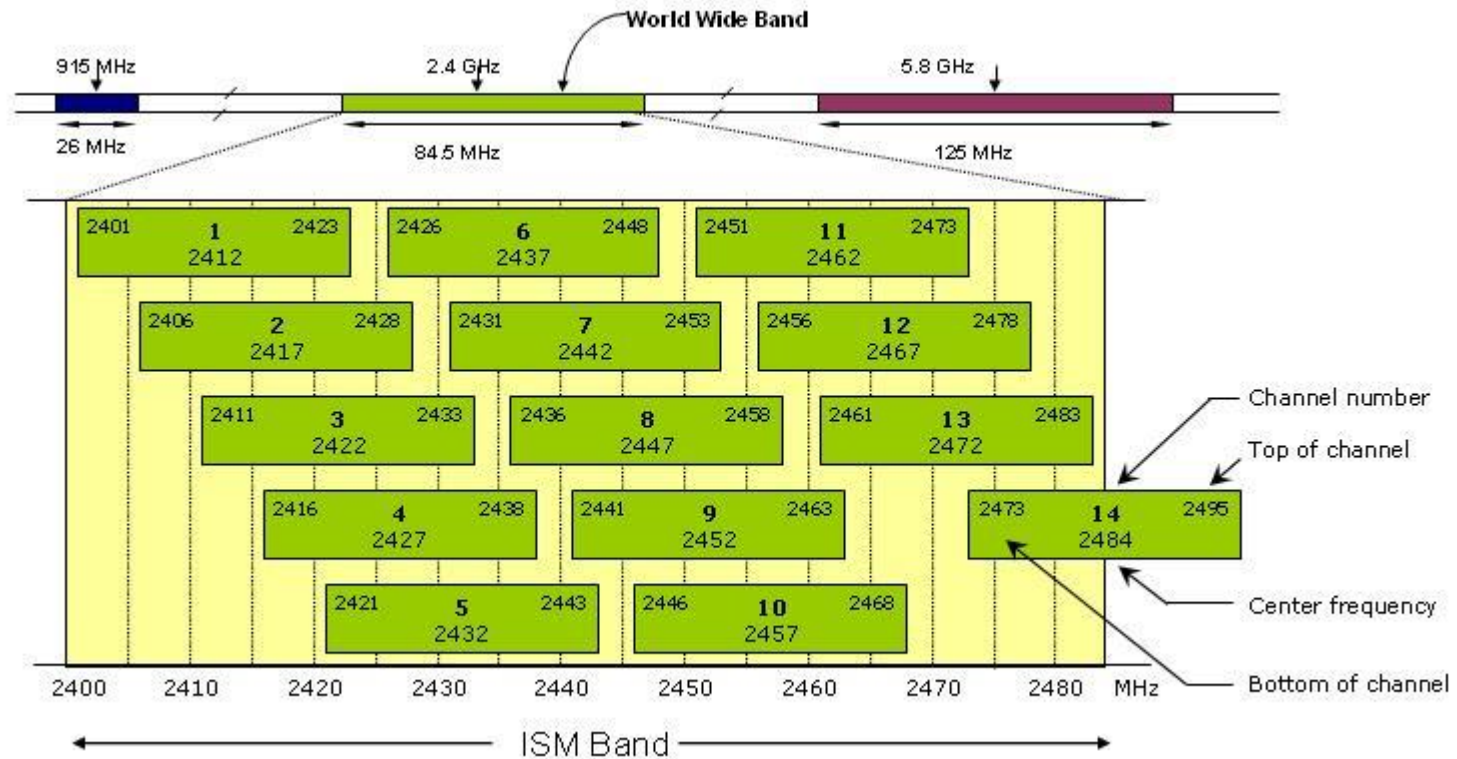
# 802.11 Wireless LAN connected devices

- IEEE standard 802.11a to 802.11n
- 802.11a data transfer rate up to 54Mbps
- 802.11b data transfer rate up to 11Mbps, beginning of market name wi-fi (wireless-fidelity)
- 802.11g data transfer rate up to 54Mbps
- 802.11n data transfer rate up to 600Mbps, approved October 2009
- Operate at 2.4GHz (based on OFDM)

# Wi-fi 802.11b frequency

Channel	Lower Frequency	Center Frequency	Upper Frequency
1	2.401	2.412	2.423
2	2.404	2.417	2.428
3	2.411	2.422	2.433
4	2.416	2.427	2.438
5	2.421	2.432	2.443
6	2.426	2.437	2.448
7	2.431	2.442	2.453
8	2.436	2.447	2.458
9	2.441	2.452	2.463
10	2.451	2.457	2.468
11	2.451	2.462	2.473

# 802.11 frequency band



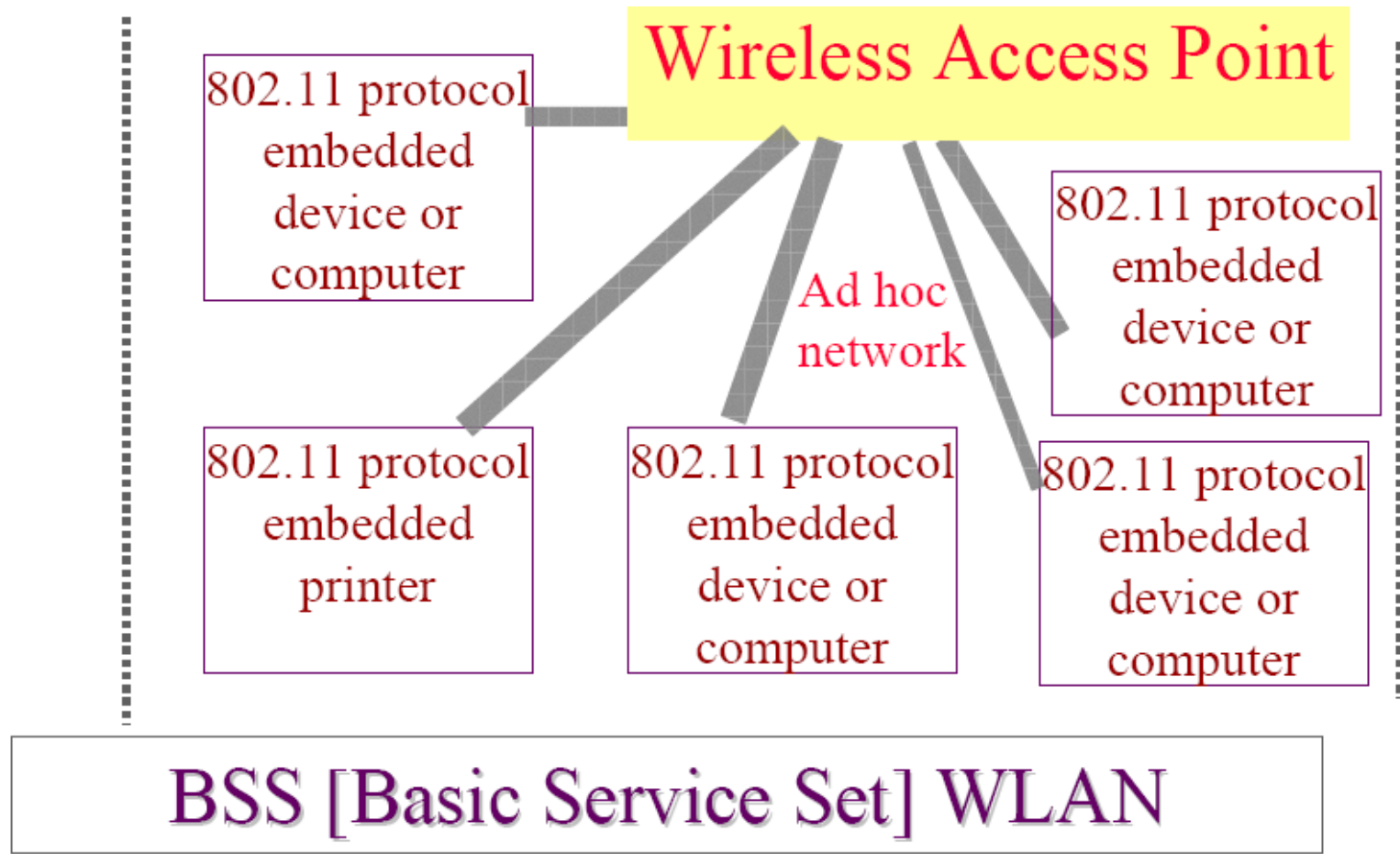
# Wireless card using PCI



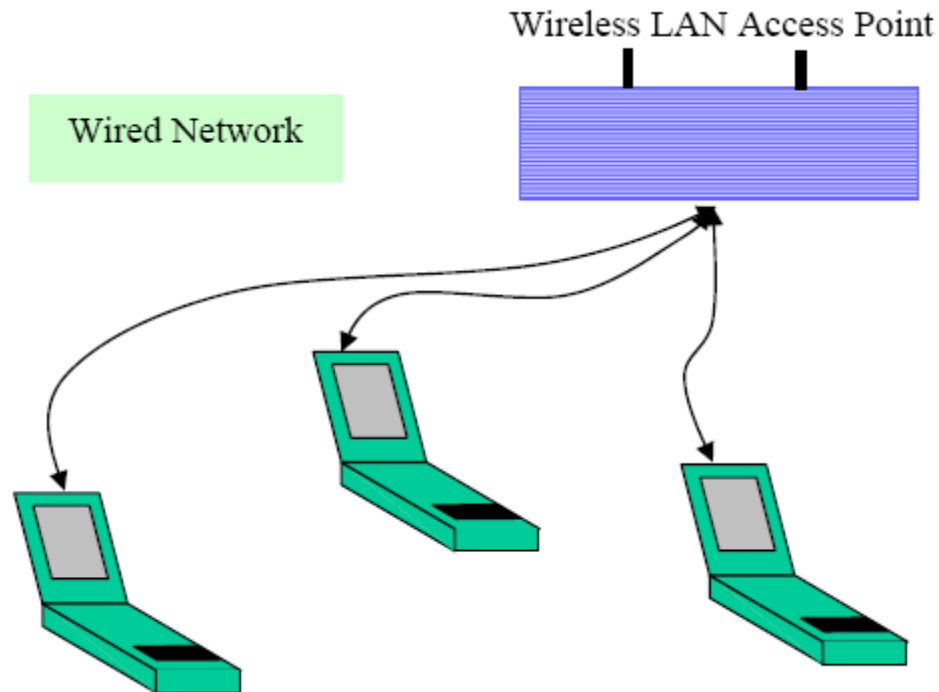
# Basic service set (BSS)

- Has one wireless station which communicate to an access point called hot-spot
- A node free to move from one BSS to another BSS

