SMART SENSORS FOR DOMOTICS AND HEALTH CARE

- Communication Systems

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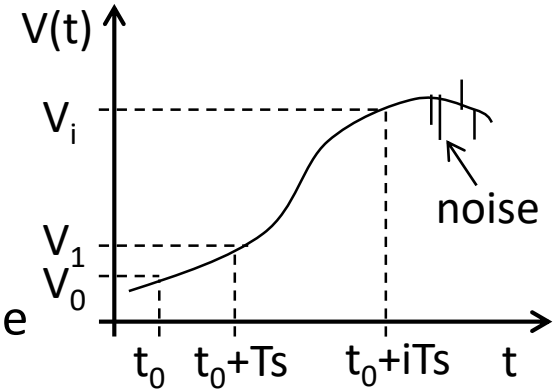
COMMUNICATION SYSTEMS: BASICS

ANALOG AND DIGITAL SIGNALS: BASICS



ANALOG SIGNAL V(t)

Voltage (or current) signal that varies as a function of time

- The instantaneous value V(t) contains information
- Normally an analog signal needs to be sampled and converted by an ADC (n bit of resolution, sampling frequency fs, sampling period Ts=1/fs, input range: 0…Vmax).
- The result is a data sequence V_{i-1} V_i V_{i+1} … where:
  - $V_0 = V(t_0)$ $V_1 = V(t_0+Ts)$ $V_i = V(t_0+i\cdot Ts)$
  - $V_i = 2^n V(t_0+i\cdot Ts)/Vmax$
- In order to limit the effect of electrical noise the filtered values V_j can be considered instead of V_i

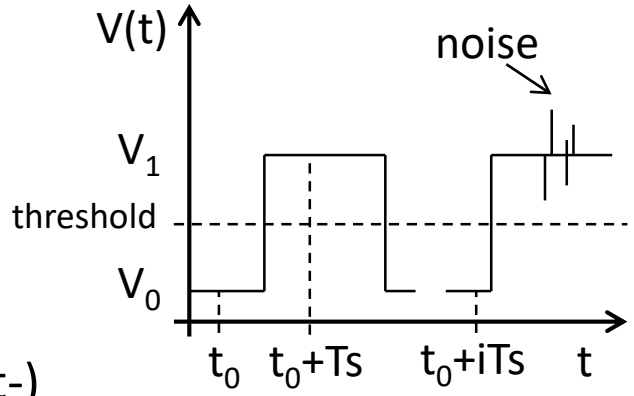
e.g. $V_j = (V_i+V_{i-1}+V_{i-2}+V_{i-3})/4$ $V_{j+1} = (V_{i+1}+V_i+V_{i-1}+V_{i-2})/4$ moving average filter

Drawbacks of analog signals

- one wire = one information
- electrical noise affects information (rarely better than 0,1%, 10 bit equivalent)

COMMUNICATION SYSTEMS: BASICS

ANALOG AND DIGITAL SIGNALS: BASICS



DIGITAL SIGNAL V(t)

Voltage (or current) signal that varies as a function of time between two levels (or few levels –Gbit Ethernet-)

- The instantaneous value V(t) contains information
- Normally a digital signal needs to be sampled (sampling frequency fs, sampling period Ts=1/fs). Very cheap sampling!
- The result is a data sequence V_{i-1} V_i V_{i+1} … where:
  - $V_0 = V(t_0)$ $V_1 = V(t_0+Ts)$ $V_i = V(t_0+i \cdot Ts)$
  - $V_i = \{V_0 \text{ or } V_1\} = \{0 \text{ or } 1\}$
- Very good noise immunity (e.g. V_0=0V, V_1=5V a threshold at 2,5V can tolerate noise of more than 1V)
- Very simple signal (2-levels only): fast, possibility of coding

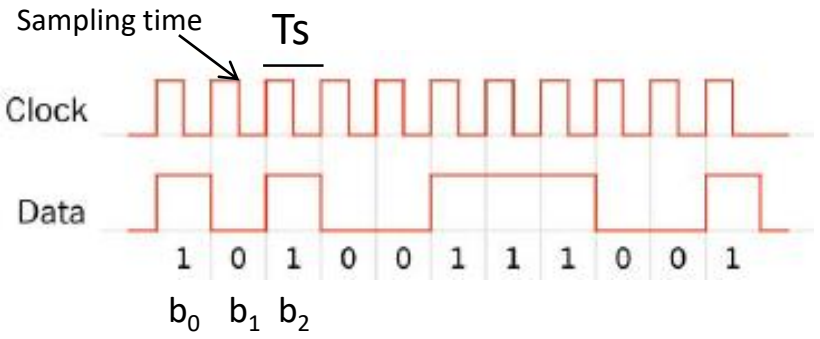
Drawbacks of digital signals (uncoded)

- one wire = one information (bit)

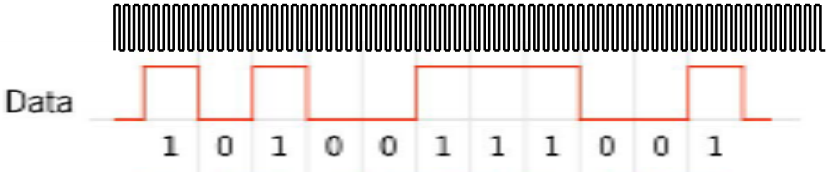
COMMUNICATION SYSTEMS: BASICS

Serial coding of digital signal

If fs (and Ts=1/fs) are known,
A clock signal can be "built" to sample
a digital signal coding more than 1 bit
(a bit stream can host more information)

