



## Networking



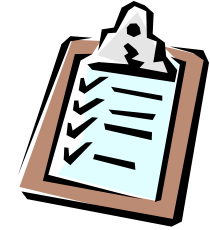
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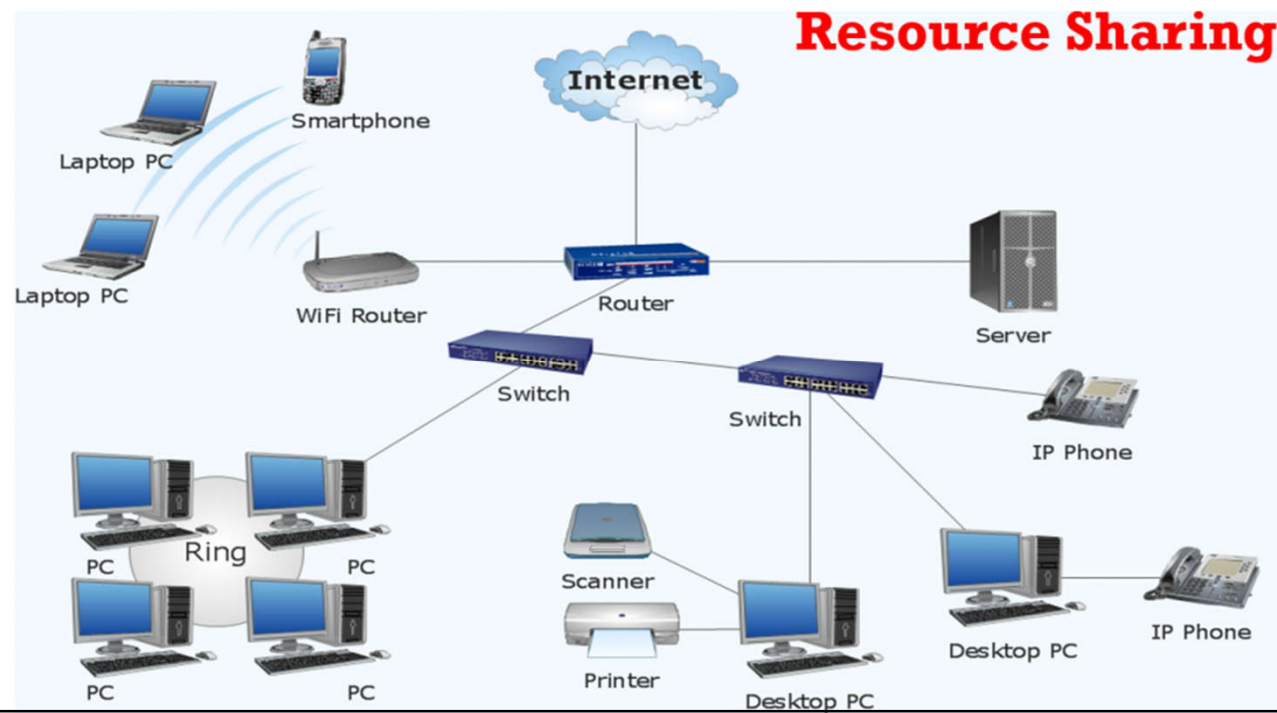


- Computer network
- Local area network
- Transmission methods
- Networking infrastructure
- Wireless networks

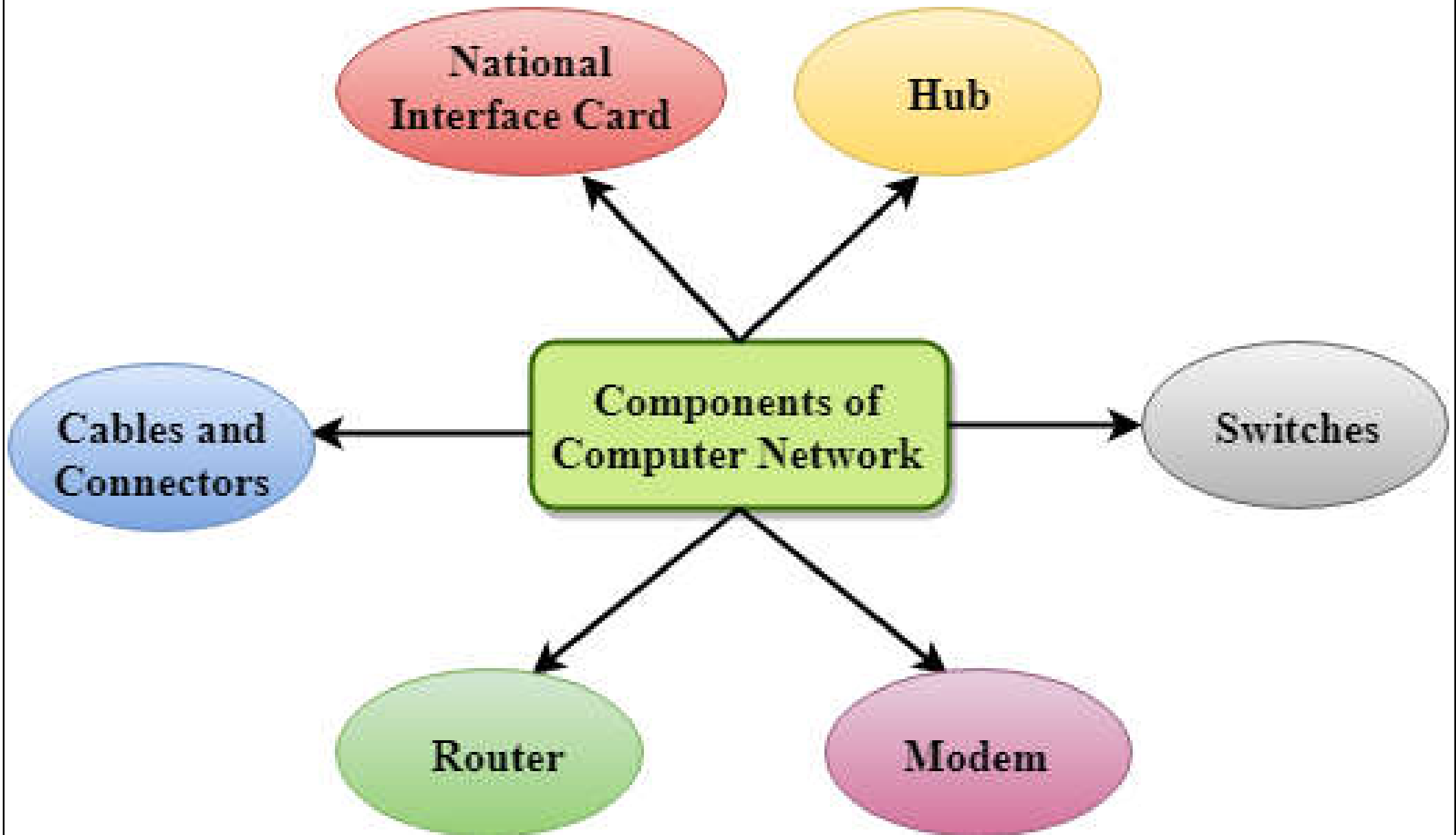


# Computer network

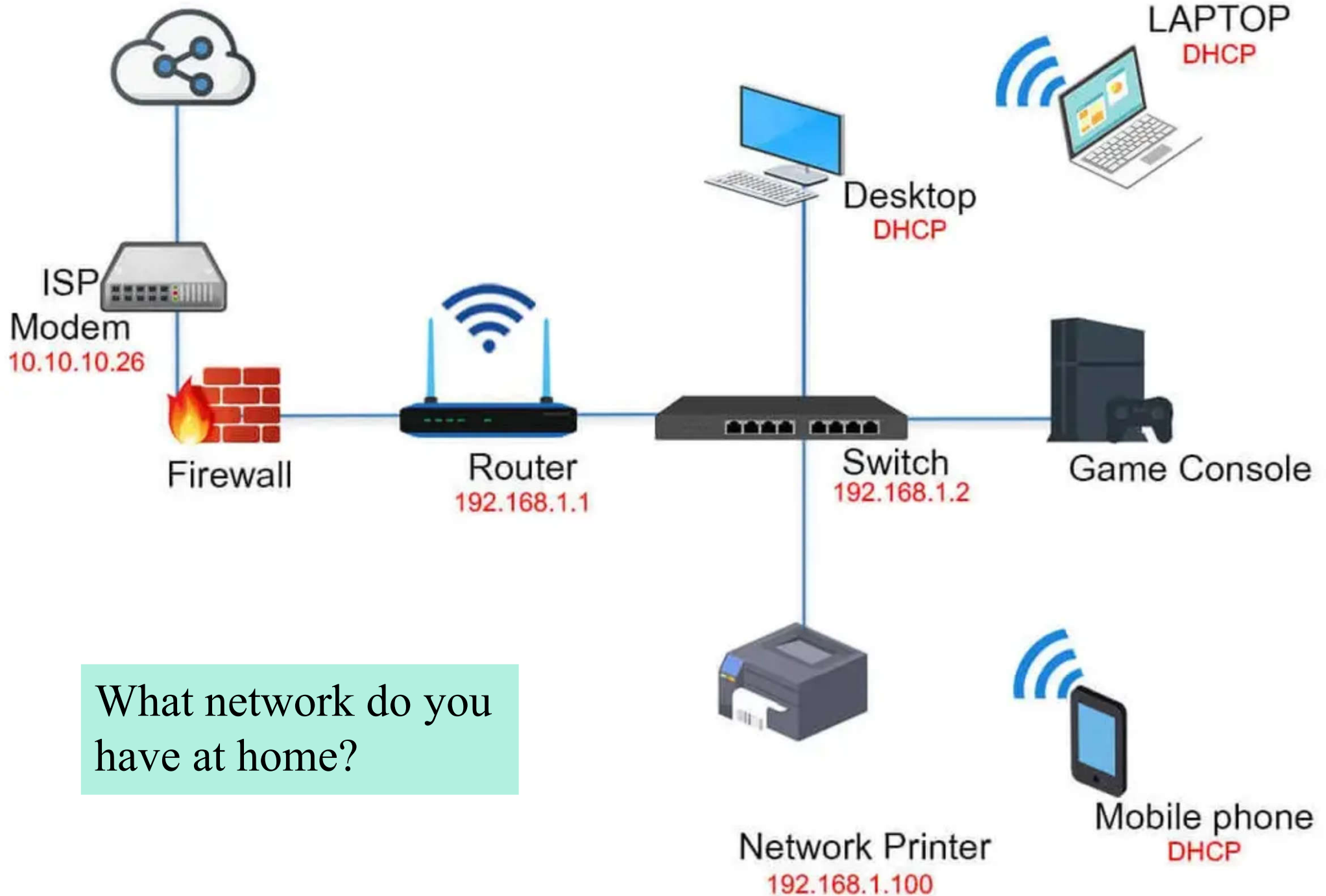
- What is a (computer) network?
  - Simply, a collection of computers and other devices connected in a way that allows them to share information and resources.