# BSS



# Client-server wireless mode

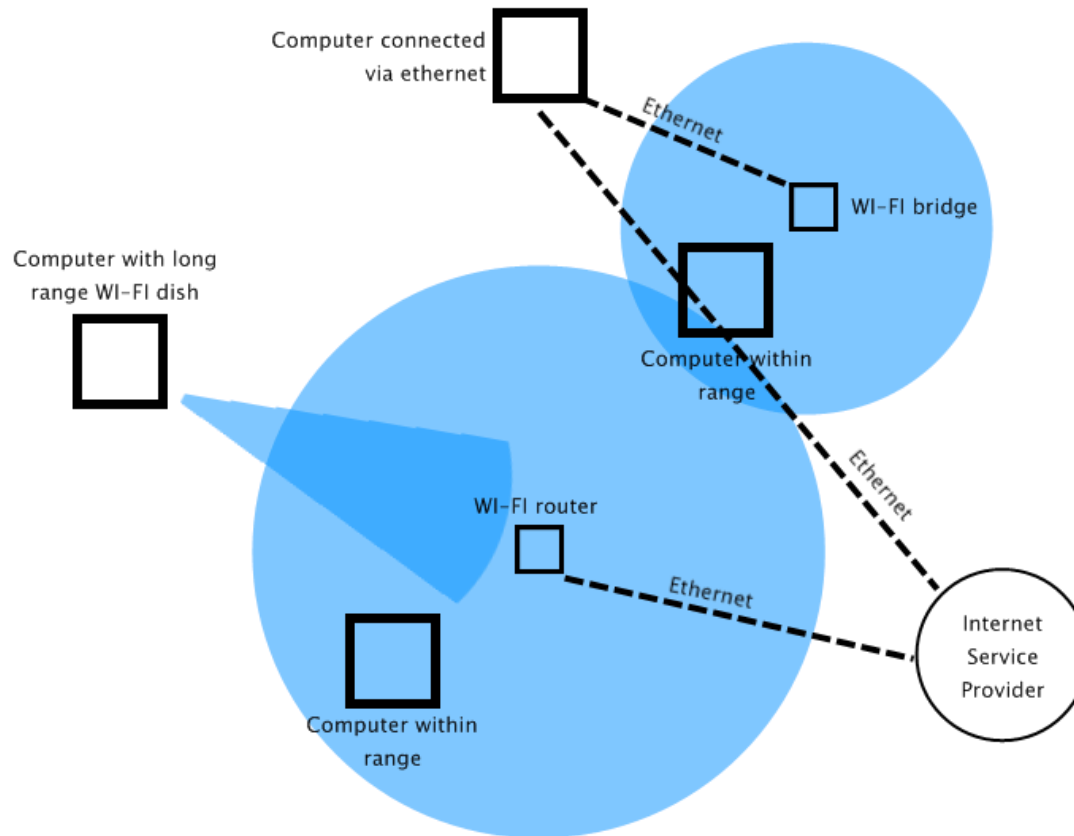


# Extended Service Set

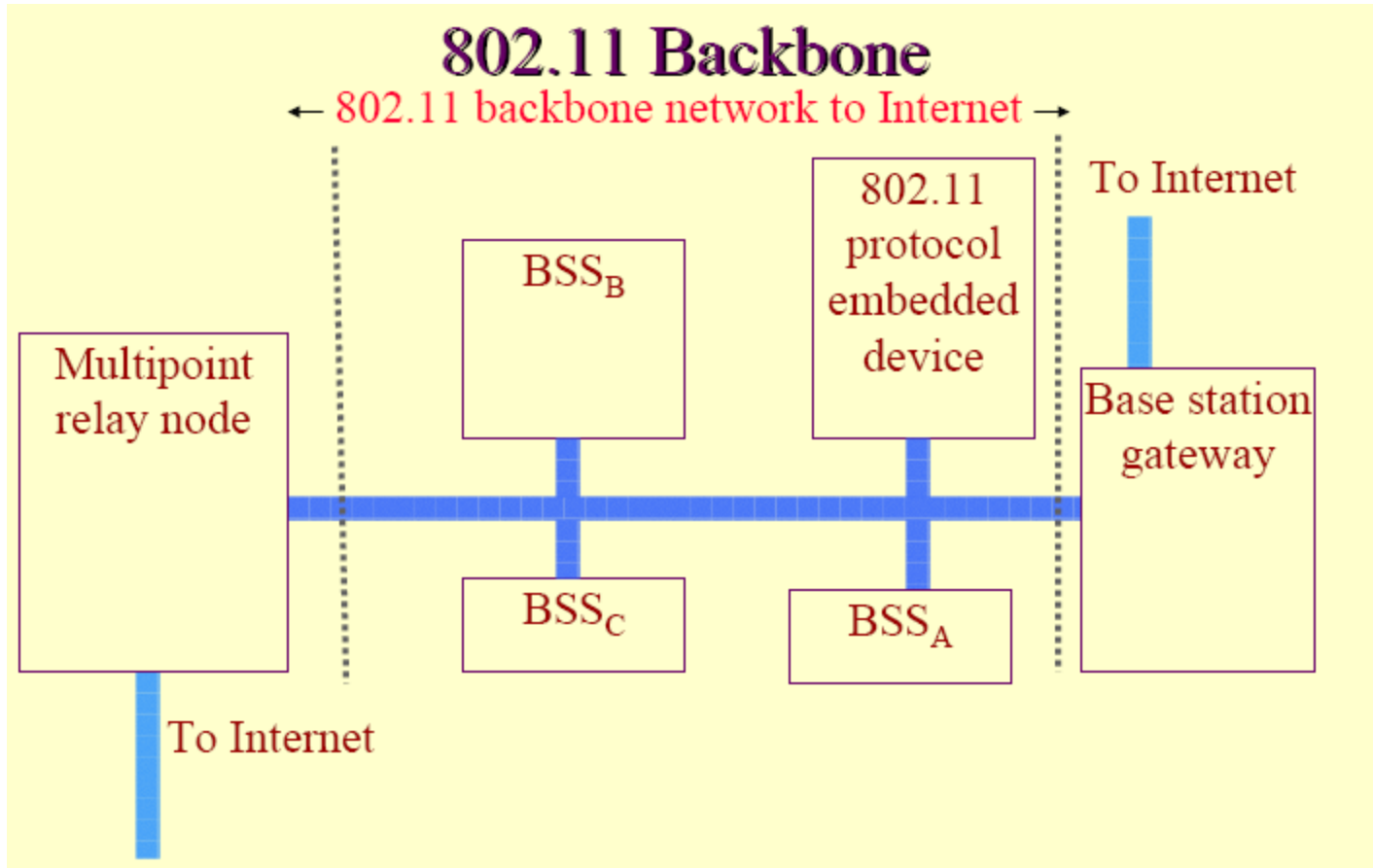
- Backbone distribution system
- A backbone set many network through internet
- ESS support fixed infrastructure network