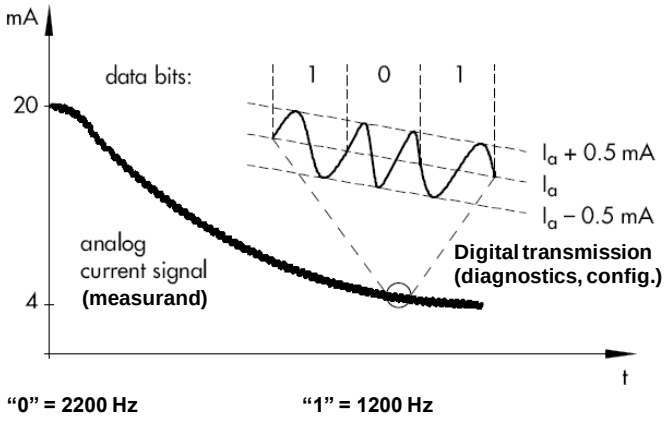


Oversampling can avoid clock transmission and the knowledge of position of sampling time.



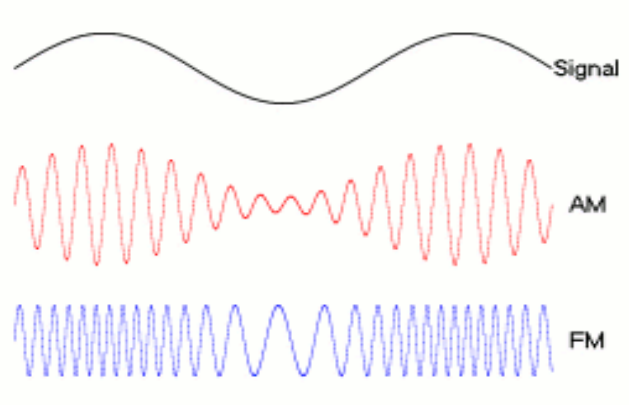
All the modern digital communication systems (wired, wireless) are based on serial coding of information

More communication links can coexist if the frequency fs is different among the links (e.g. in the same "air" more Bluetooth links can coexist, because they talks with different frequencies

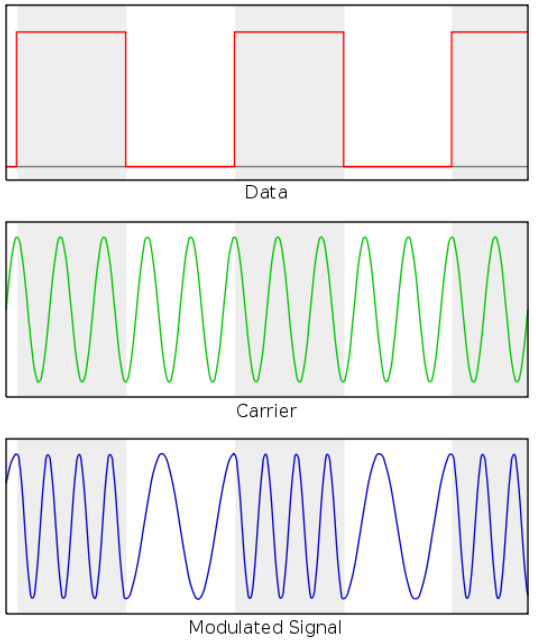


COMMUNICATION SYSTEMS: BASICS

Modulations



- Amplitude modulation (AM)
- Frequency modulation (FM)
- Phase Modulation (PM)
- Digital amplitude modulation (e.g. On-Off keying)
  - easy, low noise-immunity, optical fiber
- Digital frequency modulation
  - Ortogonal Frequency-Division Mux (OFDM) (multi-carrier, 3G, WiFi)



COMMUNICATION SYSTEMS: PC

Right Side

Left Side

Rear View

Analog Interfaces: Infrared, speaker, microphone (headset), Power
Parallel and special interface: Video, S-Video, Mouse (Parallel, Docking, PC card)
Serial: old interface for printers and peripherals (replaced by USB)
Modem: direct interface to modem for internet connection on phone cable (replaced by Ethernet in modern modem)

PC COMMUNICATION SYSTEMS: USB

USB 1.0 (1996->1999)

• slow interface, replaces RS232 for mouse, keyboards, and Centronics for printers (1,5Mbit/s -> 12Mbit/s), USB is also a source power (5V, 5A)

USB 2.0 (2000)

• increase of the speed (480Mbit/s). Good for file transfer or image transfer (USB memory stick, cameras, etc). For video signal there is HDMI

USB 3.0 (2008)