# Major components of a computer network

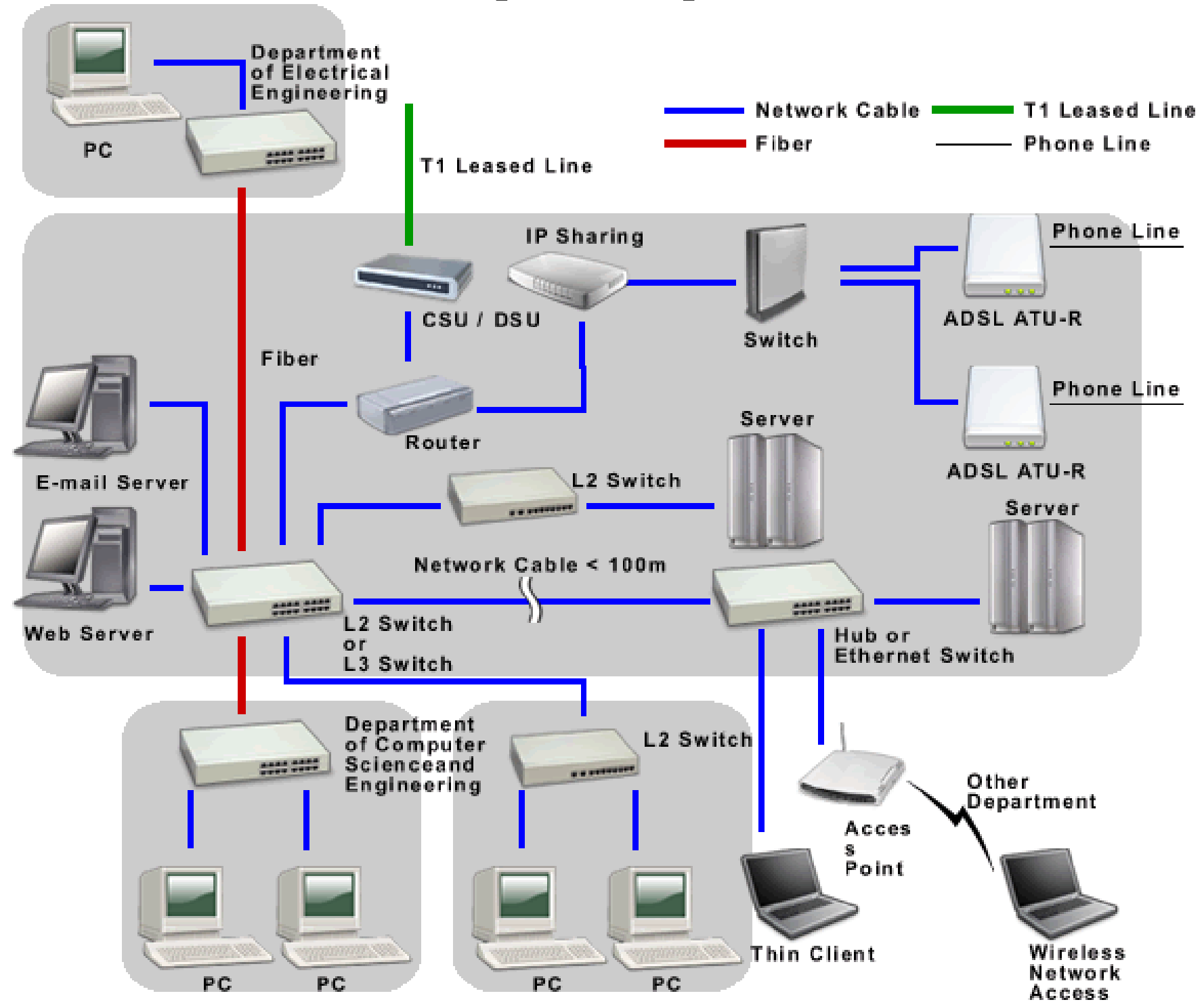


# An example of home computer network



What network do you have at home?

# Office/Enterprise computer network



# Computer network



- Why Network?
  - Devices can be shared (wired or wireless)
  - Easier to manage
  - Easier to maintain
  - Less expensive for equipment & software



# Computer network



- Why networking is important for BAS?
  - From centralised systems to distributed networks
    - Centralised systems
      - One large central computer + remote terminals
    - Distributed processing
      - Multiple smaller computers & devices, separated and connected through “networks”
- Advantages of **distributed processing**:
  - Performance, scalability, resilience & redundancy, cost-effectiveness, distributed applications



# Computer network



- Local area network (LAN)

- A computer network that spans a relatively small area, and with high-speed switched connections

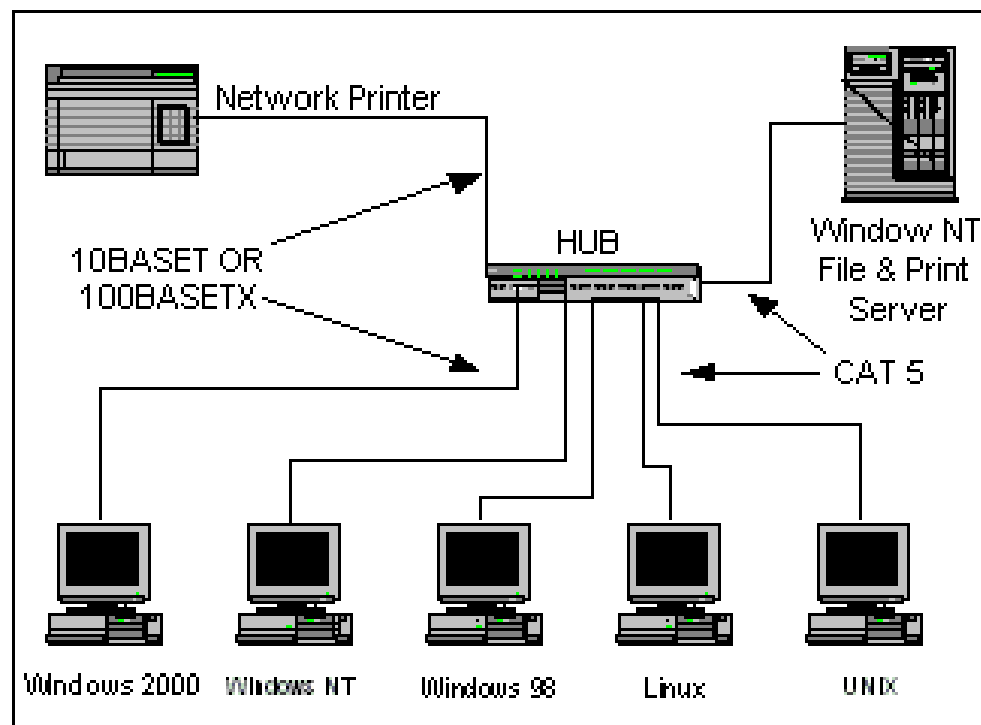
- Wide area network (WAN)

- A system of LANs connected over any distance via telephone lines and radio waves