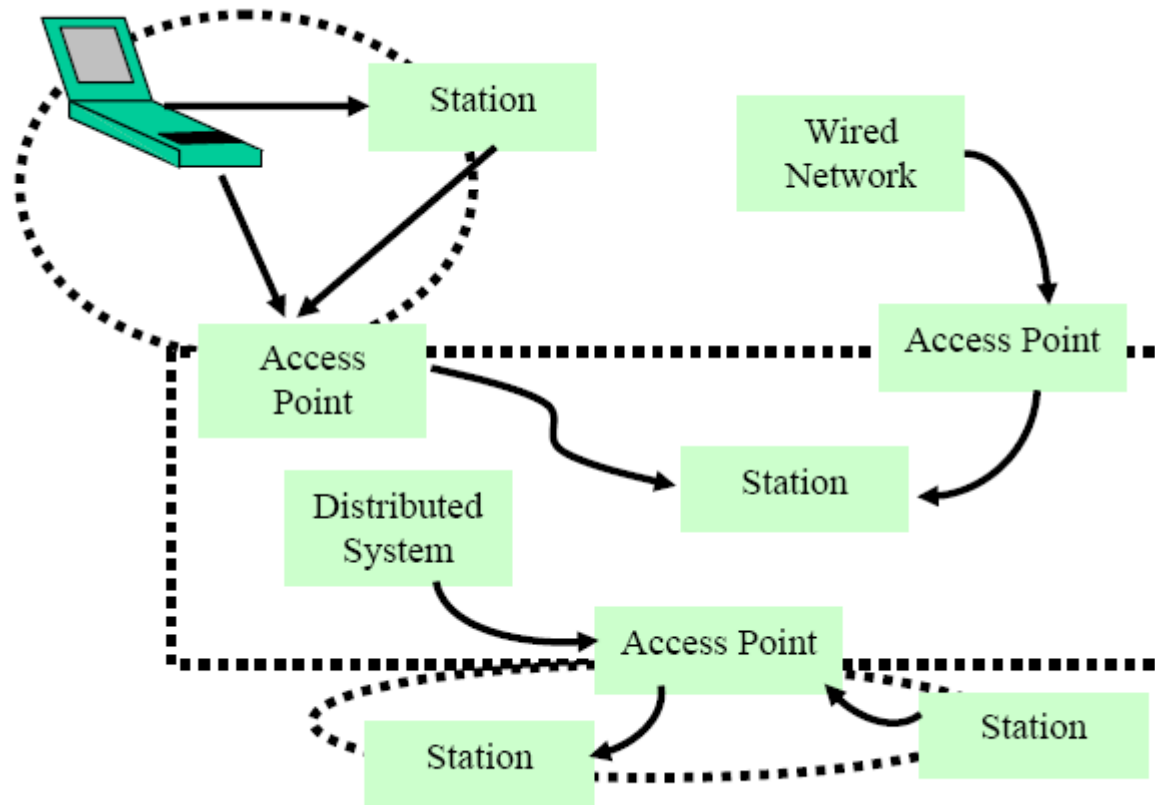
# Wi-fi setup



# 802.11 backbone



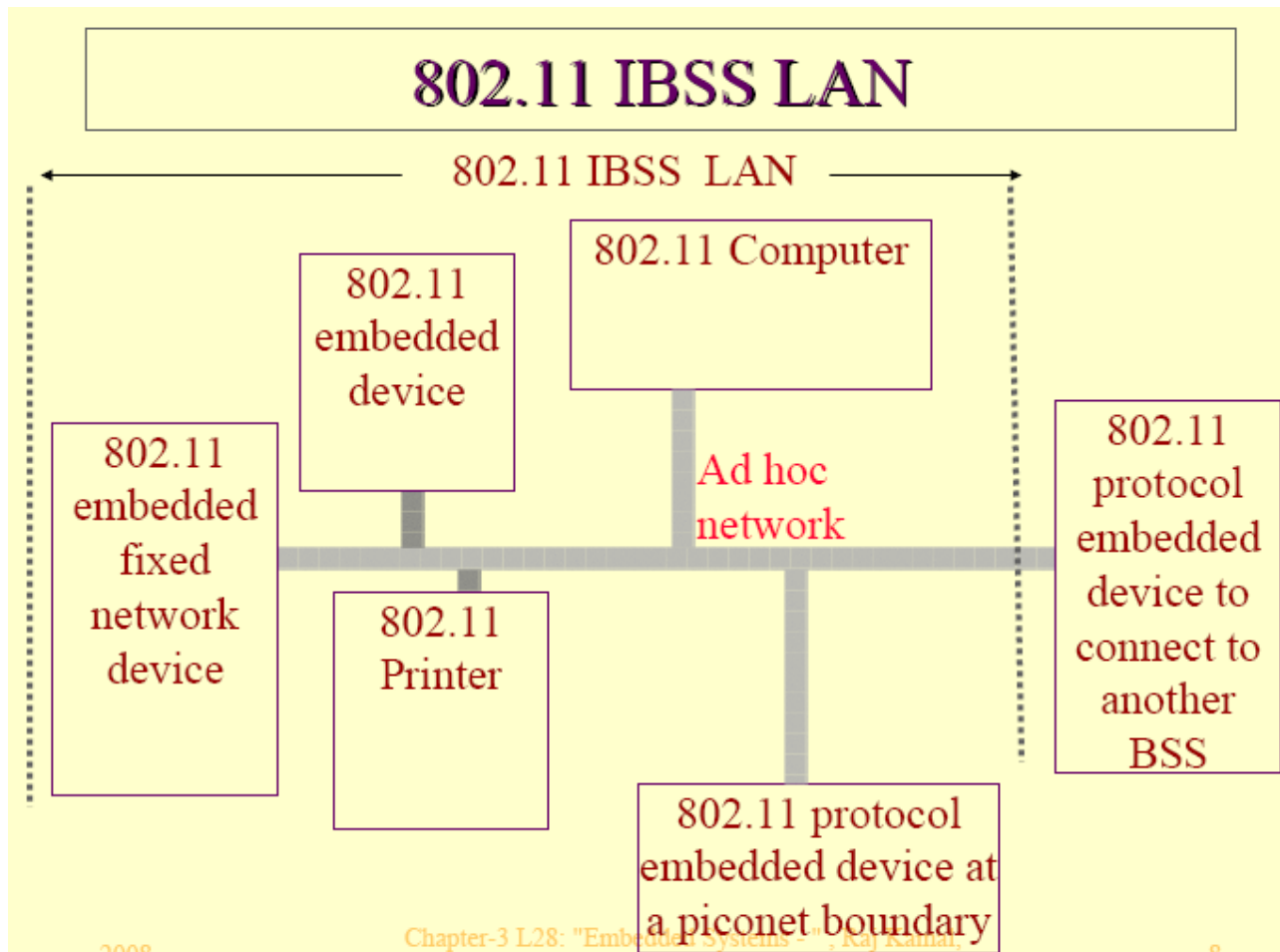
# Wired distribution network



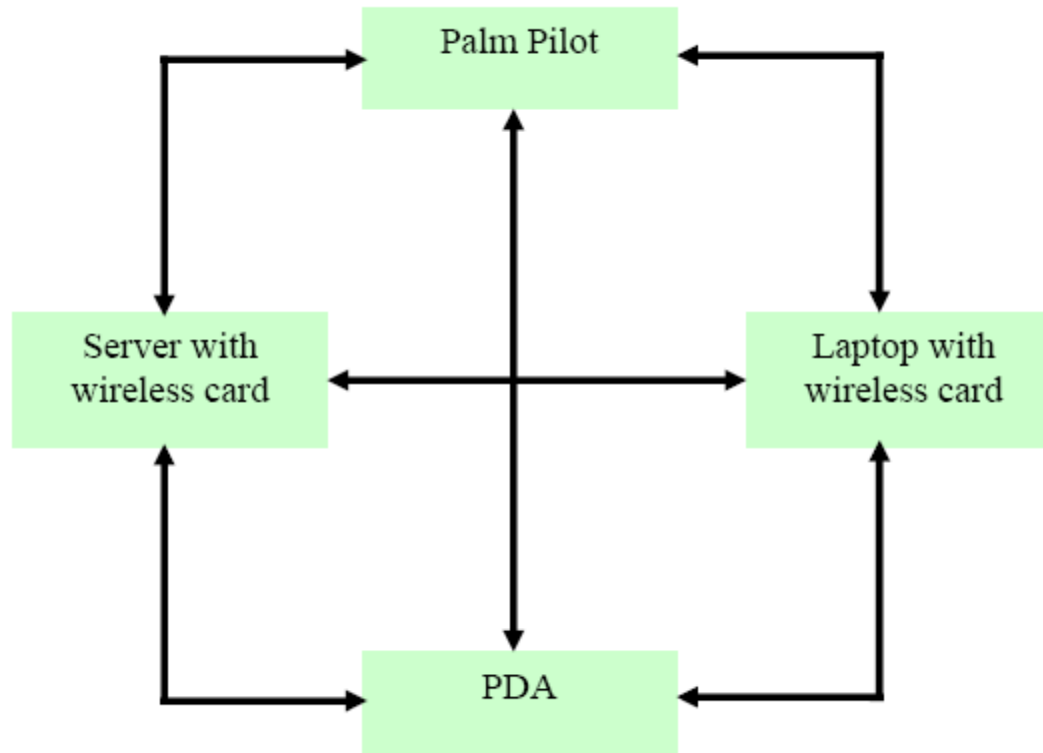
# Independent basic service set (IBSS)

- No access point
- Does not connect to distribution system
- May have multiple stations
- IBSS support ad-hoc network, when many nodes come nearby in range, they form a network

# IBSS



# Peer-to-peer wireless mode



# 802.11 protocol

- Provide specification for physical layer and data link layer
- Mac address support in data-link layer
- Power management features in specification
- Also, hand-over and roaming also in the specification
- Still use CSMA/CD

# Bluetooth connection

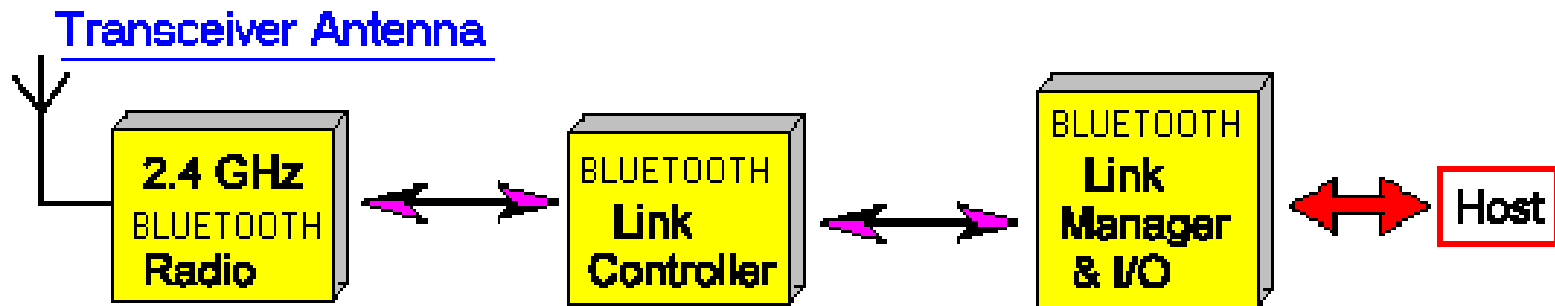




# Bluetooth

- Open wireless protocol for exchanging data over short distances
- Operate at unlicensed 2.4 GHz
- Mainly used for data transfer between two devices and multiple devices
- Decided for Wireless Personal Area Network (WPAN)
- Master/Slave topology

# Bluetooth architecture



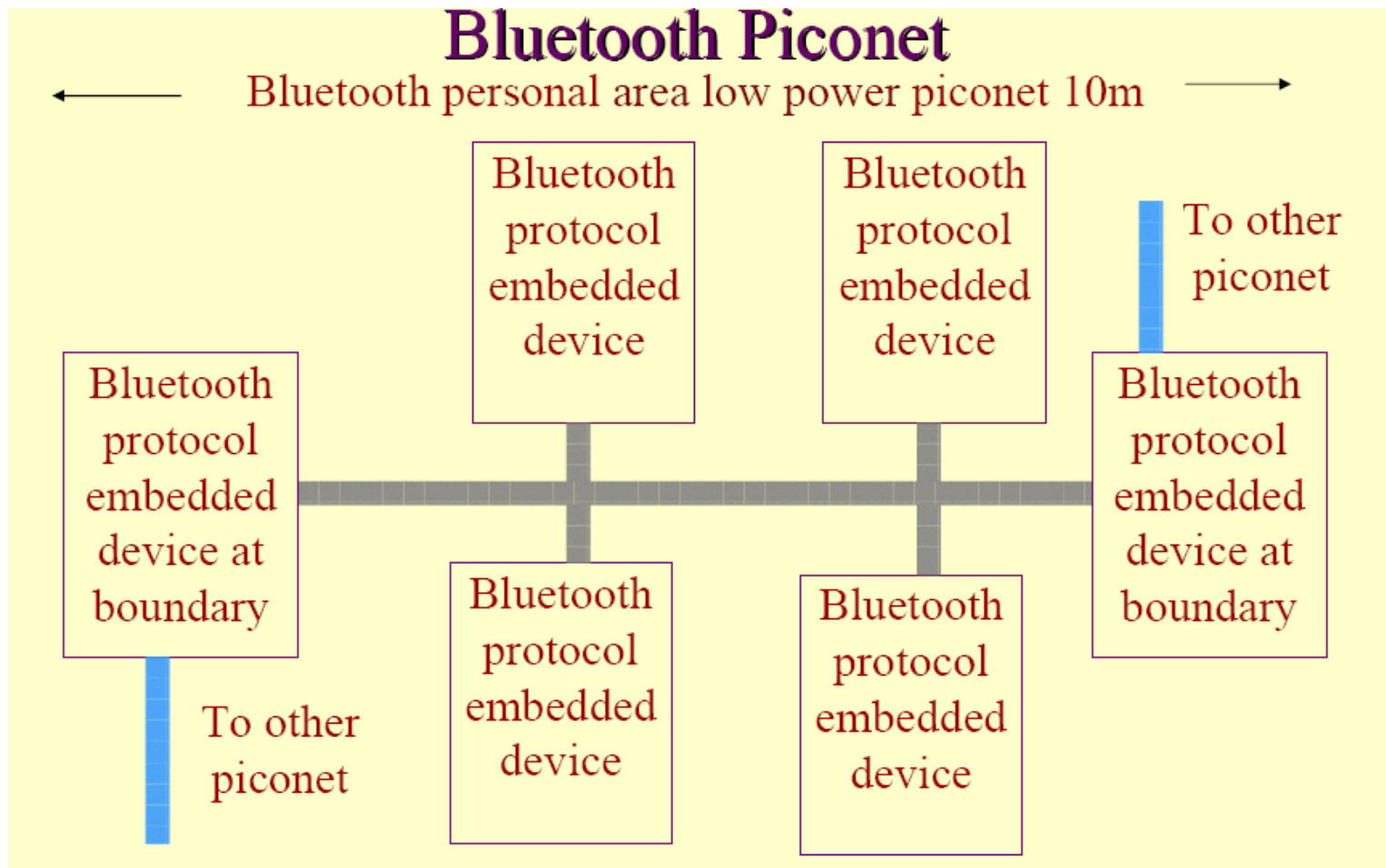
# Bluetooth enabled devices

- Synchronizing music, image, personal files
- CD players
- Mobile devices
- Digital camera
- Hand-free head-phone /head-set

# Bluetooth Piconet

- Piconet is an ad-hoc network formed by Bluetooth devices
- A master device can communicate up to 7 devices within a short distances
- At any given time, data can be transferred between a master and other device
- But the master can be switched from one device to another device in a round-robin fashion