• very fast interface (4,8Gbit/s -> 10Gbit/s), more power, more connectors

USB is the perfect link between PC and Mobiles

• different connectors

USB is used to power Mobiles

• microUSB connector is widespread as power source

USB is a master (host) - slave (peripheral) connection

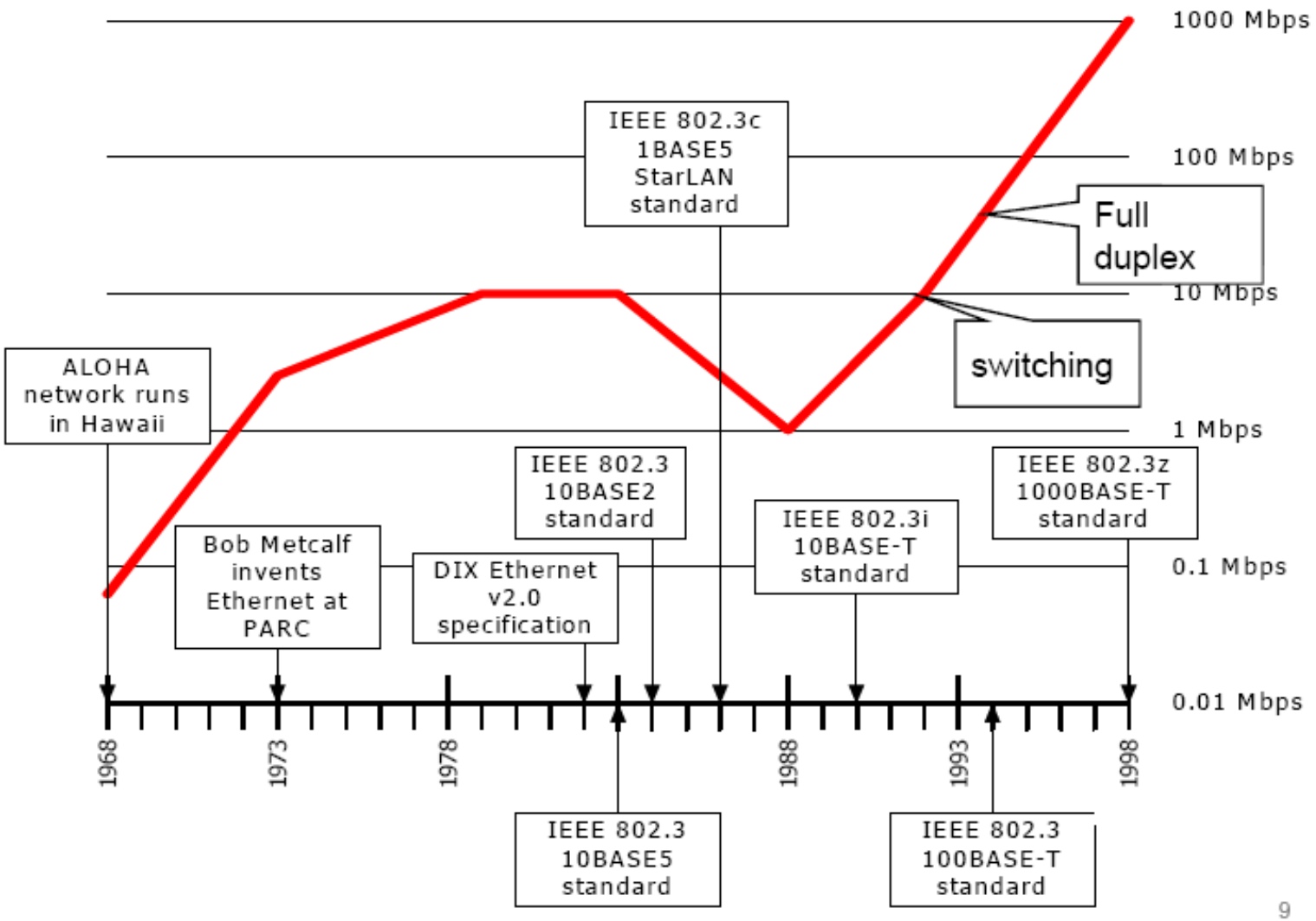
• 1 host and up to 127 peripherals; peripherals cannot communicate among them

• a HUB (port multiplier) can be used to connect peripherals (cable < 5m)

• USB On-the-Go (**USB OTG**) allow a device (e.g. Smartphone) to be both host and peripheral

Plug-and-play (no driver)

PC COMMUNICATION SYSTEMS: ETHERNET



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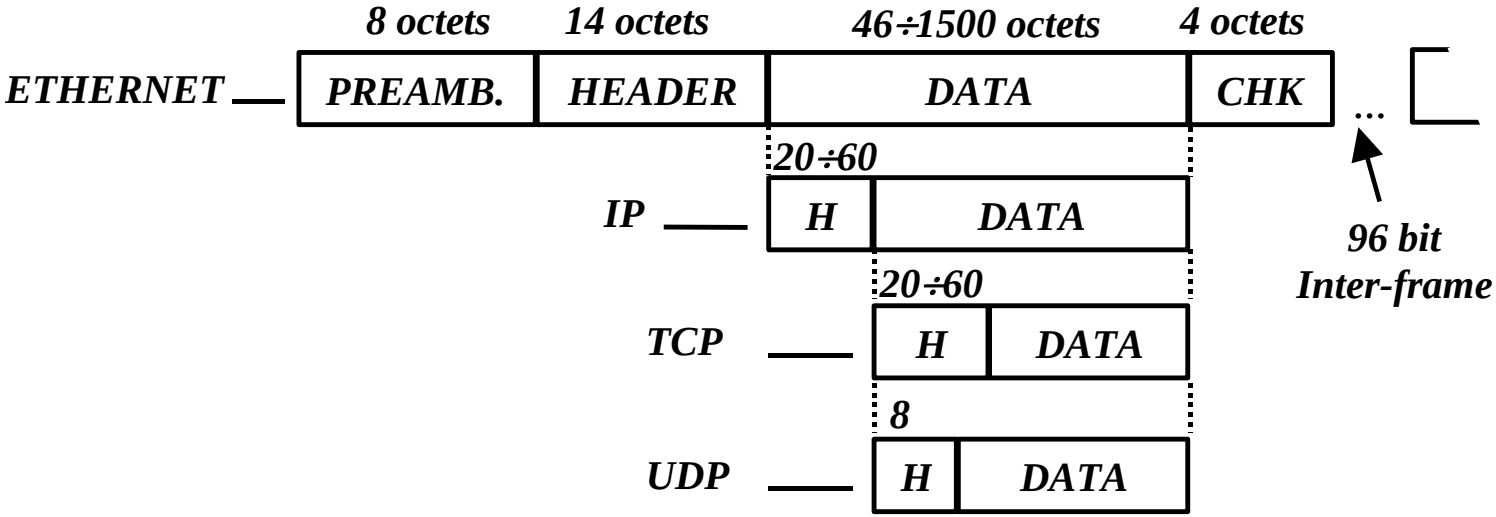
PC COMMUNICATION SYSTEMS: ETHERNET