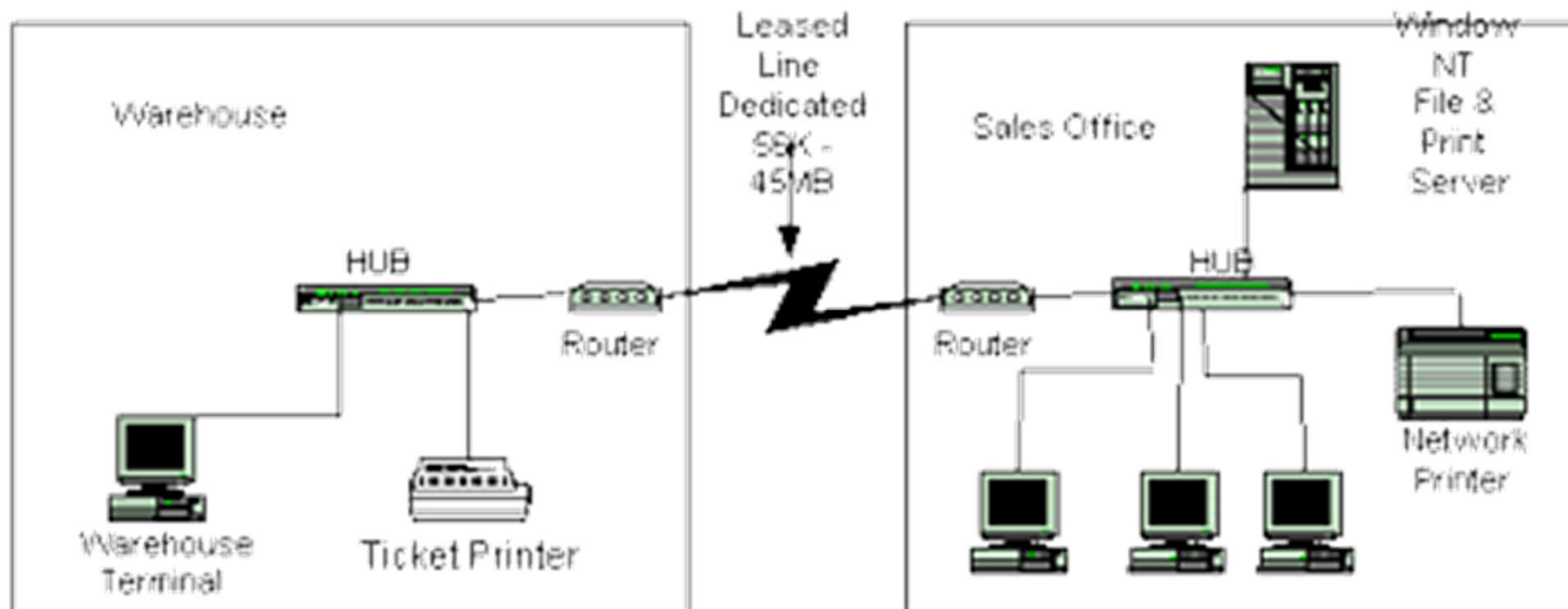
- Other types of network

- Metropolitan area network (MAN)
- Campus area network (CAN)
- Home area network (HAN), personal area network (PAN)

# Local Area Network (LAN)

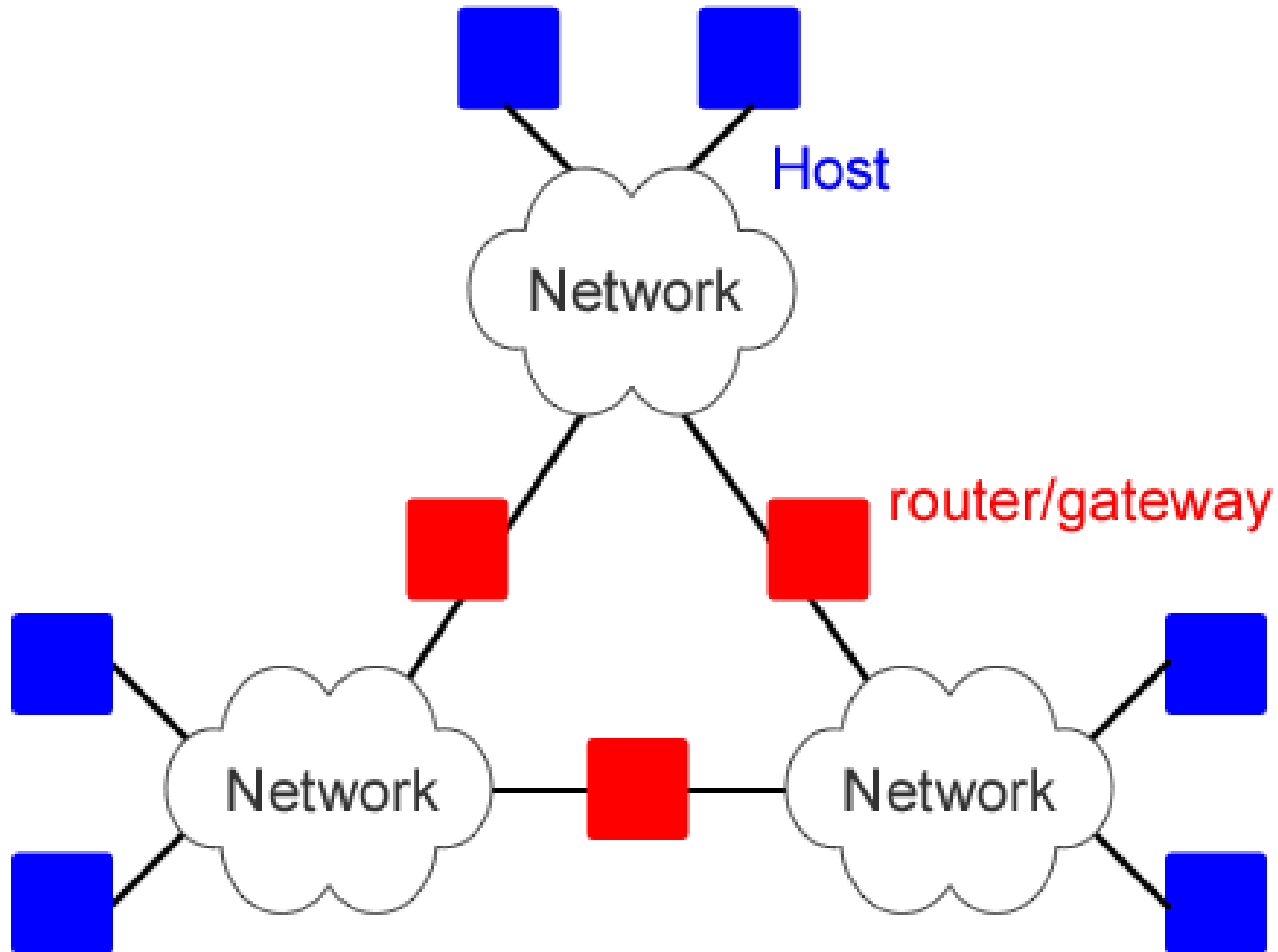


Local Area Network

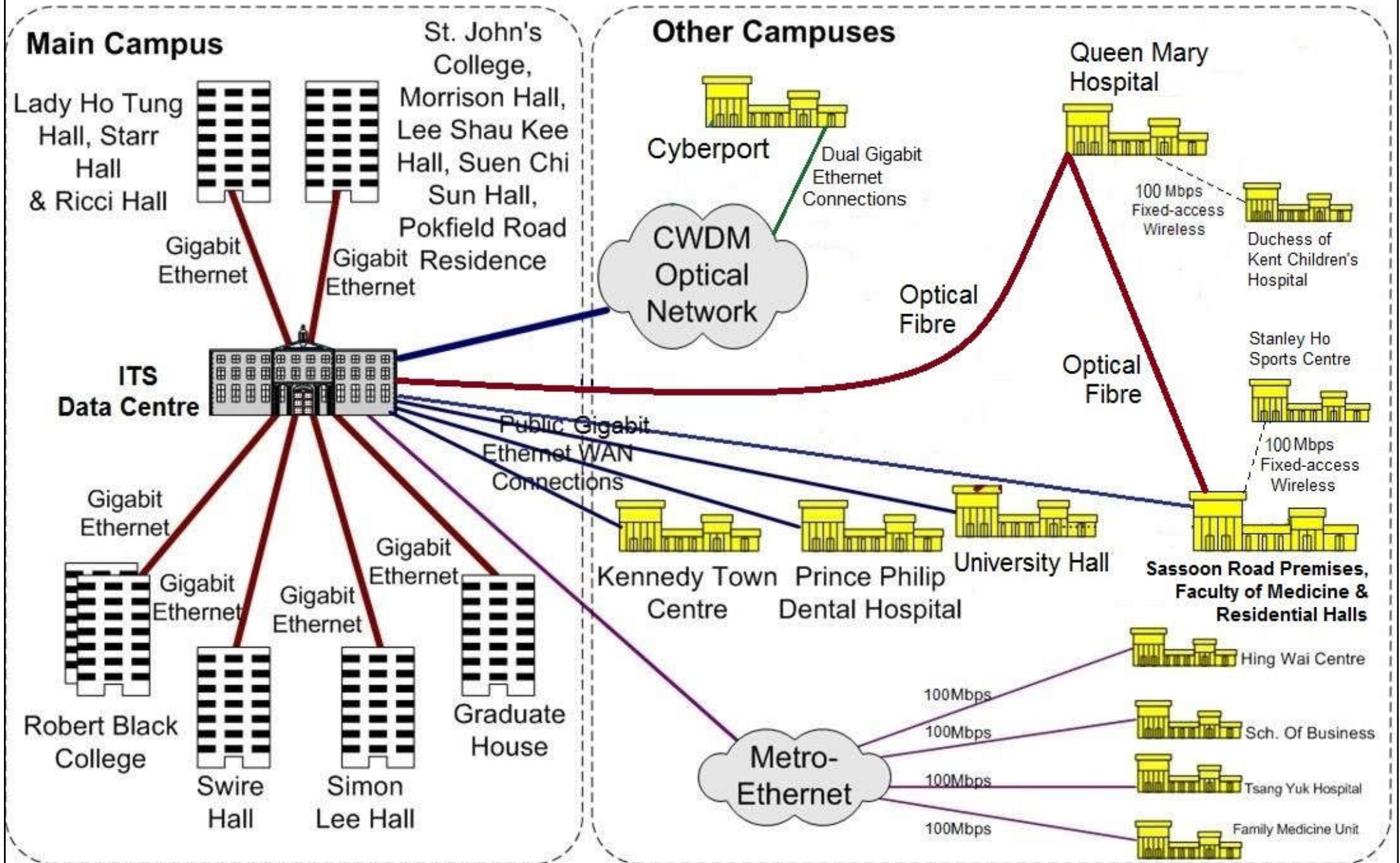


Wide/Metropolitan Area Network (WAN/MAN)