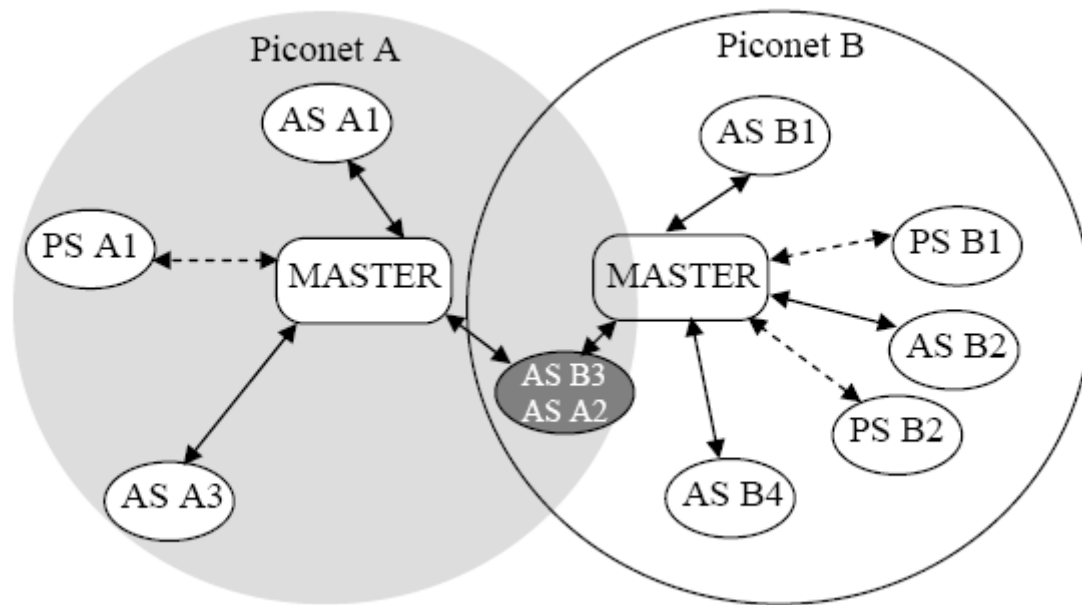
# PICO Net



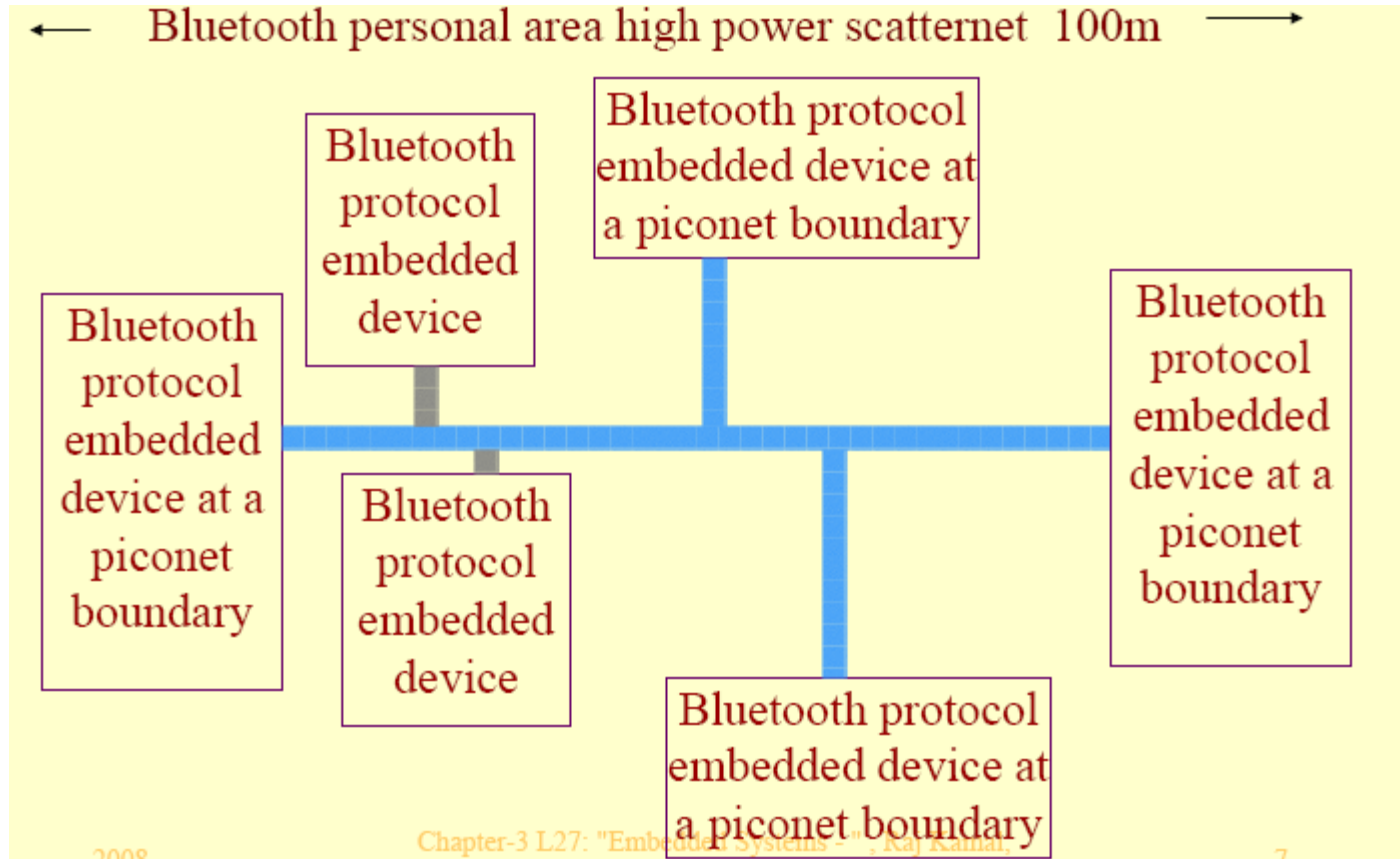
# Bluetooth Scatternet

- By connecting more than 1 piconet together will form a scatternet by using some devices as a bridge
- A device can act as a master in one piconet and a slave in another piconet