Ethernet has been introduced in 1972/3 by Bob Metcalf at PARC

- IEEE802.3 (1985) is the modern Ethernet (connector RJ45)
  - 10 Mbit/s (10Mbps, 100m), old, unused
  - 100BaseTx (100Mbps, copper, 100m), industrial, Power over Ethernet (PoE)
  - 100BaseFx (100Mbps, optical fiber, ~500m), industrial applications
  - Gbit Ethernet (1Gbps, copper or optical fiber), PC
  - 10Gps (optical media only)
- Ethernet is the basis for IP (Internet Protocol) and TCP/IP (encapsulation)
- There are also Jumbo Frames (up to 9000bytes of payload –data-)



PC COMMUNICATION SYSTEMS: ETHERNET

Ethernet infrastructure

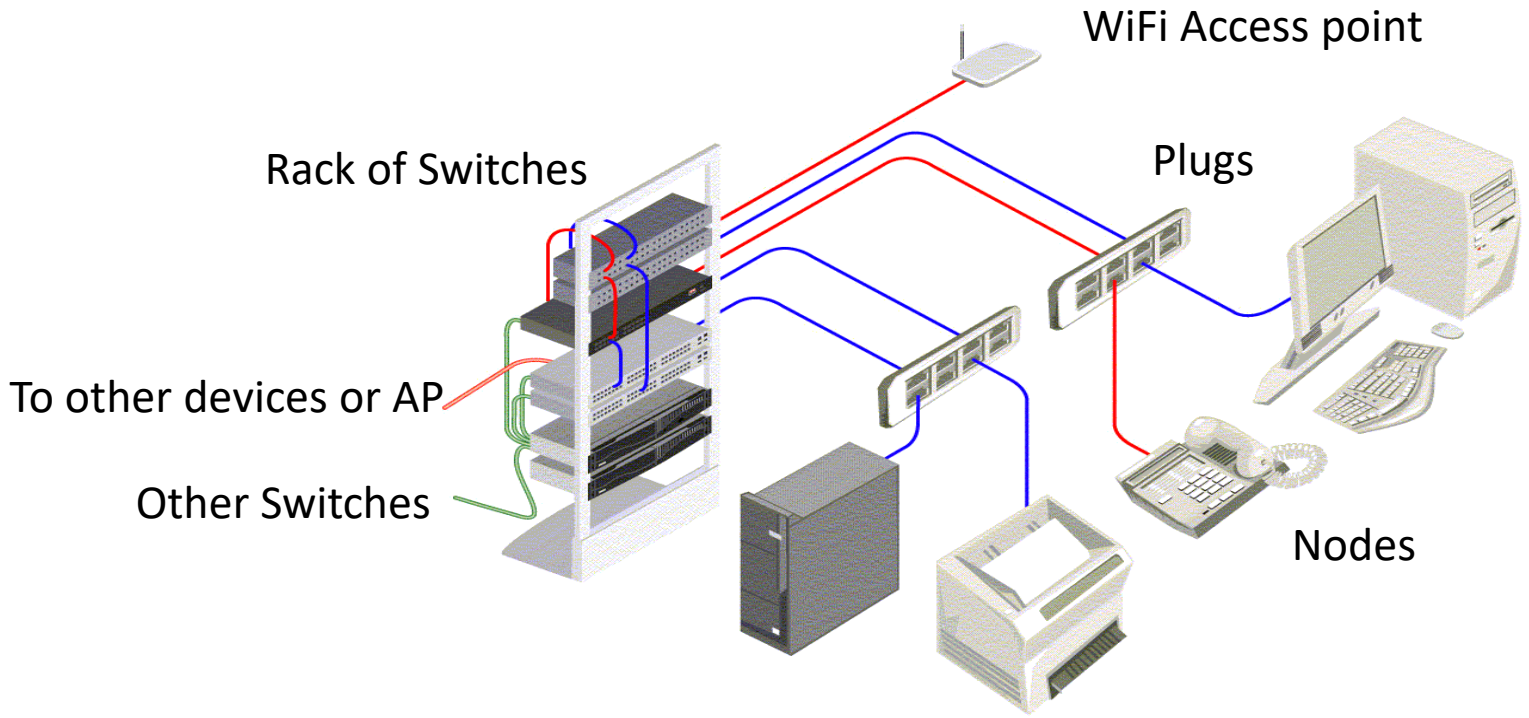
• An Ethernet link is a point-to-point connection between the PC (or WiFi Access Point –AP- or other device) and one port of a Switch.