Internetworking (two or more computer network LANs or WAN or computer network segments are connected using devices)



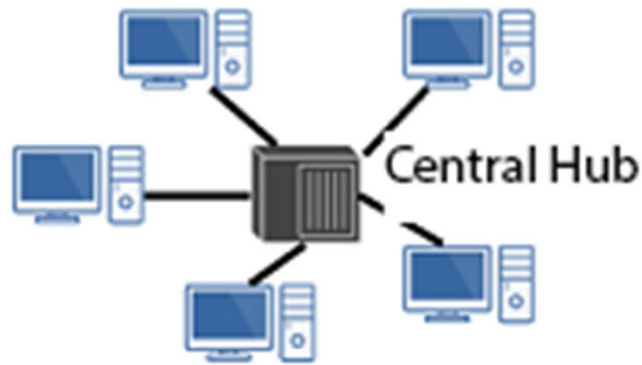
# Computer network of HKU remote campuses and residential halls



# Different types of network topologies



Ring



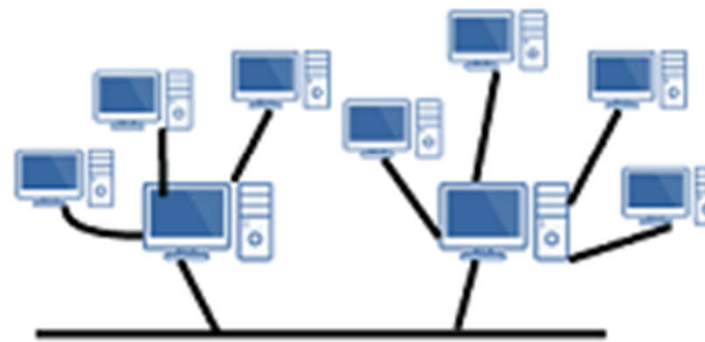
Star



Bus



Point to Point



Tree



Mesh

## Comparison of different types of network topologies

Types	Cost	Speed	Robustness	Used In
Star Topology	Less	Fast	No	WAN
Ring Topology	Less	Slow	No	LAN
Bus topology	Medium	Medium	Yes	LAN
Mesh Topology	Expensive	Fast	Yes	LAN
Tree Topology	Expensive	Medium	Yes	MAN

(Further info.: Compare and Contrast Network Topologies

<https://www.networkstraining.com/compare-and-contrast-network-topologies/>)



# Local area network

- Ideal LAN
  - As easy to use as an electrical distribution system
    - One-time installation (plugged in)
    - Widespread access (any device/component)
    - Application independence
    - Excess capacity, easy maintenance & administration
  - Current obstacles
    - No single standard, diverse requirements
    - Cost \$\$ of transmission media
    - Sophisticated functional requirements

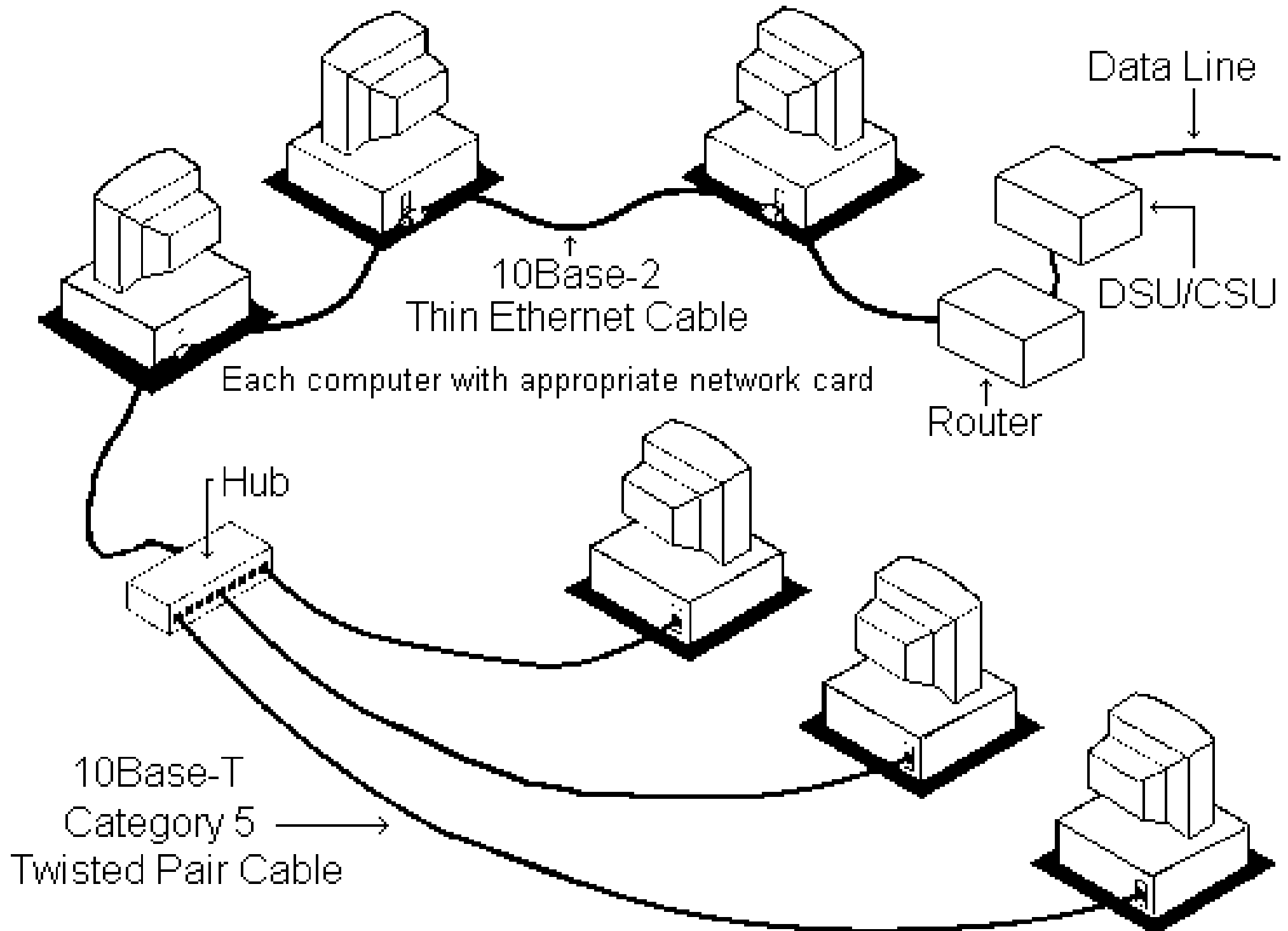


# Local area network

- Common LAN standards
  - Ethernet
    - ISO 8802-3 by Digital Equipment Corp., Intel Xerox
    - Peer-to-peer connection: carrier sense multiple access w/ collision detection (CSMA/CD)
    - Speed: 10 to 100 Mbps
  - ARCNET (Attached Resource Computer Network)
    - Developed by Data Point Corp.
    - Star or bus topology, peer-to-peer token-passing
    - Speed: 2.5 Mbps