# Scatternet

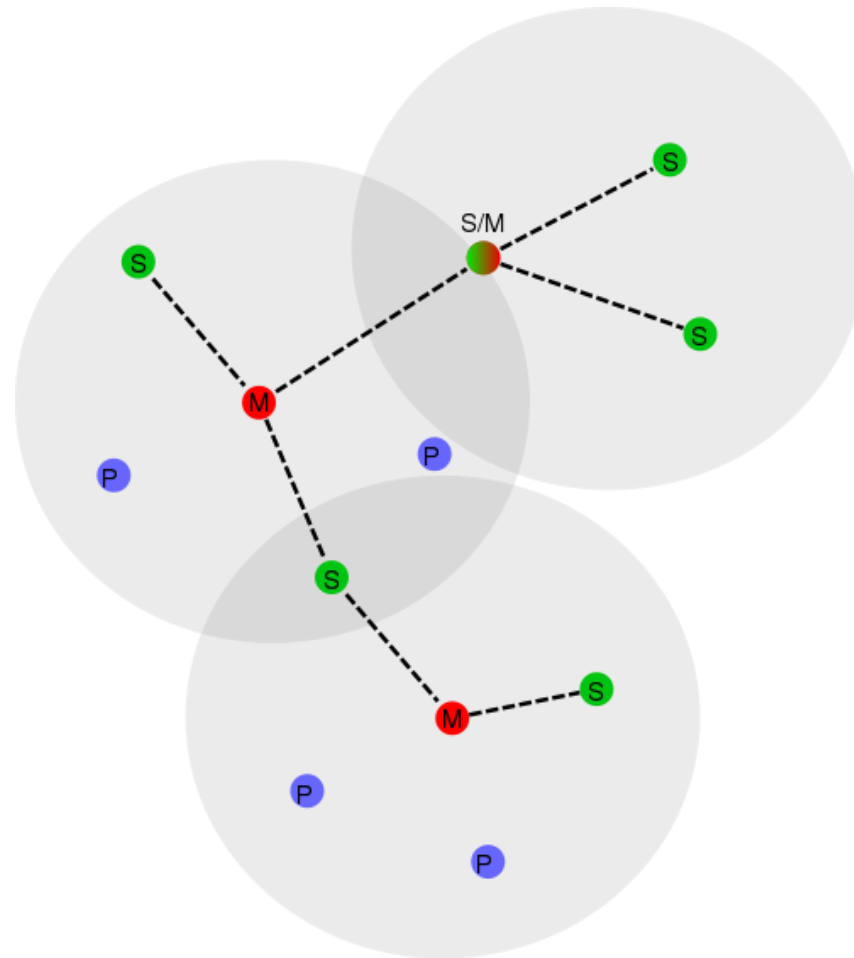


# Scatternet





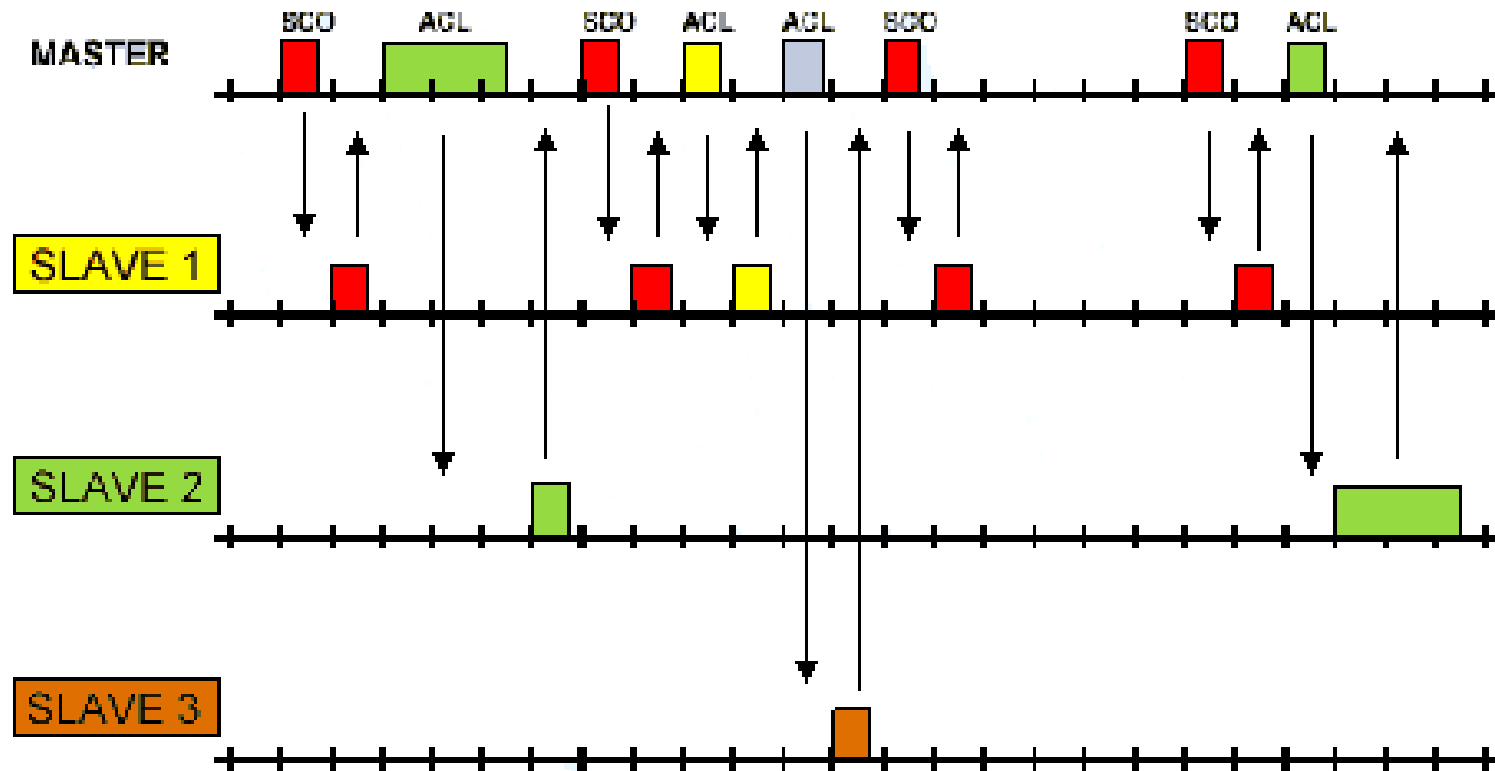
# Scatternet



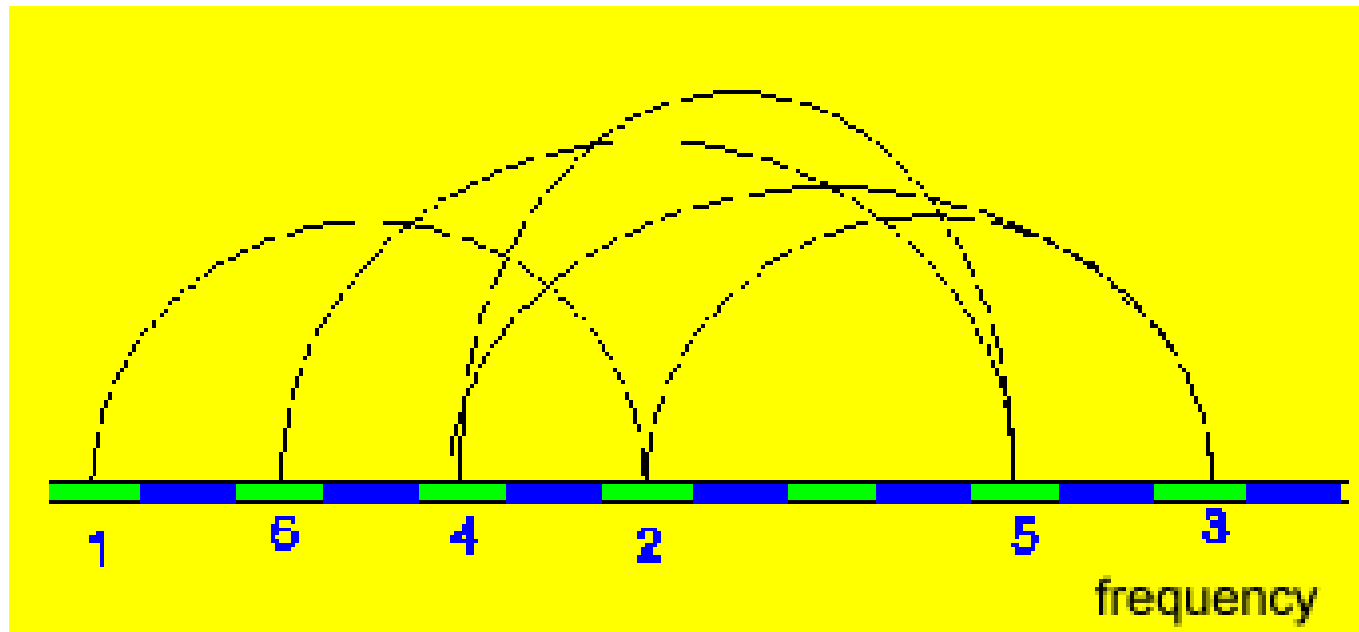
# Bluetooth protocol

- IEEE standard 802.15.1 protocol
- Physical layer radio communicates at carrier frequencies in 2.4 GHz with frequency hopping
- Hopping interval is 624  $\mu\text{s}$  and number of frequencies are 79 different, 1 MHz each
- Bluetooth 1.x support transfer rate of 1 Mbps
- Bluetooth 2.0 support 3 Mbps over 100m

# Bluetooth communication



# Hopping frequency



# Bluetooth protocol features

- Support automatic self discovery
- Support self organization of network
- Bluetooth self discovery device is within 10 meter and will form WPAN
- Support power control feature
- Support real-time traffic uses reserved bandwidth (Packet is about 350 bytes)

# Zigbee



- IEEE standard 802.15.4 protocol
- Physical layer operates at 2.4 GHz
- Support range up to 70 meters
- Data transfer rate up to 250 kbps
- Support sixteen channels

# Zigbee network feature

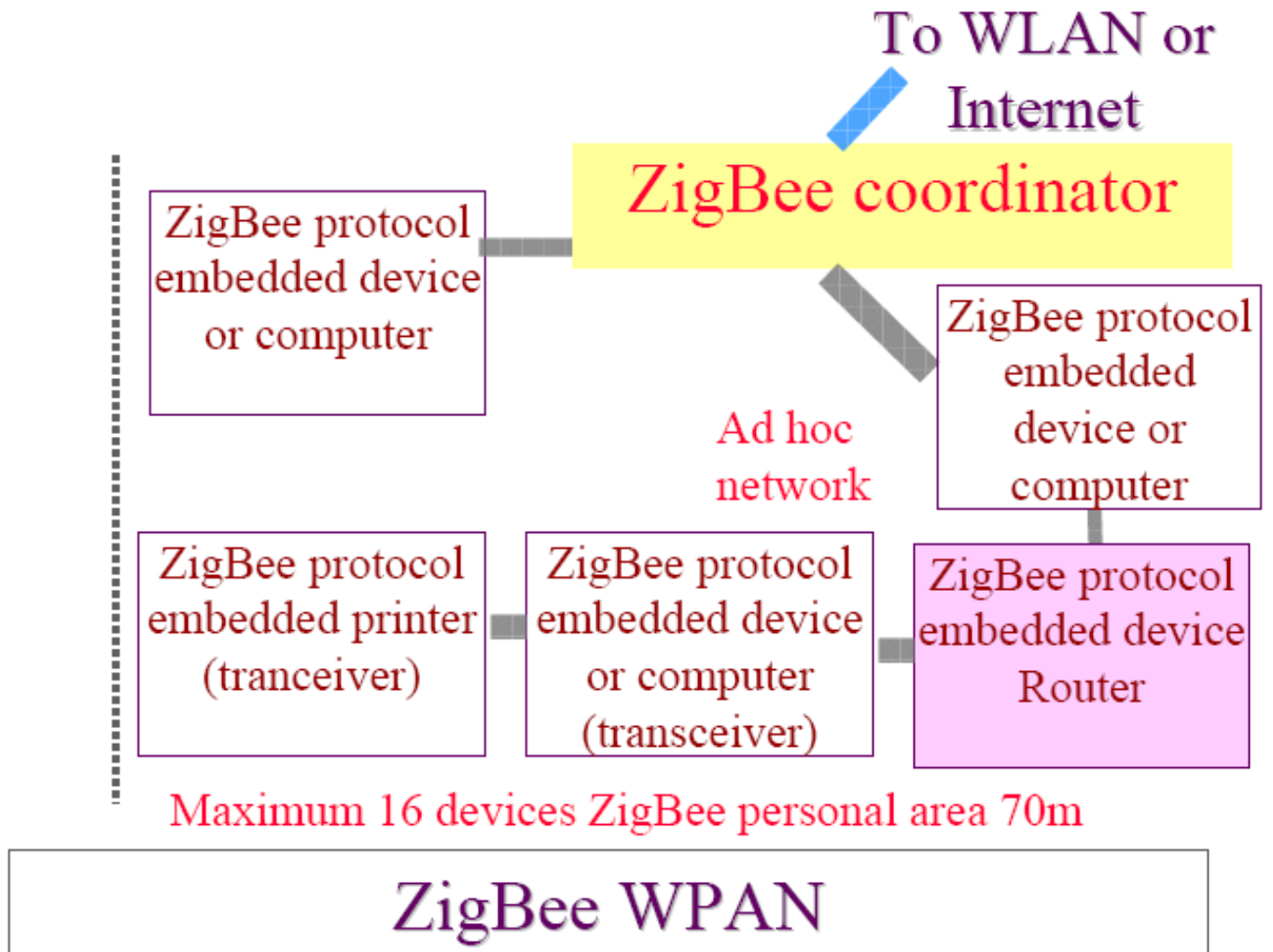
- Self-organizing and support peer-to-peer and mesh networks
- Self-organizing means detect nearby devices and establishes communication network

# Peer-to-Peer and Mesh network

- Each node functions as requesting devices as well as responding devices
- Mesh network means each node function as a mesh
- A node can connect other node directly
- Data transfer can be between two devices in peer-to-peer
- Or it can be a device and multiple devices in the mesh network



# Zigbee WPAN



# Zigbee supporting devices

- Large number of sensors
- Lighting devices
- Air conditioner
- Industrial controller
- WPAN

# Zigbee devices

- Zigbee router: Transfer packets received from a neighbor source to nearby node in the path to destination
- Zigbee coordinator: connect one Zigbee network to another, or connect to WLAN or cellular network
- Communication latency : 30 ms

# Zigbee vs. Bluetooth

- Zigbee is low data rate WPN where Bluetooth is high data rate WPN
- Zigbee is focused on control and automation
- Bluetooth is focused on connectivity between devices
- Zigbee consumes less power, larger devices, and longer range than Bluetooth

<b>Feature</b>	<b>802.11b/WiFi</b>	<b>802.15.1/Bluetooth</b>	<b>802.15.4/ZigBee</b>
Application Area	Web, Email, Video	Cable Replacement	Control & Monitoring
Target Cost	\$25	\$15	\$5
Memory Requirement	1MB+	250KB	4KB - 32KB+
Battery Life	.5-5 Days	1-7 Days	100-1000 Days
Network Size	11,000+	7	20-250
Peak Data Rate	1, 2, 5.5, 11, (54-802.11g) Mbps	1Mbps	250 Kbps @ 2.4 GHz 40 Kbps @ 915 MHz 20 Kbps @ 868 MHz
Power Consumption (targeted)	1.5 W active @ 20 dBm 45 mW sleep	80 mW active @ 0 dBm  100 mW sleep	60 mW active @ 0 dBm 5–2000 mW sleep (mode dependent)
Adjacent Channel Rejection	>35 dB	0 dB	0 dB
Receiver Sensitivity	–80 dBm	–70 dBm	–85 dBm –92 dBm @ 868/915 MHz
Range Line of Sight	~200 m @ 11 Mbps ~500 m @ 1 Mbps	~30 m ~100 m, Class 1	~50 m @ 0 dBm
Range—Indoor (approx.)	~40 m @ 11 Mbps ~100 m @ 1 Mbps	~10 m ~30 m, Class 1	~10 m @ 0 dBm
Number of Channels	11 - DSSS 79 - FHSS	79	16 @ 2.4 GHz 10 @ 915 MHz 1 @ 868 MHz
Modulation Technique	GFSK—FHSS BPSK/QPSK—DSSS	GFSK	O-QPSK @ 2.4 GHz BPSK @ 868/915 MHz
Maximum Transmit Power	20 dBm—FHSS 30 dBm—DSSS	20 dBm	30 dBm