• The Switch is the basic block of the Ethernet infrastructure

– a Switch is a fast computing system with several ports

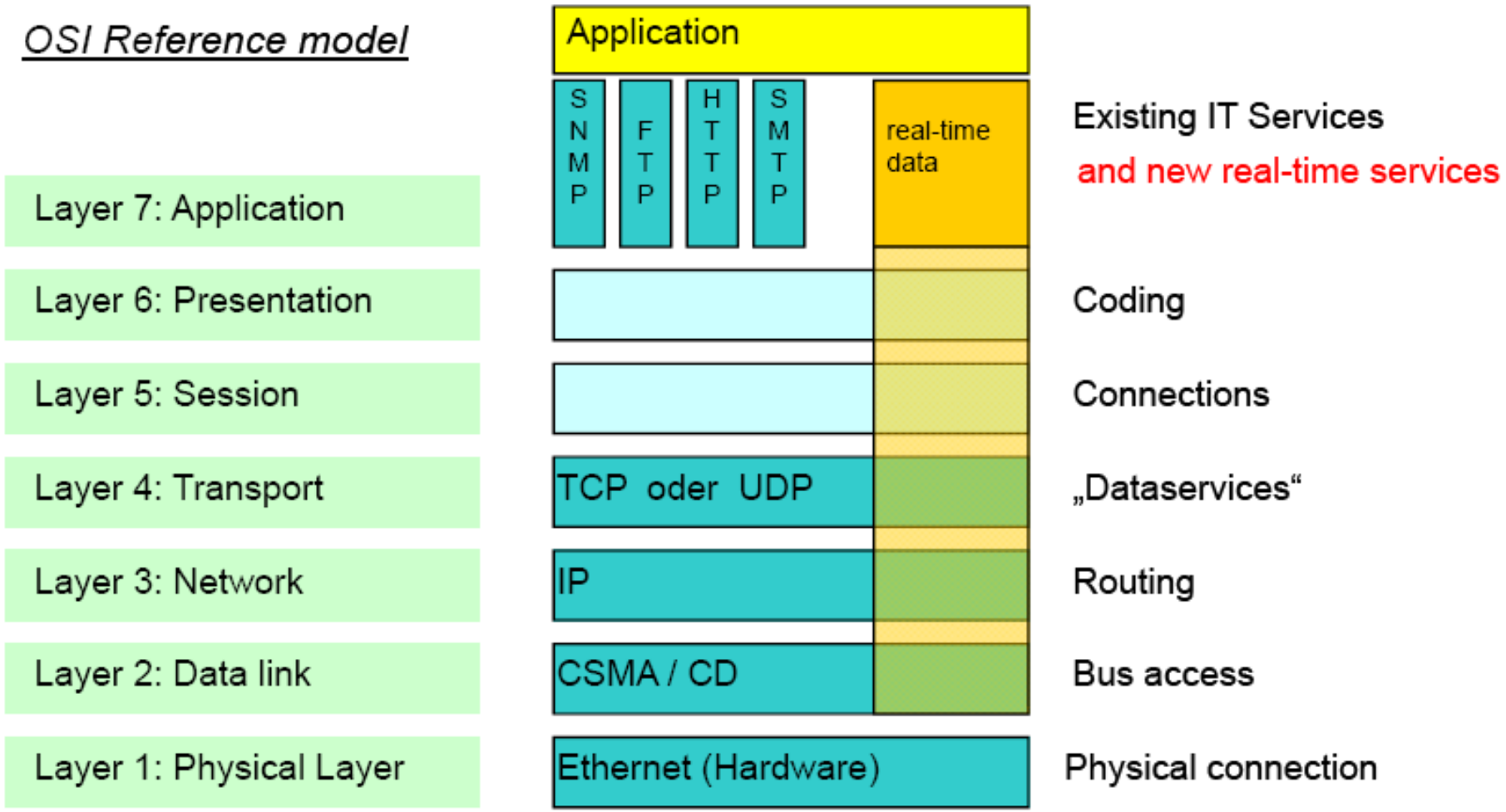
– it “learns” who is attached at a port and associate that port to those addresses

– the unknown addresses are sent to all the ports



PC COMMUNICATION SYSTEMS: ETHERNET, INTERNET

OSI Reference model



PC COMMUNICATION SYSTEMS: ETHERNET, INTERNET

Physical (e.g. 100BaseTx, 100BaseFx)

• The cables, the connectors, the signals, the bit rate, and so on

Data Link (e.g. Ethernet, PING messages)

• Distinguish nodes among them (Addressing) -> MAC address, static

• How to access the communication medium

– "is someone already communicating? Is the medium free?"

– "I try to communicate, if there is collision, I'll retry"

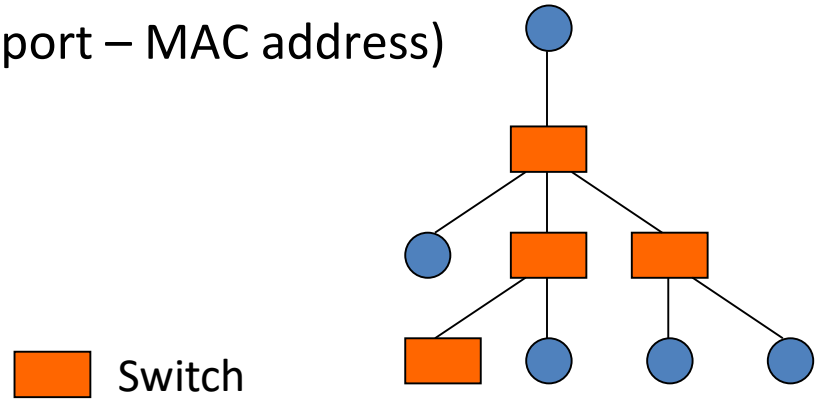
– "I'll communicate only when I'll be allowed or when it is my time"

• The Switch (sends the message to the right port, connected to the path toward destination)

– creates a reference table (port – MAC address)

– check the message

– introduces a delay



PC COMMUNICATION SYSTEMS: ETHERNET, INTERNET

Network Link (e.g. Internet Protocol, IP)