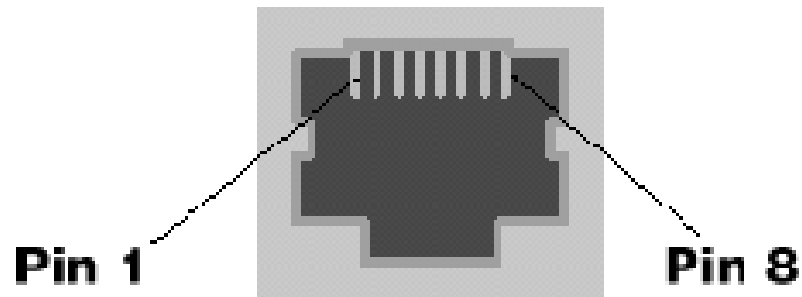


# Example of a wired Ethernet local area network



# Example of Ethernet port and connector

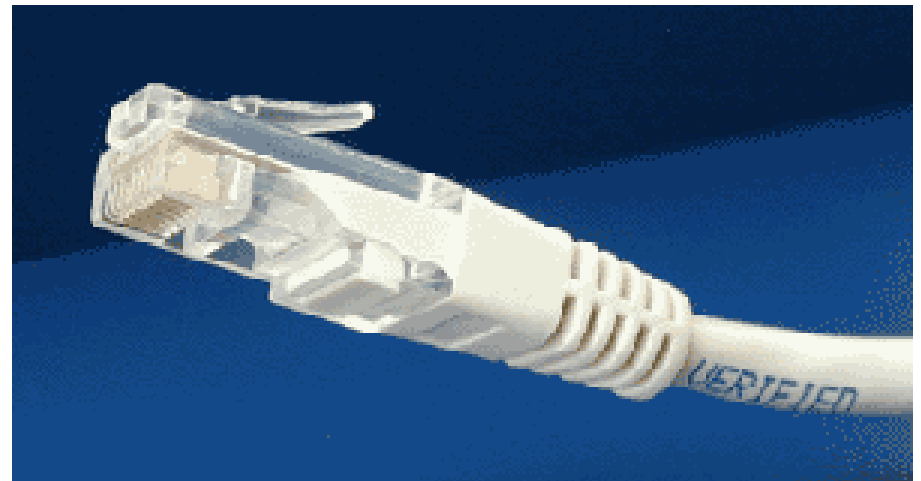
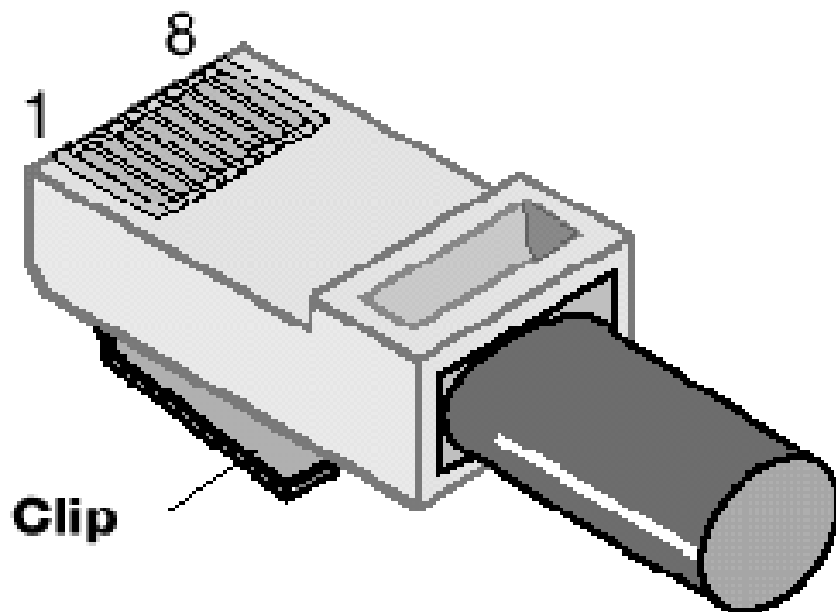
## Ethernet Port



“100 Base T” means:

- 100 Mbps
- Baseband signal
- Twisted pair

## RJ-45 Connector



RJ-45 = Registered Jack-45 (8-wire)  
(RJ-11: for telephone, 4- or 6-wire)

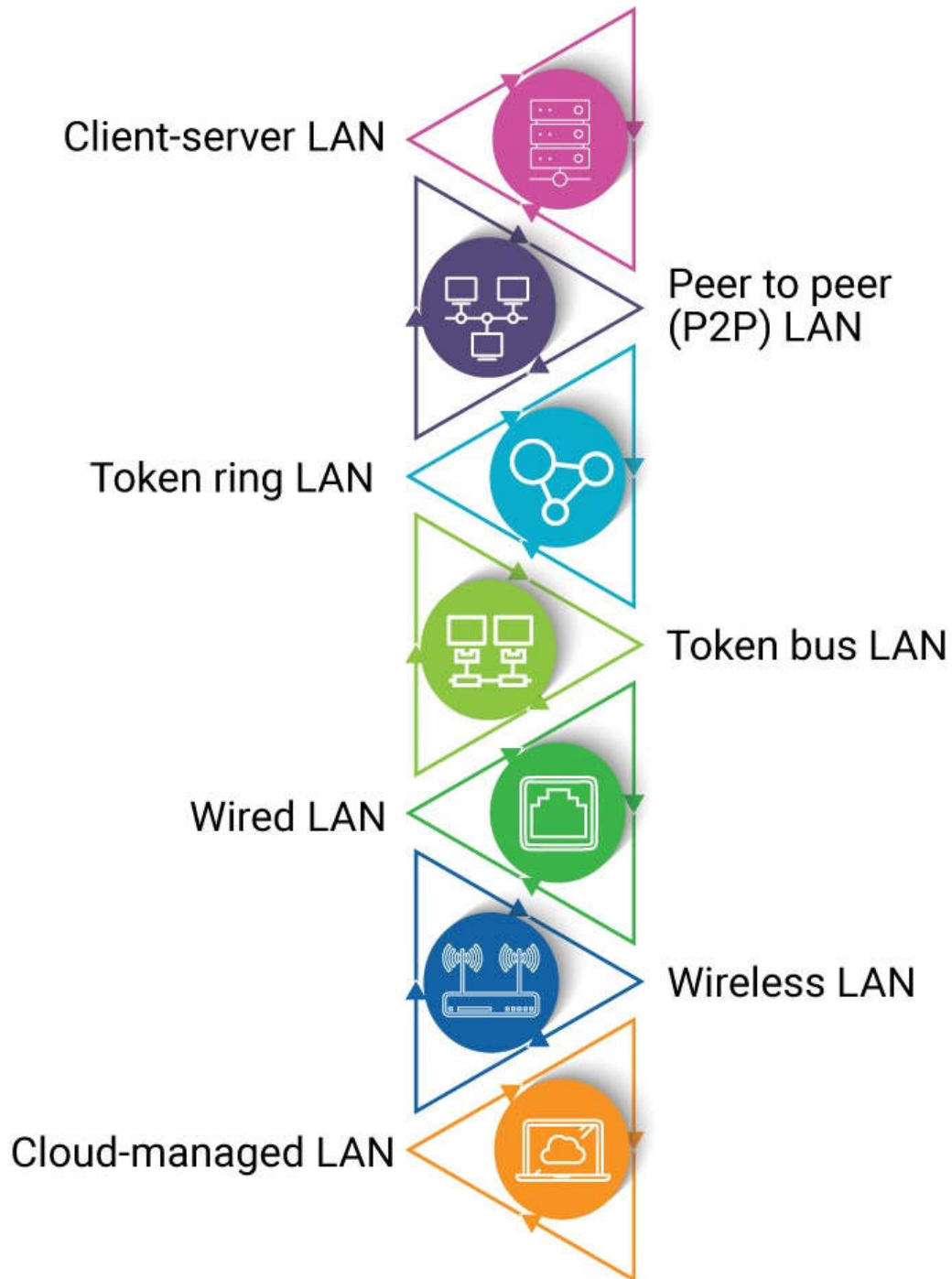


# Local area network

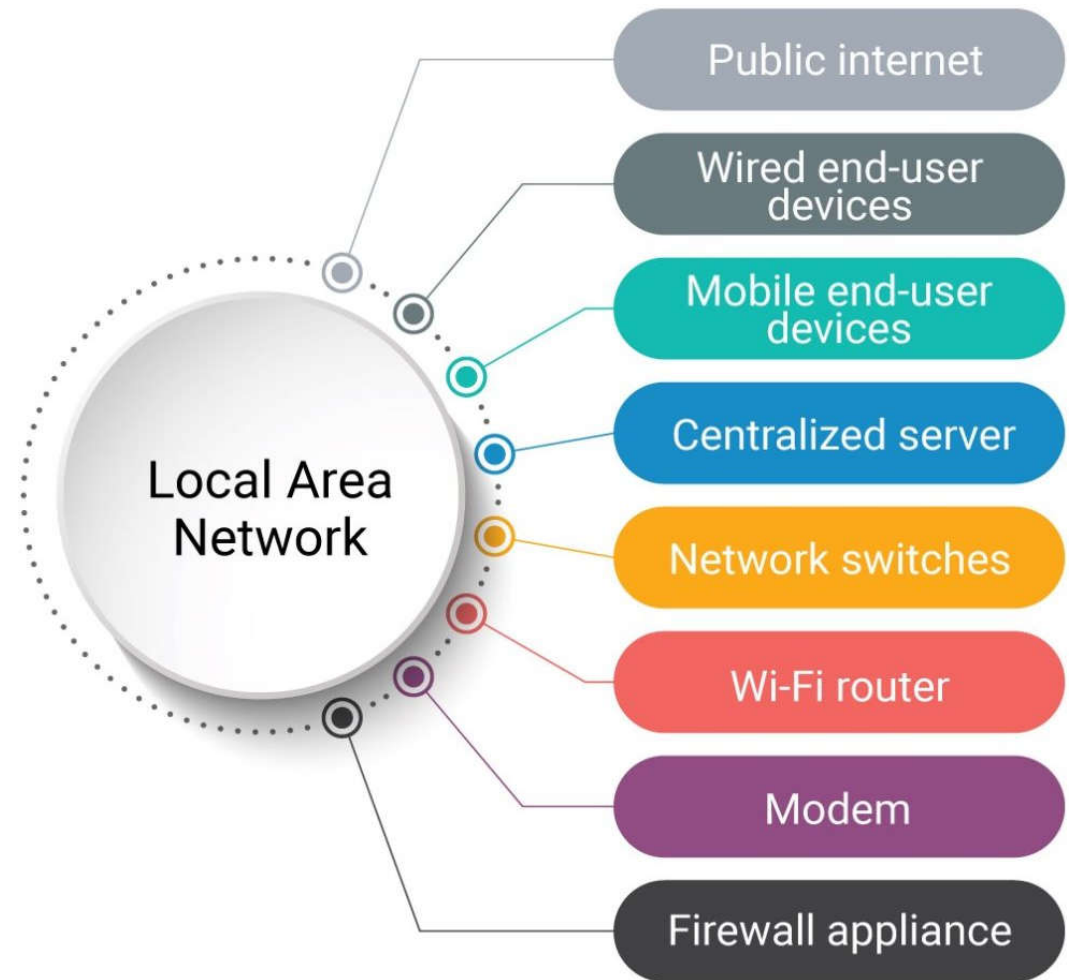
- Network speed
  - How fast is fast? (time to transmit 1MB of data)
    - 28.8 kps modem: 5 minutes
    - 56 kps modem: 2 min. 38 sec.
    - 128 kps (ISDN): 1 minutes
    - 1.544 Mbps (T-1): 5 seconds
    - 10 Mbps (10BaseT): 8 seconds
    - 100 Mbps (100BaseTX): 0.8 seconds
    - 1000 Mbps (1000BaseT1): 0.08 seconds
    - 10 Gbps (10GBaseT): 0.008 seconds

The world is  
going Gigabit!