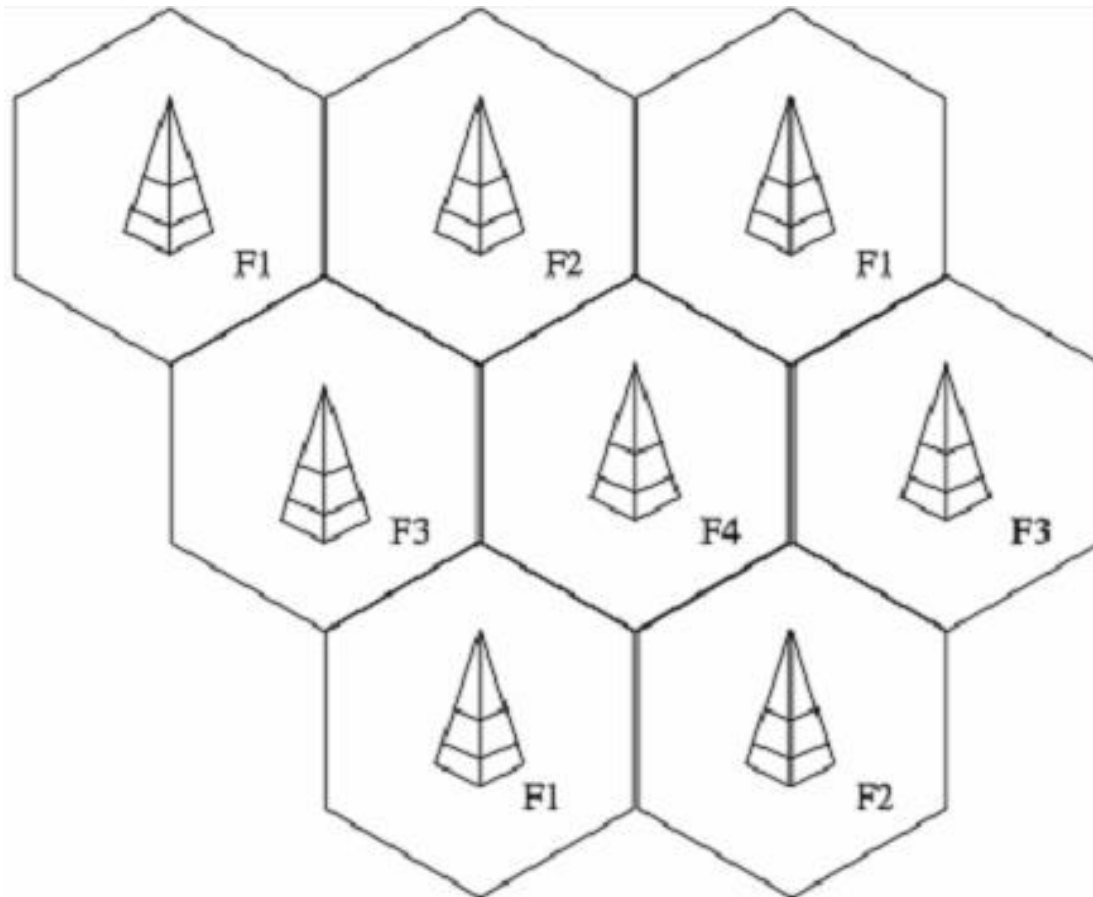
# LoRA communication

- Maximum data rate is up to 27 kbps
- It uses (un)frequency 923.3-927.5 MHz
- It can transfer data up to 10 kilometers
- The competitors are NB-IOT, and Sigfox

# Cellular communication

- A radio network made up of many radio cells
- Each cell serves at least one fixed location transceiver known as cell site or based station
- The portable transceiver can move from one cell to another

# Cellular communication





# Signal multiplexing

- Time Division Multiple Access (TDMA): sharing time
- Frequency Division Multiple Access (FDMA): sharing frequency such as GSM
- Code Division Multiple Access (CDMA): sharing code

# First Generation Cellular network (1G)

- Analog communication
- Data communication is used with modem
- Slow connection speed

# Second Generation Cellular Network (2G)

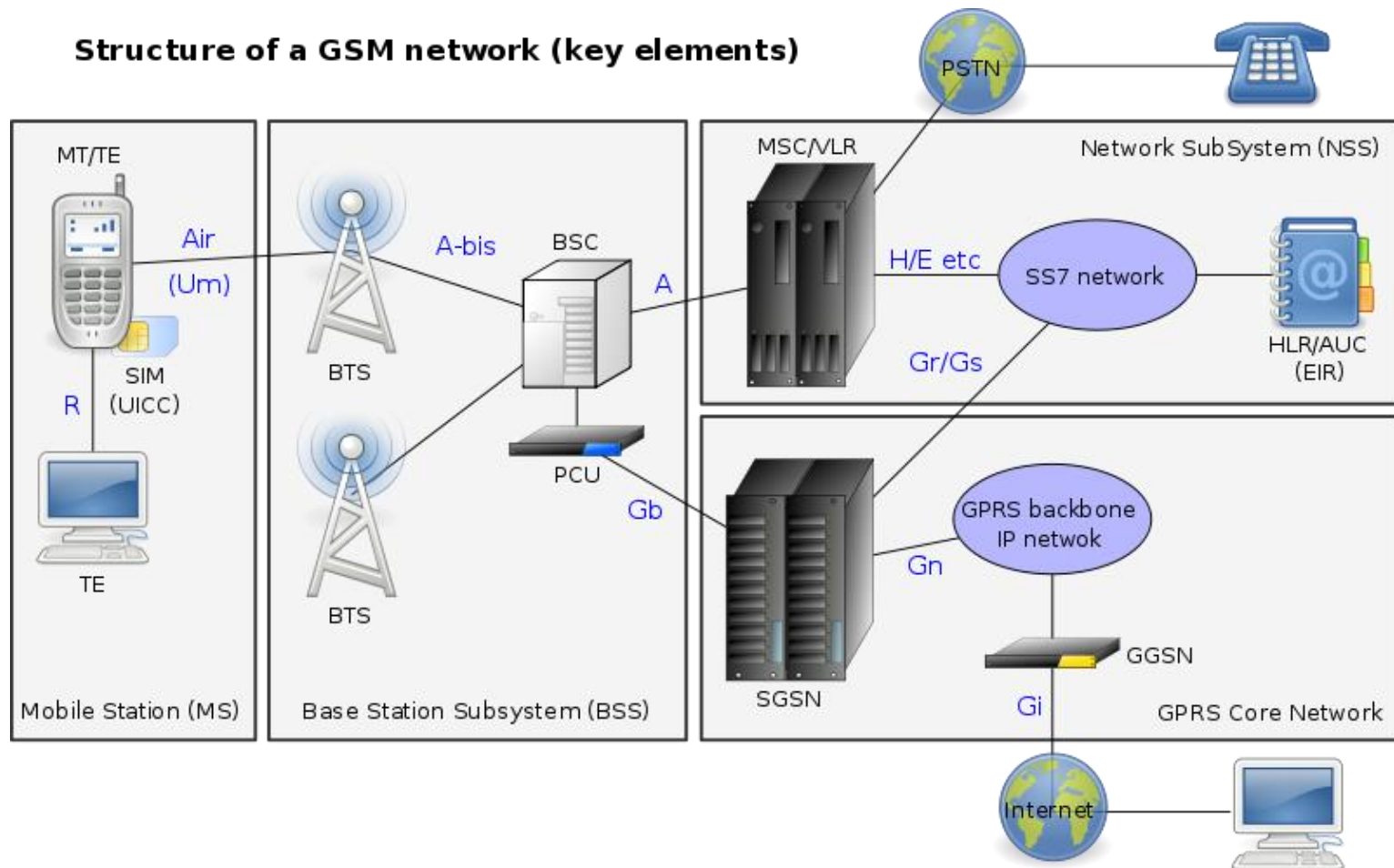
- Digital communication
- Provide data communication support such as GPRS
- GPRS data rate is between 56-114kbits/s
- GPRS supports IP protocol, PPP protocol, and X.25 protocol

# GPRS features

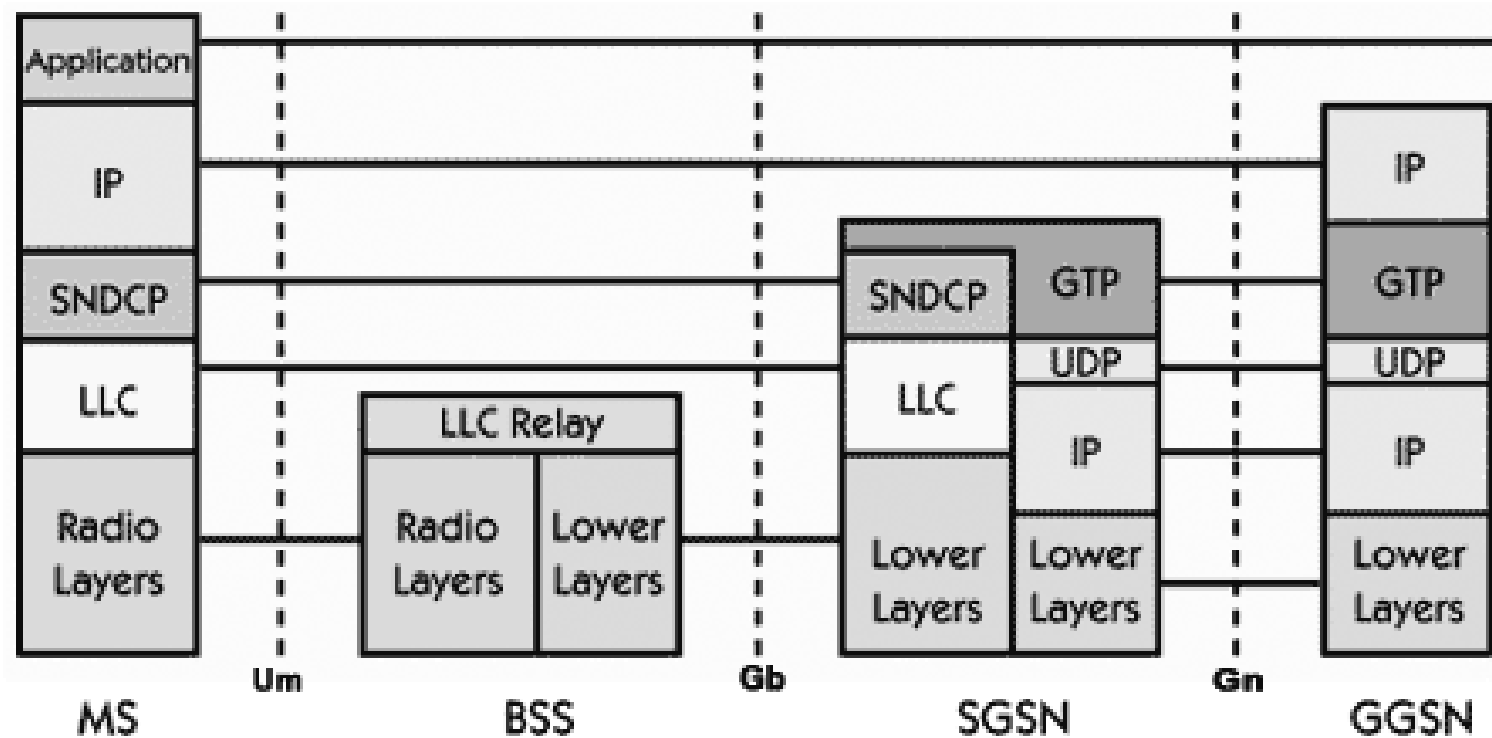
- Packet switch (allow connection only when have data to send or receive)
- The communication is between Mobile station (MS), Base station (BSS), Serving GPRS support node (SGSN), and Gateway GPRS support node (GGSN)
- EDGE is Enhanced Data Rate for GSM Evolution to support EGPRS ( up to 384 kbps)