- Distinguish nodes among them (Addressing) -> IP address, static or dynamic
- Creating sub-nets
- From IPv4 to IPv6
  - Ethernet: MAC address or LAN address (48 bit, 6 bytes)
  - IP, IPv4: IP address or DNS (Domain Name System or symbolic name), 32 bit
  - IP, IPv6: IP address, 128 bit (more nodes)
- Note: ARP protocol provides correspondence between IP addr. and MAC addr.
- Note: IP can operates over Ethernet, but also over wireless Ethernet or other protocols (e.g. telephone connection, RS232, and so on, by means of a modem)
- Note: an IP packet can be fragmented

Transport (e.g. UDP/IP, TCP/IP)

- User Datagram Protocol (UDP/IP) establish a communication link (“ports”)
  - Connectionless, no retry, used for dataflow (audio or video stream)
- Transmission Control Protocol (TCP/IP)
  - establishes a connection between two nodes (a conn. starts, lives, is closed)
  - retry if no Acknowledge (Ack); quite slow but reliable

PC COMMUNICATION SYSTEMS: ETHERNET, INTERNET

Application (e.g. HTTP, FTP)

• The Application level establishes a communication over a Transport layer
• FTP (File Transfer Protocol). One of the simplest protocol to transfer files.
• HTTP (HyperText Transfer Protocol) uses a request/response mechanism over port 80 and TCP/IP protocol. It is basic the protocol of the WEB

WWW (World Wide Web)

• ideated and developed in 1991 by Tim Berners-Lee at CERN of Ginevra (first on-line web page), public since 1993
• HTTP is the protocol between a Web client (e.g. browser, like Internet explorer or Chrome) and a web server (data containers, e.g. web pages)
• a web page is normally reachable by URL (Uniform Resource Locator) and written in HTML (HyperText Markup Language)
• URL (e.g. http://www.ieee.org/) and IP are related by DNS Domain Name System or distributed datatbase
• an Hypertext is a set of linked documents (WWW is a hypertext of all the web pages thanks to links)

PC/MOBILE COMMUNICATION SYSTEMS: WiFi

WiFi (Wireless Fidelity) is also known as wireless Ethernet (1999)

- IEEE802.11 is a wireless communications stack operating at 2.4GHz (11Mbit/s or 54Mbit/s) and at 5GHz (about 100m as the range)
- An IEEE802.11 network is normally composed by Access points (APs), connected among them by an Ethernet network
- the AP periodically transmits broadcast (to every node) the SSID (service set identifier) of the networks it supports so the wireless node can choose the network to connect with
- IEEE802.11 defines physical and data layers (as Ethernet)
- the ISM (Industrial Scientific and Medical) bandwidth 2400-2480MHz is divided in 14 channels (20MHz wide, overlapped)
  - only 3 channels can coexist
- "Dual Band" devices support both 2.4GHz and 5GHz

Problems of wireless connections

- The wireless channel is unreliable (reflections and absorption of radio signals)
- Security: everyone can hear the message –Encryption, authentication-
- Jamming: everyone can transmit power at 2.4GHz killing every communication

PC/MOBILE COMMUNICATION SYSTEMS: BLUETOOTH

Bluetooth (BT) takes the name from an ancient Danish king (1999)

• With respect to WiFi is more cheap and consumes less power (as USB with respect to Ethernet)

• IEEE802.15.1 (Physical and data layer of BT) is a wireless communications stack operating at 2.4GHz and supporting 3 classes

  – Class 1: big power (100mW), long distance (100m)
  – Class 2: medium power (2,5mW), medium distance (10m)
  – Class 3: low power (1mW), small distance (1m), Personal Area Network

• BT divides the bandwidth 2400-2480MHz into 80 channels and a communication link “hops” from a channel to another channel 1600 times at a second (frequency hopping)

• Several versions

  – BT 1.1 (IEEE802.15.1, 2002), 1,5 Mbit/s
  – BT 1.2 (2005) widespread
  – BT 2.0 (2008) Encryption, 3Mbit/s
  – BT 3.0 (2009) Quality of Service, diagnostic
  – BT 4.0 (2010) **Bluetooth Low Energy (BLE)**, adopted for Body Area Networks

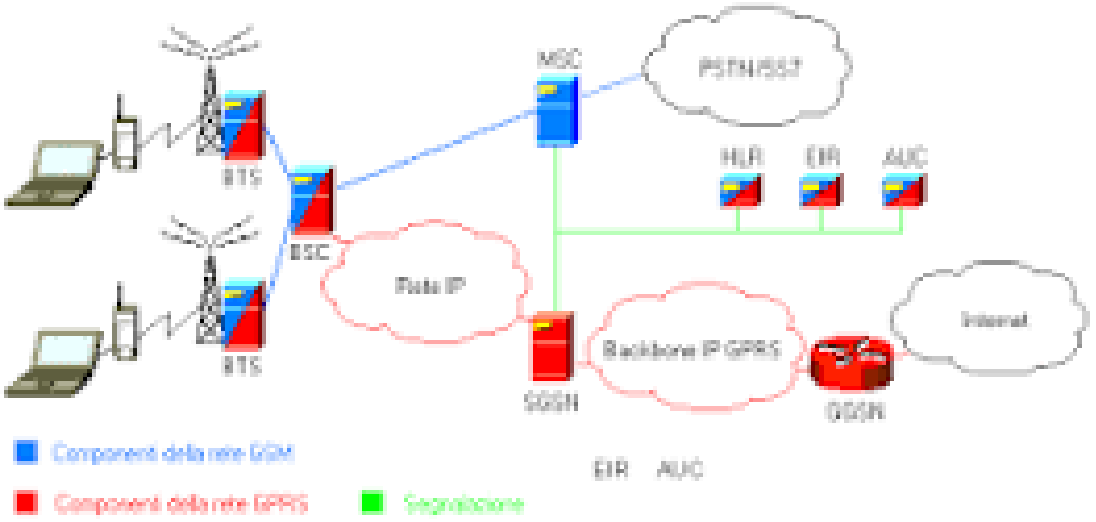
MOBILE COMMUNICATION SYSTEMS: GSM/LTE

GSM (Global System for Mobile Communication). 2G network (1987)