# Types of local area network (LAN)



## Key components of LAN architecture



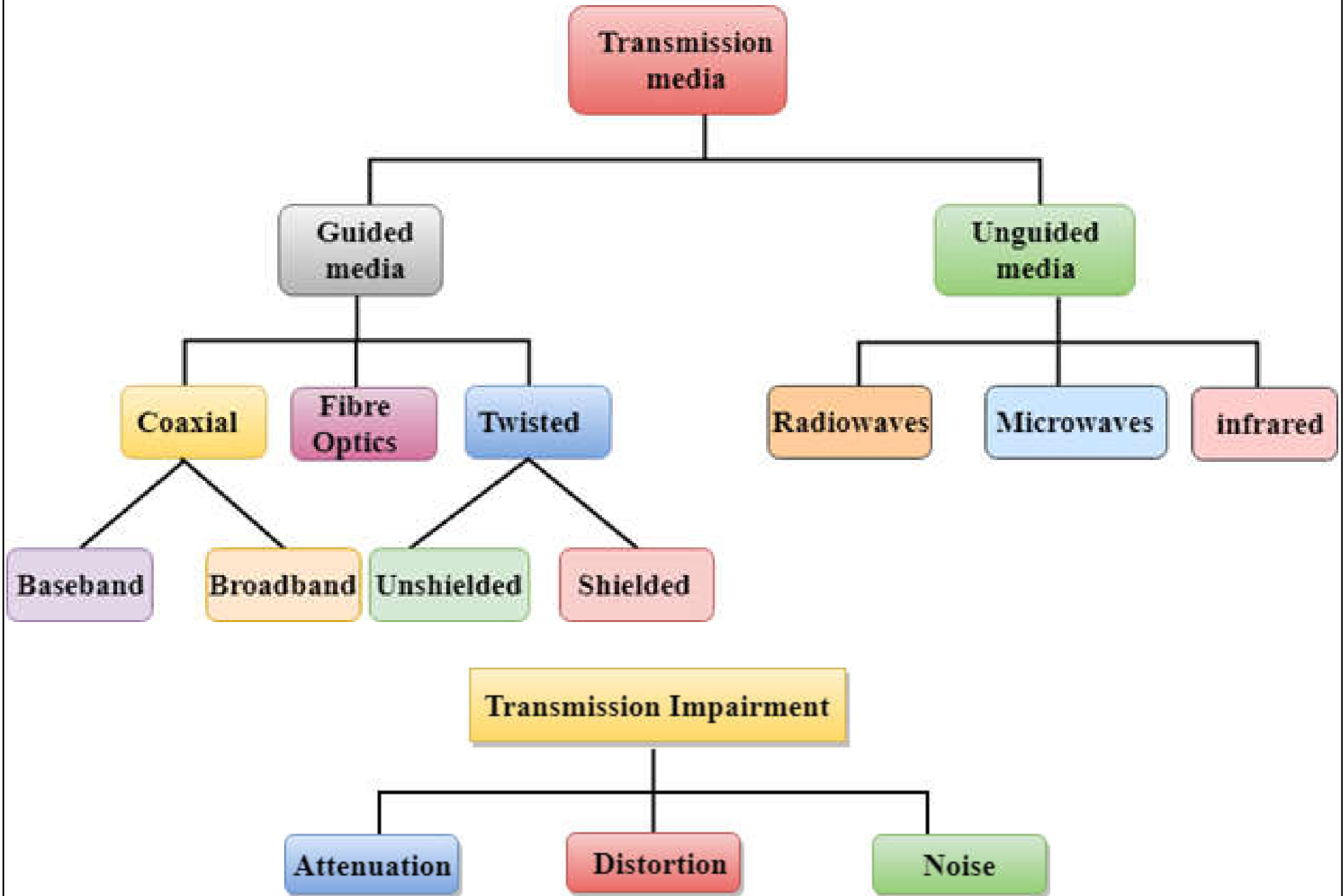


# Local area network

- Leading official standards organisation
  - IEEE 802 LAN/MAN Standards Committee ([www.ieee802.org](http://www.ieee802.org)) and its working groups
    - 802.1: Interface between OSI levels 1 & 2 with five higher level layers
    - 802.2: Logical data link
    - 802.3: CSMA/CD (Carrier Sense Multiple Access /Collision Detection)
    - 802.4: Token bus
    - 802.5: Token ring
    - 802.11: Wireless LAN



# Network transmission media/methods and transmission impairment





# Transmission methods

- Transmission methods/media

- Twisted pairs (TP)

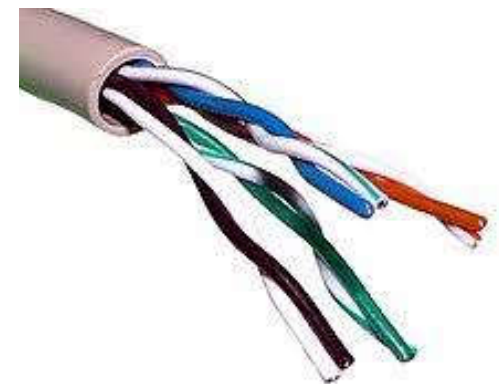
- Two insulated conductors twisted together to minimise interference by unwanted signals

- Line bandwidth (300-3000 Hz)
      - Signal-to-noise ratio
      - Conditioning (of the line)

- Conditioned line has speed up to 9600 bps

- In most cases, 1200 bps is maximum

- Unshielded twisted pairs (UTP)



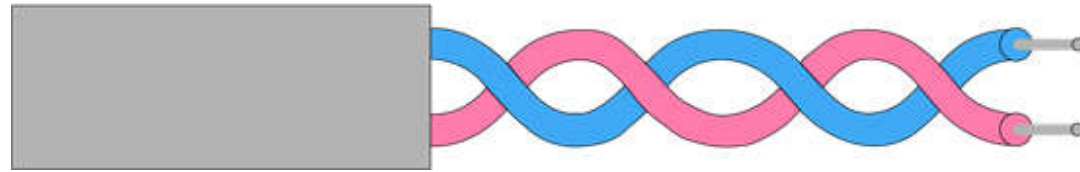
# Example of twisted-pair cables



Jacket

Twisted Pair

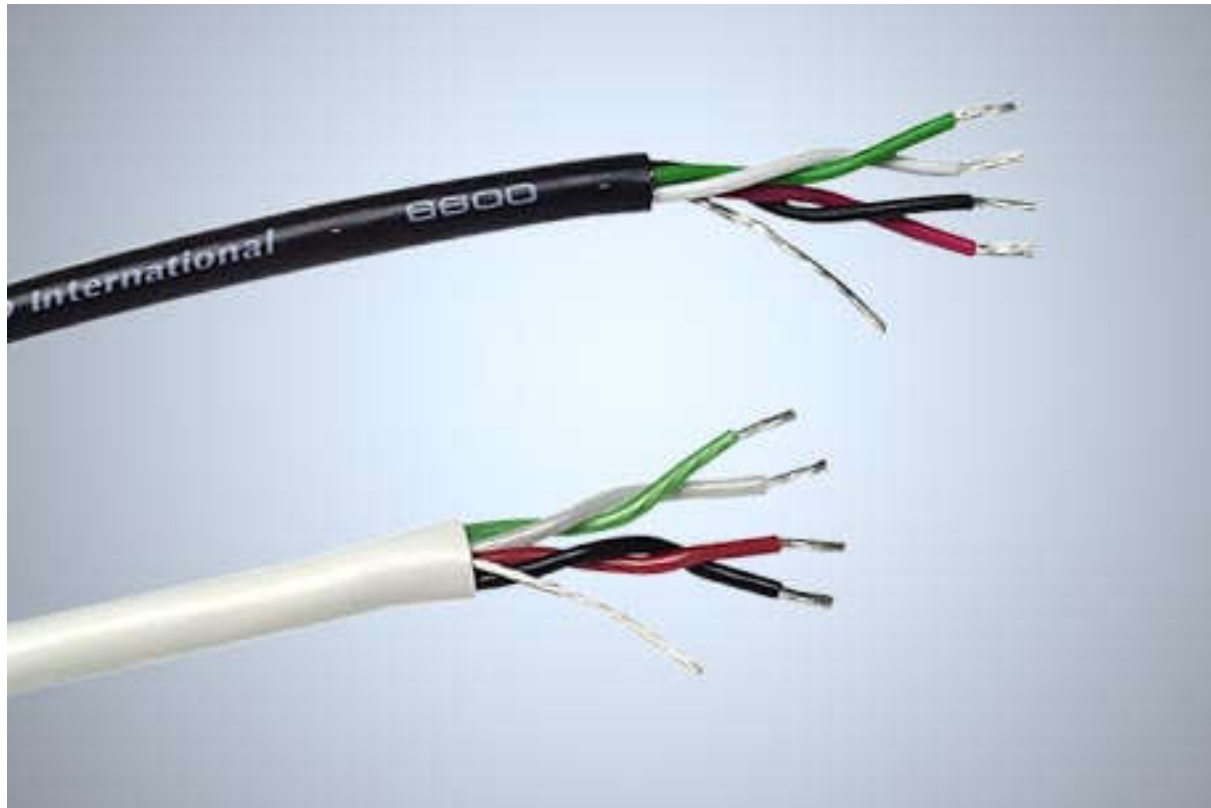
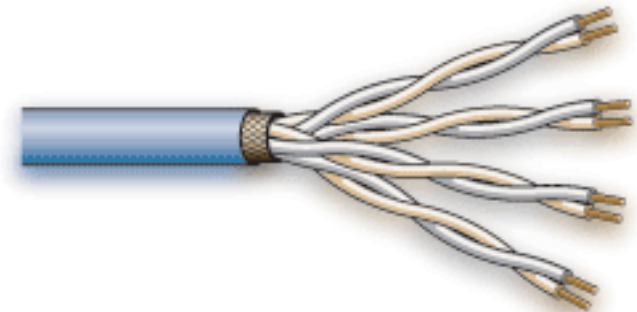
Bare Wire