# Structure GSM network

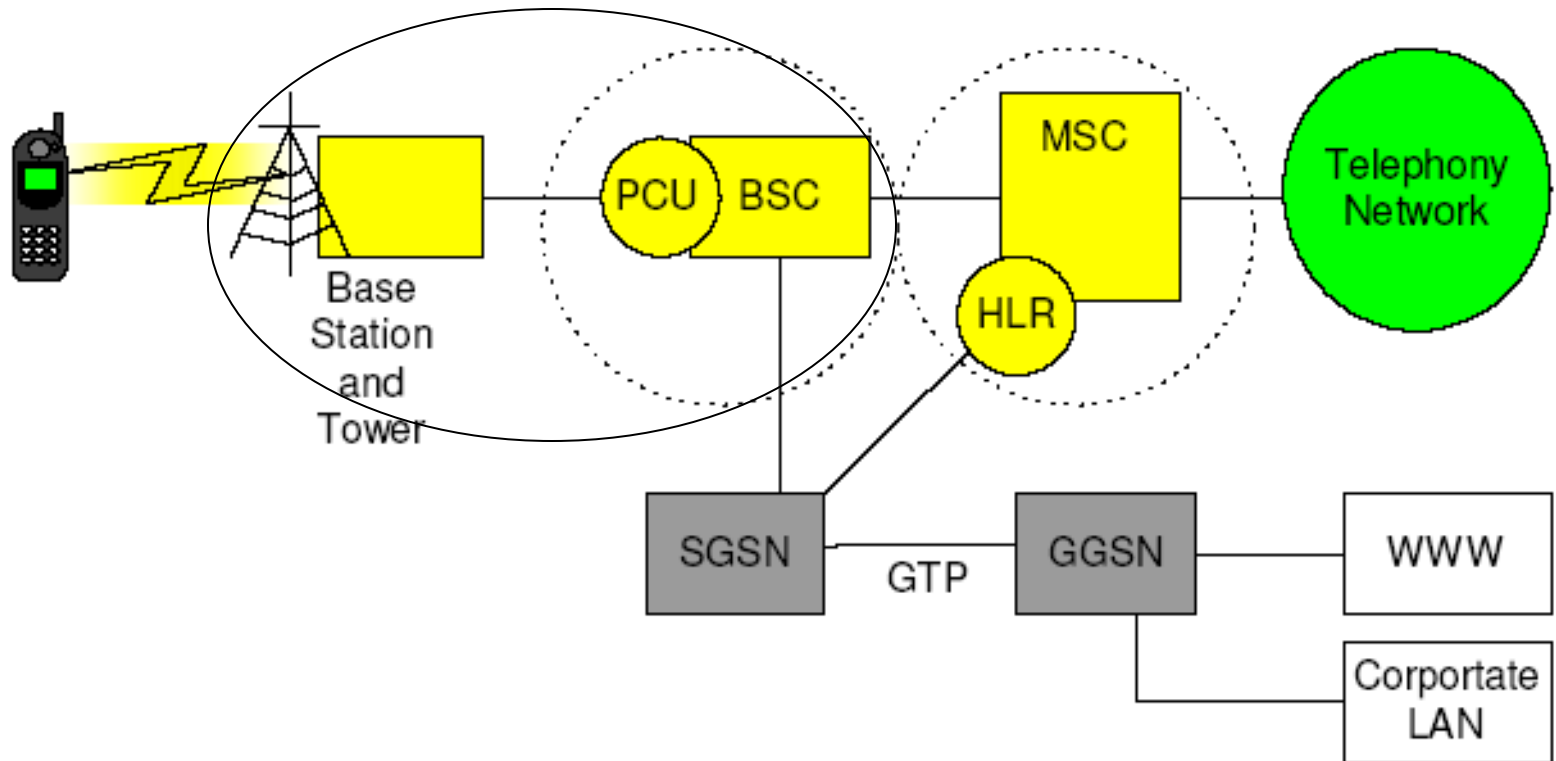
**Structure of a GSM network (key elements)**



# GPRS protocol stack



# GPRS Core Structure



# GPRS units

- Base Station (BSS): communicate with tower station to get your data packet
- SGSN: routing, handover, and IP address assignment
- GGSN: Gateway network through the Internet
- PCU: Packet Control Unit
- HLR: Home Location Register – contain subscriber information



# GSM frequency band

System	Band	Uplink	Downlink	Channel Number
GSM 400	450	450.4 - 457.6	460.4 - 467.6	259 - 293
GSM 400	480	478.8 - 486.0	488.8 - 496.0	306 - 340
GSM 850	850	824.0 - 849.0	869.0 - 894.0	128 - 251
GSM 900 (P-GSM)	900	890.0 - 915.0	935.0 - 960.0	1 - 124
GSM 900 (E-GSM)	900	880.0 - 915.0	925.0 - 960.0	0 - 124, 975 - 1023
GSM-R (R-GSM)	900	876.0 - 880.0	921.0 - 925.0	955 - 973
DCS 1800	1800	1710.0 - 1785.0	1805.0 - 1880.0	512 - 885
PCS 1900	1900	1850.0 - 1910.0	1930.0 - 1990.0	512 - 810

# Third Generation Cellular Network (3G)

- The first commercial of 3G is launched by NTT Docomo in Japan May 2001 based on CDMA
- High speed data communication
- Up to 14 Mbps for downlink and 5.8 Mbps for uplink

# Fourth Generation Cellular Network (4G)

- For high mobility devices, up to 100 Mbps
- For low mobility devices, up to 1 Gbps

# IrDA

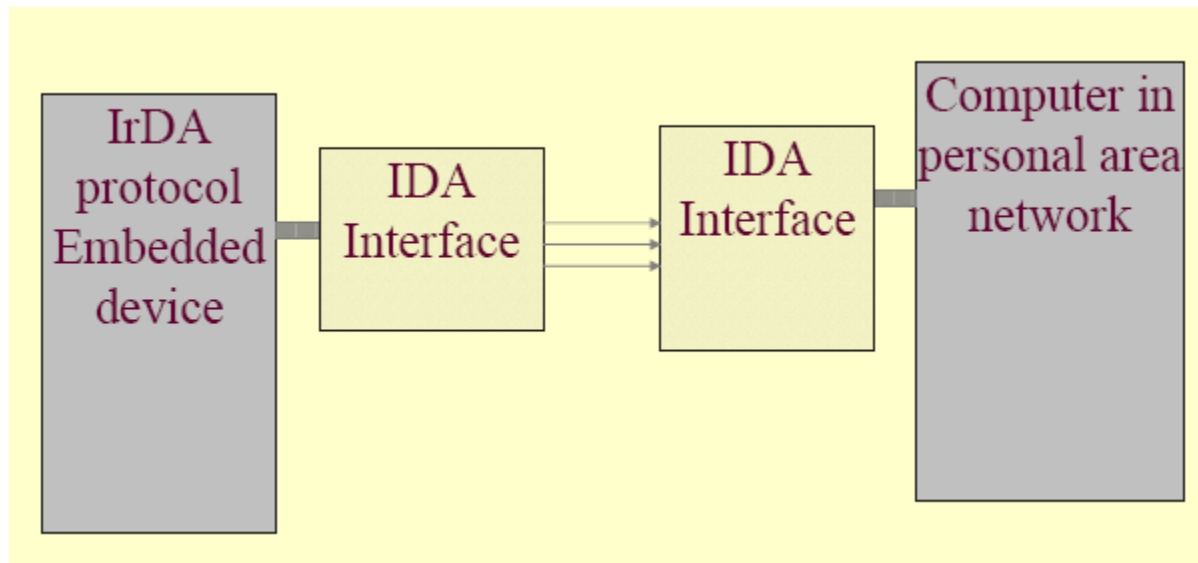
- Infrared Data Association
- The transmission (sometimes called Serial IR, SIR)
- SIR data range is up to 115.2 kbit/s
- Operate at 1-430 THz



# IrDA

- Used in mobile phone, digital cameras, keyboard, mouse, printers
- Used to control TV, air-conditioner, LCD, VCD
- Use infrared (IR) after modulation of data bits
- Communicates over a line of sight
- Phototransistor receiver for infrared ray

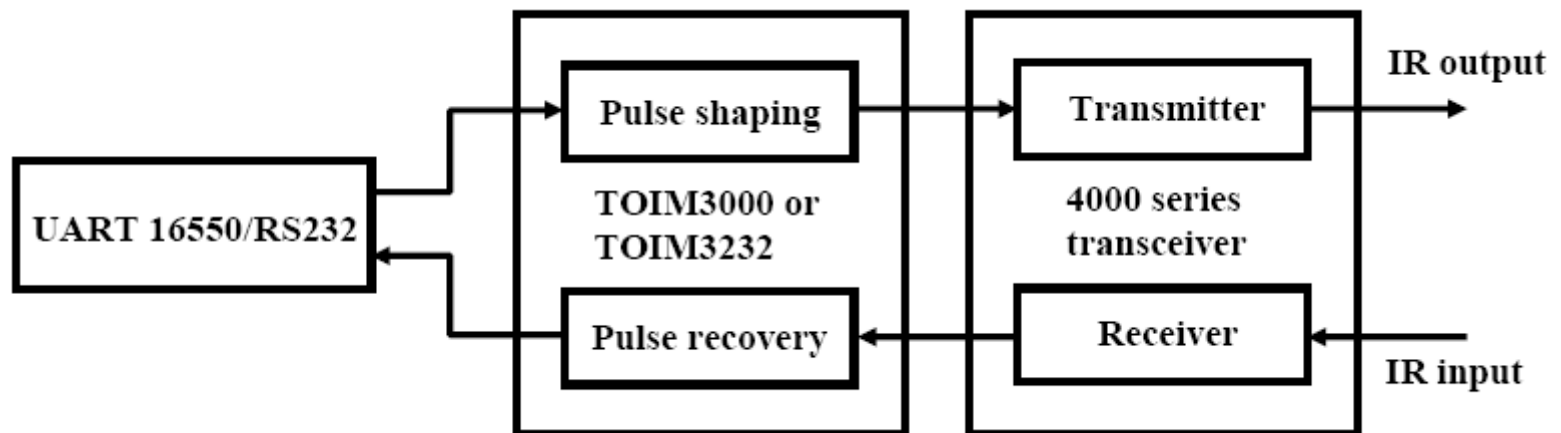
# IrDA interface



# IrDA protocol

- Support data transfer rate up to 4 Mbps
- Support bi-directional serial
- Communicate over view of angle 15 degree and distance nearly 1 meter
- At 5m, IR transfer rate can be up to 75 kbps
- Should be no obstruction or wall in between