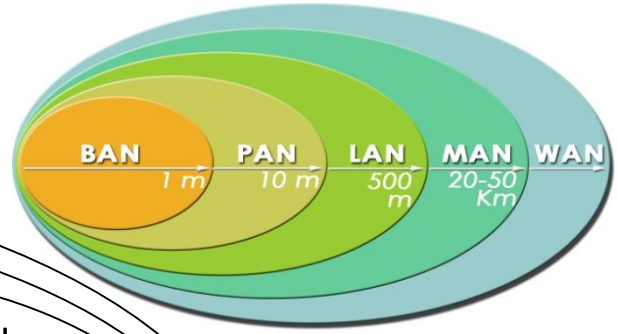
2G (1987)
- GSM for voice, SMS for messages,GPRS for data and IP, SIM card for identification
- Europe (900MHz, 1800MHz), USA (850MHz, 1900MHz). Dual band, triband,…

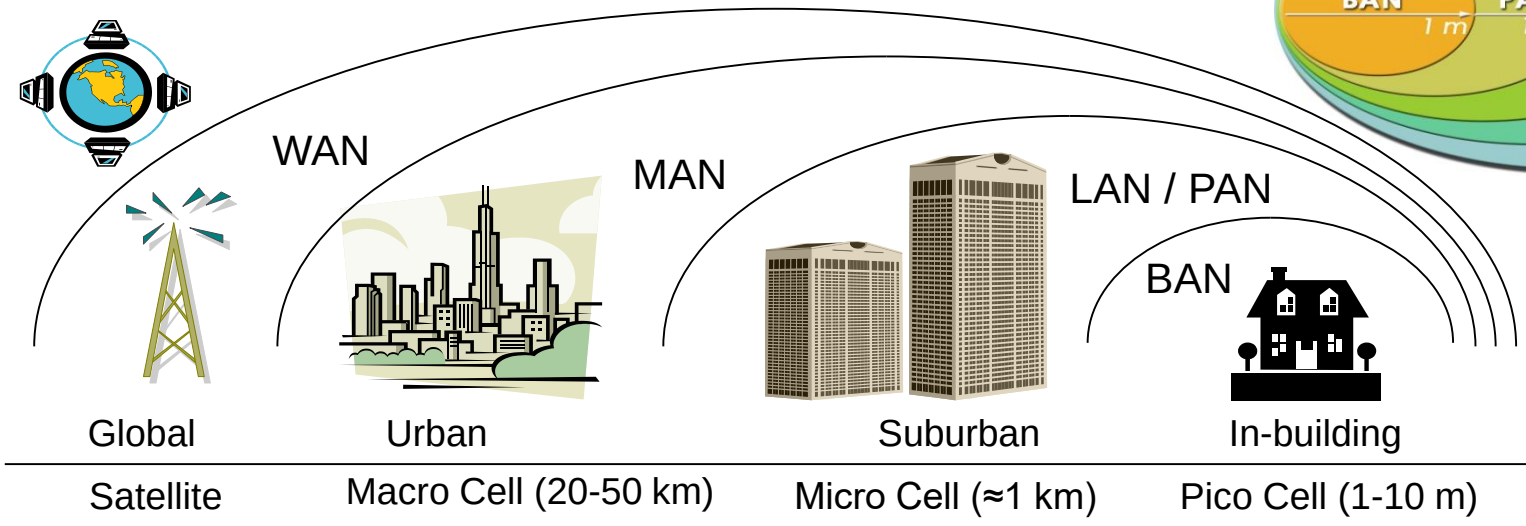
3G (2005)
- Digital voice, data, IP, email, instant messaging, 3Mbit/s
- UMTS (Universal Mobile Telecommunications System)

4G (2010)
- Multiprotocol (WiMax, LTE,…),
- up to 1Gbit/s
- LTE, Long Term Evolution,
- WiMax ≈ WiFi2
- good performance in mobility (up to 500km/h)



WIRELESS and WIRELESS SENSOR NETWORKS

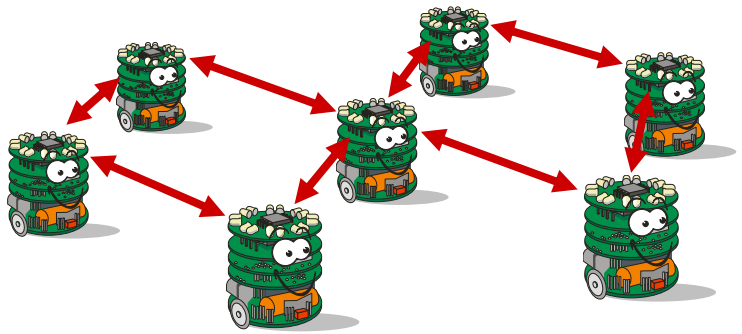




BAN: Body
PAN: Personal
LAN: Local
MAN: Metropolitan
WAN: Wide Area Network

The ideal Wireless Sensor Network (WSN)