**Unshielded twisted-pair**



**Foiled twisted-pair**



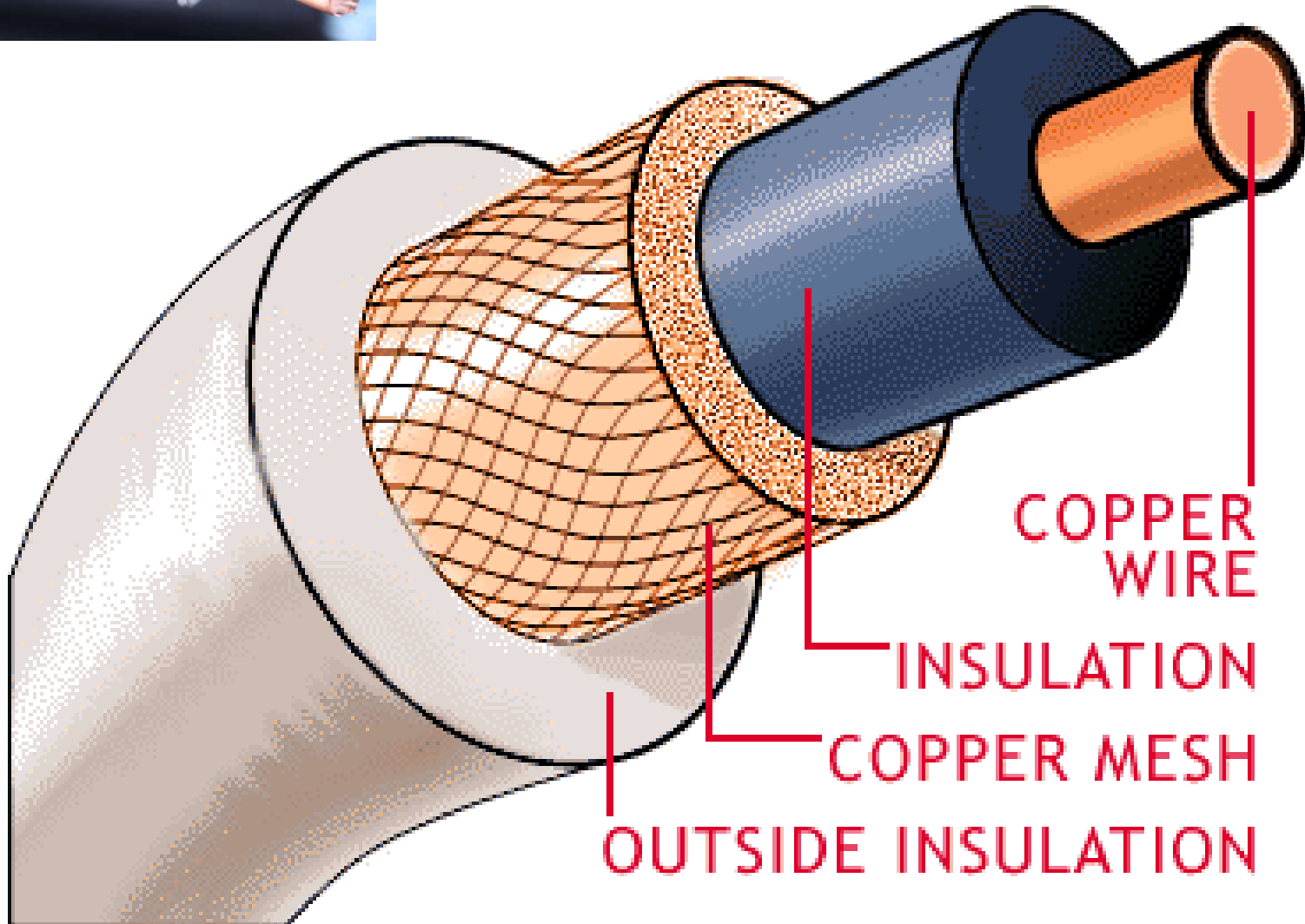
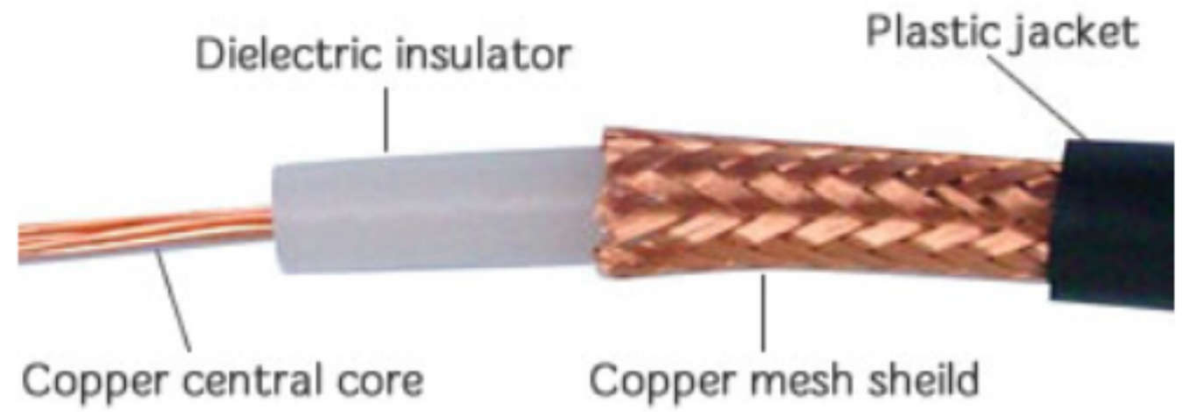
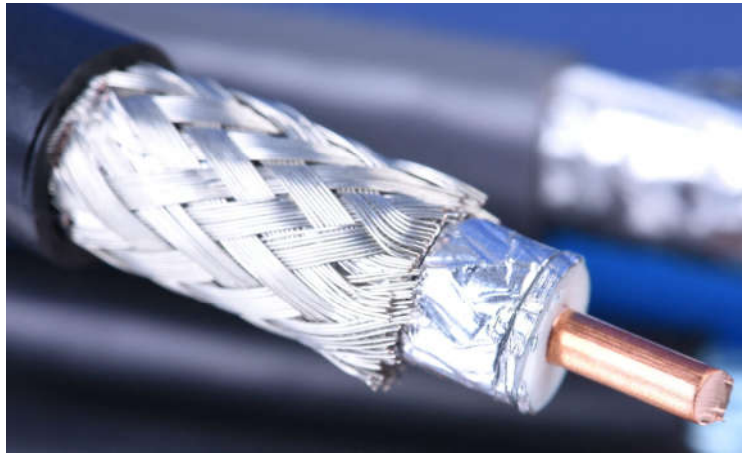