# IR connection





# IrDA 5 layers

## IrDA 5 layers

Application for example, IrDA Alliance Sync protocol
Session Layer IrLAN, IrBus, IrMC, IrTran, IrOBEX (Object Exchange) and standard serial port emulator protocol IrCOMM (IR communication). IrBus
Transport Layer Tiny TP or IrLMIAS
Data-link IrLMP and IrLAP Sublayers
Physical 1.0 (9.6 kbps to 115.2 kbps) or 1.1 (115.2 kbps to 4 Mbps)

# OS support

- Detects a nearby IR source
- Controls, detects, and selects IR communication activity
- When IR communication is inactive, the Monitor enables plug and play

# Wireless communication

Properties	INFRARED	Wi-Fi	Bluetooth
Range	5m <	100m<	10m<
Tranmission rate	4Mb/s	11Mbits/s	1Mbit/s
Connection limit	1	Multiple	Multiple
Direction	Line of site	Omni	Omni
Hop Frequency	-	Low 2.5Hop/s	High 1600Hops/s
RF output power	-	100mW-1W	1mW-100mW
Application area	Ad-hoc network	Local Area network	Ad-hoc network
Operating freq.	1- 430 THz	2.4 GHz	2.4GHz

# Applications

# RFID

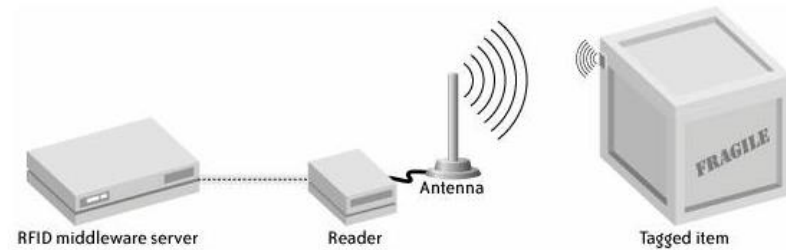
- Aims to replace bar codes
- MIT setup a consortium called Auto-ID center in 1999
- The vision is to have “Internet of objects”
- Walmart plan to replace bar codes with RFID
- Also, widely used in US military

# RFID vs. Barcode

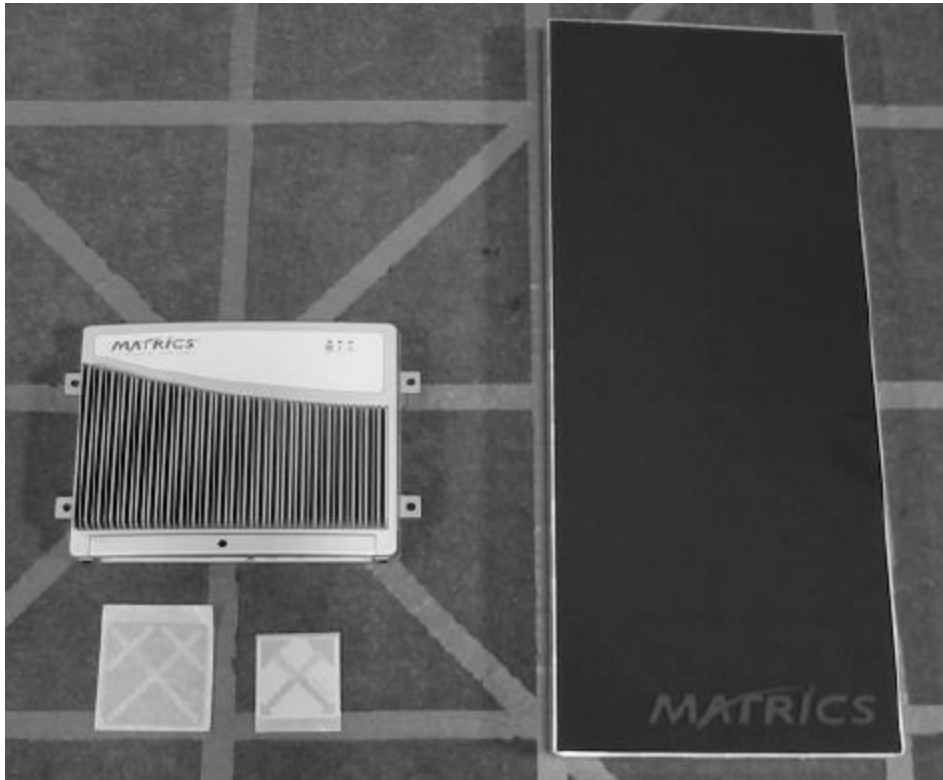
- Reduce human intervention
- Higher throughput
- Increased system security
- Real-time information
- Small size

# RFID Architecture

- RFID readers
- RFID Tags

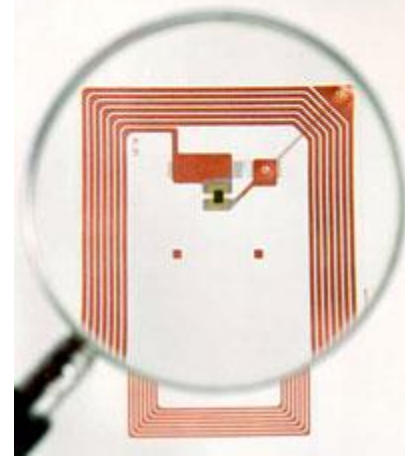


# RFID reader and tags





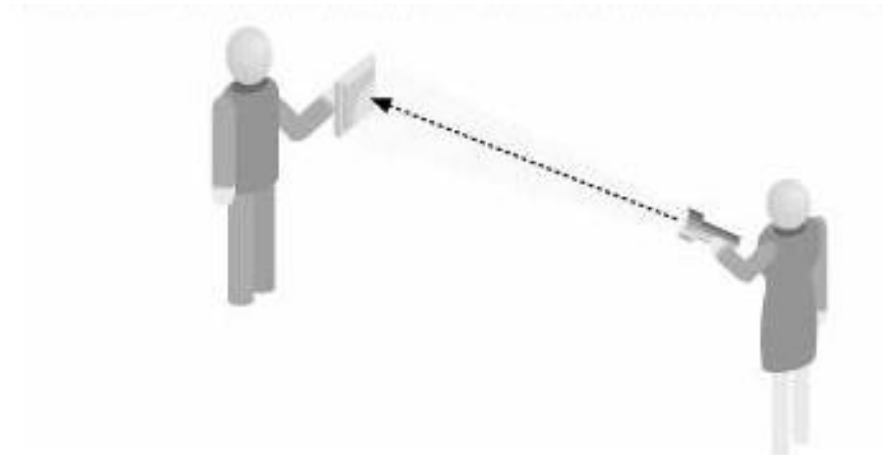
# RFID tags



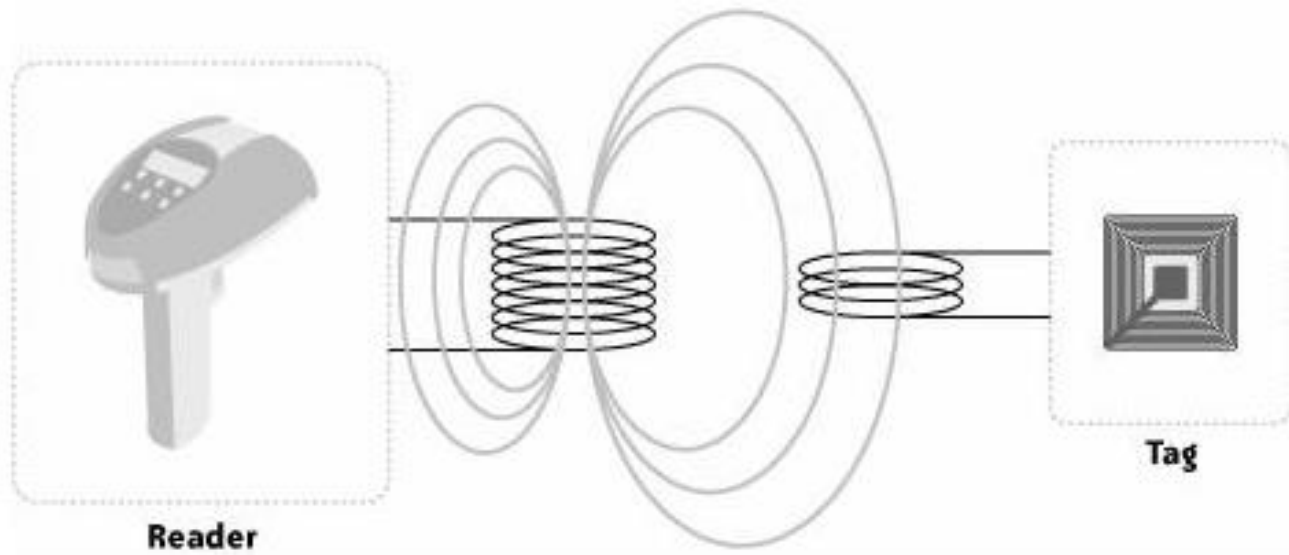
## Three types of RFID tags

- Active RFID: require battery power
- Passive RFID: no battery power, require external power source (RF radio power)
- Semi-active RFID: use battery to run the chip, but use radio power to communicate

# Back scattering



# Back scattering



# Comparison

	Bar code	Passive tag	Active tag
Modification	No	Yes	Yes
Security	Low	High-Low	High
Data	7,200 digit	64KB	8MB
Cost	Low(<10 baht)	Medium(10-40 baht)	High (100-5000 baht)
Standard	Stable	Evolving	Evolving
Life space	Short	Very long	3-5 years
Distance	3-5 feet	50 feet	100 meter
Interference	Optical barrier	RF barrier	RF barrier

# RFID Frequency

Name	Frequency range	ISM frequencies
LF	30300 kHz	< 135 kHz
HF	330 MHz	6.78 MHz, 13.56 MHz, 27.125 MHz, 40.680 MHz
UHF	300 MHz-3 GHz	433.920 MHz, 869 MHz, 915 MHz
Microwave	> 3 GHz	2.45 GHz, 5.8 GHz, 24.125 GHz

# RFID frequency

<i>Type</i>	<i>Read Distance</i>	<i>Applications</i>
LF (low frequency)	Reads at very close range, just beyond actual contact.	Access control and payment technologies. Usually not used for tagging objects.
HF (high frequency)	Can move out to several inches — around a foot with good planning.	Many items in close proximity, like pharmaceuticals on a shelf. HF works well on liquid medicine vials and similar products.
UHF (ultrahigh frequency)	Can easily read several yards and, in a perfect environment, 30 or 40 feet and beyond. Because a typical dock door is ten or twelve feet across, UHF is the darling of the Auto-ID world.	Supply chain, asset management, and access control for vehicles. UHF has challenges with direct contact on liquids and metals because the frequency is easily reflected and absorbed.

# Applications

- Farming
- Electronic toll collection
- Human implant
- Logistics and supply chain management



# LoraWAN

- Proprietary low-power wide area network
- It was developed by Cecleo of Grenoble, France (acquired by Semtech)
- Use license-free radio frequency e.g., 433 MHz, 868 MHz, and 915 MHz
- It can achieve 0.3 kbits/s and 27 kbit/s
- Distance can cover up to 10 km



# NB-IOT

- Narrowband – Internet of Thing
- Support by all major mobile equipment
- Use narrow-band of mobile phone frequency
- Speed is between 26 – 127 kbit/s

# Questions?