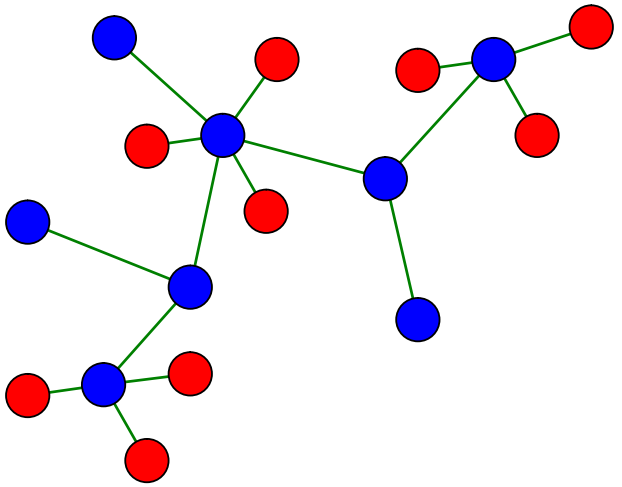
- Mobile, self-powered, self-organized, localized, miniaturized and synchronized sensors
- High performance, high reliability
- Security
- Ultra low cost



WIRELESS SENSOR NETWORKS: ZIGBEE

ZIGBEE (IEEE802.15.4 at Physical and data layer), 2004

- Very low-power communication system to organize a “mesh” among more widespread nodes
- Full-function device (FFD, blue) and Reduced Function device (RFD, red)
- A RFD normally sleeps to save battery, periodically wakes up, measures and communicates to a FFD
- FFDs send to the network their information and information of other nodes (routing)
- 250kbit/s, short messages, short distance (10m)
- 2,4GHz, 16 channels, slow frequency hopping
- An RFD sending 1 measures every second powered with 2 AA stylos has a life of a little bit more than 1 year
- widespread for industry
- used for domotics and metering
- open technology
- not supported by PC or Mobiles
- failed projects for SIM



ZigBee® Alliance

WIRELESS SENSOR NETWORKS: Z-Wave

Z-Wave, 2008

• Z-Wave is a wireless communication **specifically designed for domotics**, that is to allow devices in the home (e.g. lighting, access controls, household appliances) to communicate with one another for the purposes of home automation.

• 900MHz (far from the crowded 2.4GHz), up to 232 nodes, 100Kbit/s, up to 100m

• Very low-power communication system to organize a “mesh” (up to 4 hops) among more widespread nodes

• Network ID, node ID

•The simplest network is composed by a controller and a device. More devices can be added (pairing).

• Low-cost, good battery life, easy to be connected

• Many products for home automation

- Temperature, pressure, humidity sensors
- Lighting and light sensors
- Appliance and smart plugs
- Gas sensors, air quality sensors
- Sensors for safety and security

WIRELESS SENSOR NETWORKS: OTHER TECHs

	IR	RF 433 868/915	802.11	802.15.1	WirelessUSB	802.15.4	UWB	NFC
Frequency	800-900 nm	433 MHz 868/915 MHz	2.4/5 GHz	2.4 GHz	2.4 GHz	868-902 MHz, 2.4GHz	3.1-10.6 GHz	Inductive Connections (13.56MHz)
Data Rate	20k-16Mbps	0.3kbps	11-54 Mbps	1 Mbps	62.5 kbps	20-250 kbps	100-500 Mbps	106-424 kbps
Area	1-9m (LOS)	10m	50-100m	10m	~ 50m	10-100m	<10m	~20cm
Network topology	Peer-to-peer	Peer-to-peer	Star	Star	Star	Star, tree, mesh	Peer-to-peer	Peer-to-peer
Stack Complexity	Low	Low	High	Medium /High	Low	Medium	Medium	Low
Power dissipation	Very low (10mW, depends on distance)	Low (~200mW)	High ~1W	Medium ~300mW	Low ~200mW	Low ~100mW	Low ~100mW	Low
Applications	Remote control, short range communications	Remote control	Wireless LAN	Cable replacing	Peripherals, PC	Automation, sensor networks	Wide-band communication	Short range communication

COMMUNICATION SYSTEMS: tests

Tests

1) An analog signal is sampled $V_n \div V_{n+9}$={5, 8, 6, 3, 5, 6, 4, 6, 1, 5}. The result of a moving average filter $V^*_n \div V^*_{n+3}$ is (truncation) [b]:

a. 5, 8, 6, 3 b. 5, 5, 5, 4 c. 5, 5, 5, 5, d. 3, 4, 5, 6

2) USB transmits …. [c]

a. uncoded digital signals b. analog signals

c. coded digital signals d. all of responses a. b. c.

3) The …. Interface is characteristic of PC (practically not present in Mobiles) [a]

a. Ethernet b. USB c. WiFi d. Bluetooth

4) USB OTG (on-the-go) allows… [d]

a. to be a power source for PCs b. to transmit TCP/IP packets

c. High quality video signal transfer d. a device to be host and peripheral

5) An Ethernet … sends to the correct port a received message [c]

a. Rack b. RJ45 c. Switch d. HUB

COMMUNICATION SYSTEMS: tests

Tests

6) The …. Address can be dynamically assigned and ARP protocol provides correspondence with MAC address [b]

a. USB b. IP c. URL d. HTML

7) HTTP is the most popular protocol of the Web and it is a ….mechanism [c]

a. USB b. Master-slave c. Client-server d. MAC

8) IEEE802.11 Access Points are normally connected to a …. network [b]

a. USB b. Ethernet c. ZigBee d. Z-Wave

9) LTE Long Term Evolution is characteristic of … networks [d]

a. GSM b. 2G c. 3G d. 4G

10) The technology for wireless sensor networks, with RFD and FFD nodes, is [c]

a. WiFi b. 3G c. ZigBee d. Z-Wave

11) The technology specifically designed for domotics is [d]

a. GSM b. USB c. ZigBee d. Z-Wave

12) The technology recently adopted for Body Area Networks is [c]

a. WiFi b. 4G c. BLE d. Z-Wave