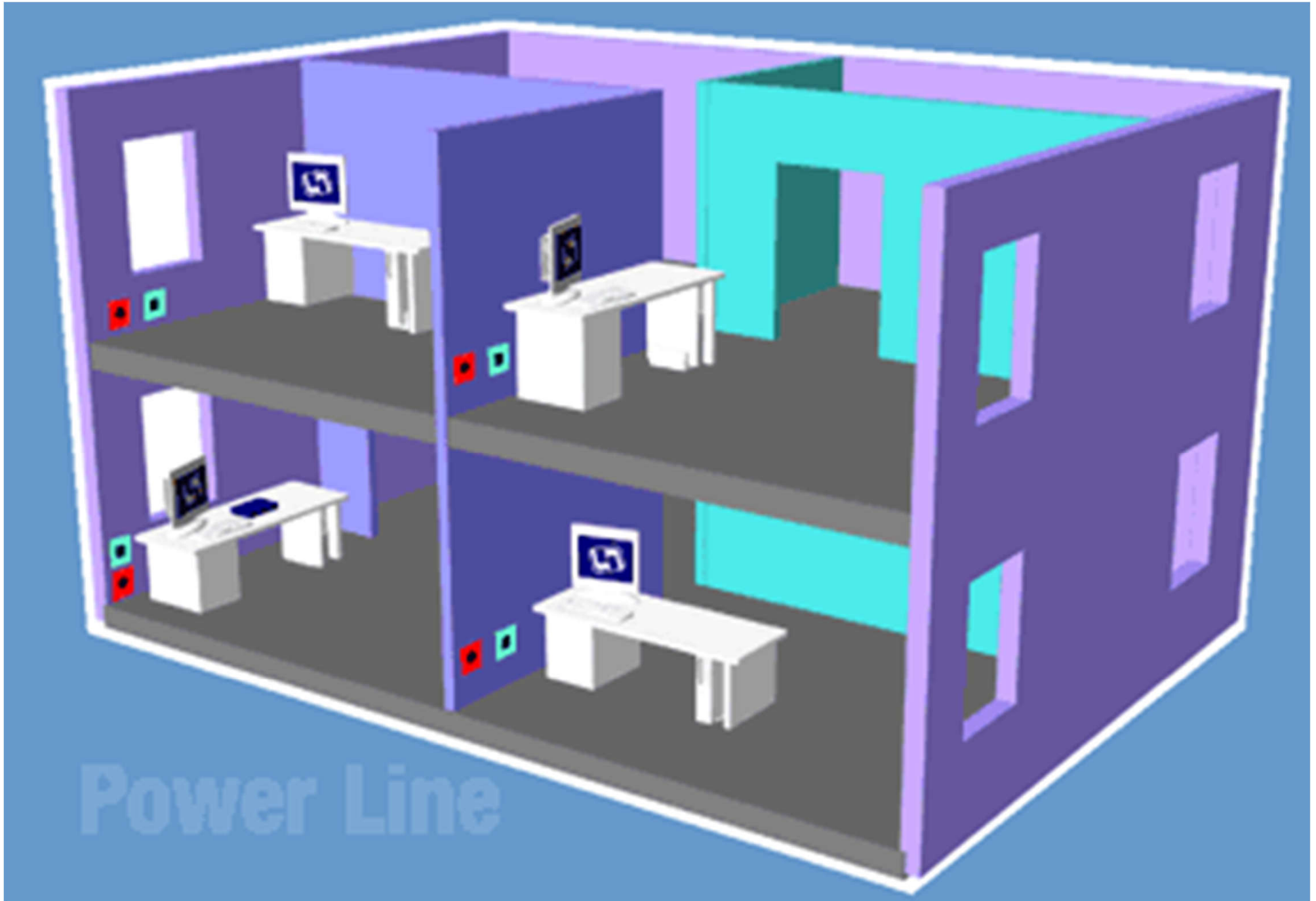
# Transmission methods

- Transmission methods/media (cont'd)
  - Voice grade lines
    - Type 3002 in in the Bell Telephone Company's standard BSP41004
  - Coaxial cable
    - Centre conductor surrounded by a shield
    - Electromagnetic interference
  - Power lines carrier (PLC)
    - Using carrier current transmission that superimposes a low RF signal (100 kHz) onto the 50/60 Hz power distribution system

# Coaxial cable



# Power line carrier

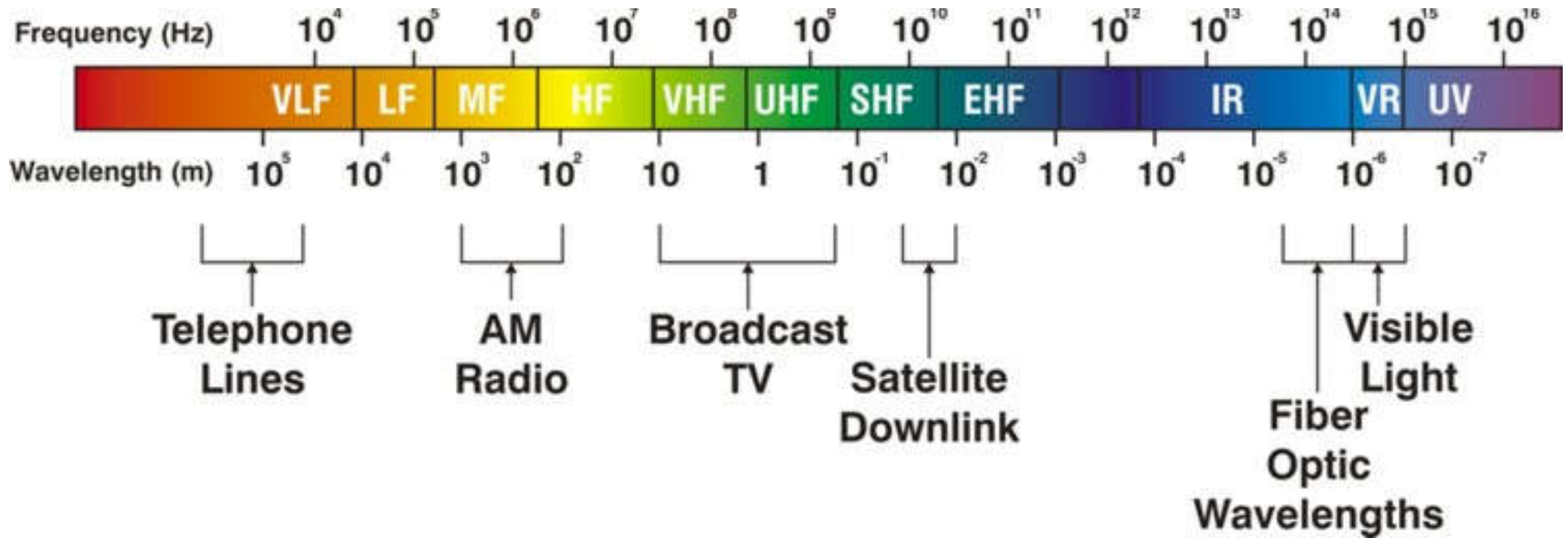
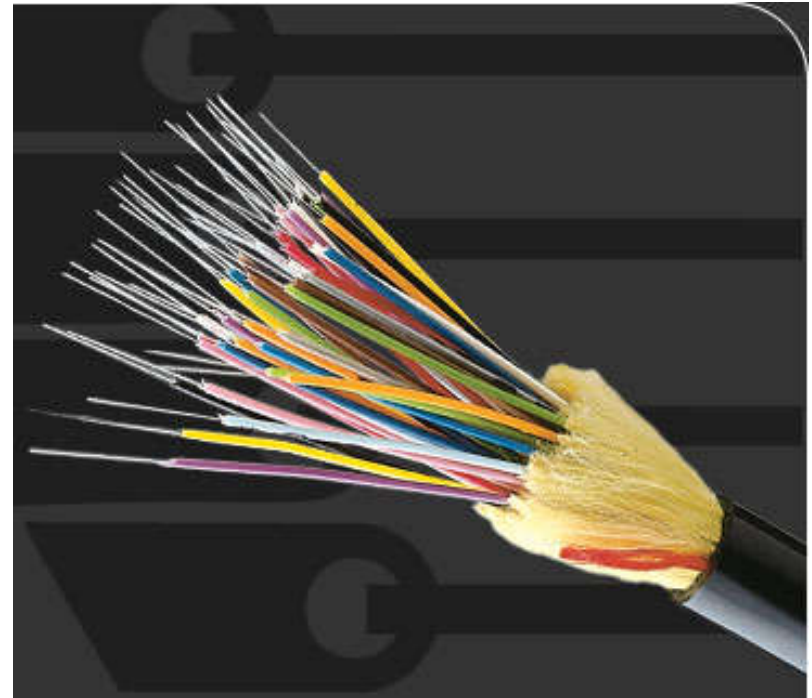
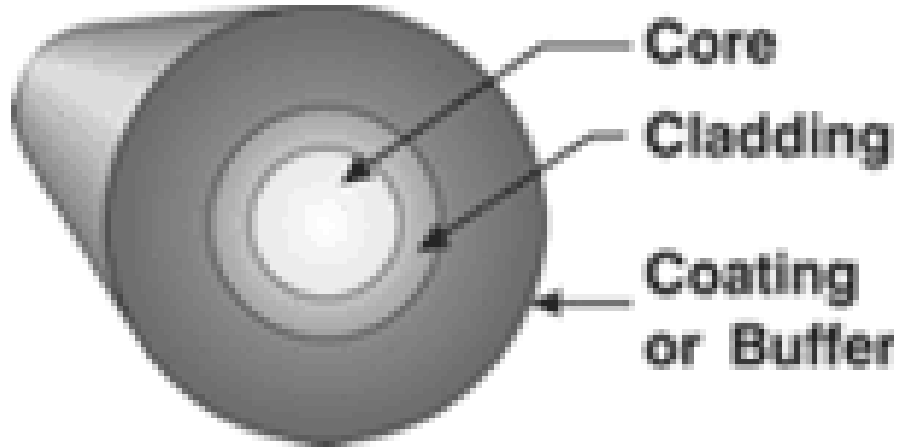




# Transmission methods

- Transmission methods/media (cont'd)
  - Radio frequency (RF)
    - Modulated RF, with radio receivers and transmitters
  - Microwave
    - Terrestrial and satellite microwave
    - Used by TV stations, very high cost
  - Fibre optics
    - Infrared light travelling through transparent fibres
    - Best suited for point-to-point high speed transmission
    - Bandwidth virtually unlimited

# Fibre optics transmission



# Comparison of transmission methods

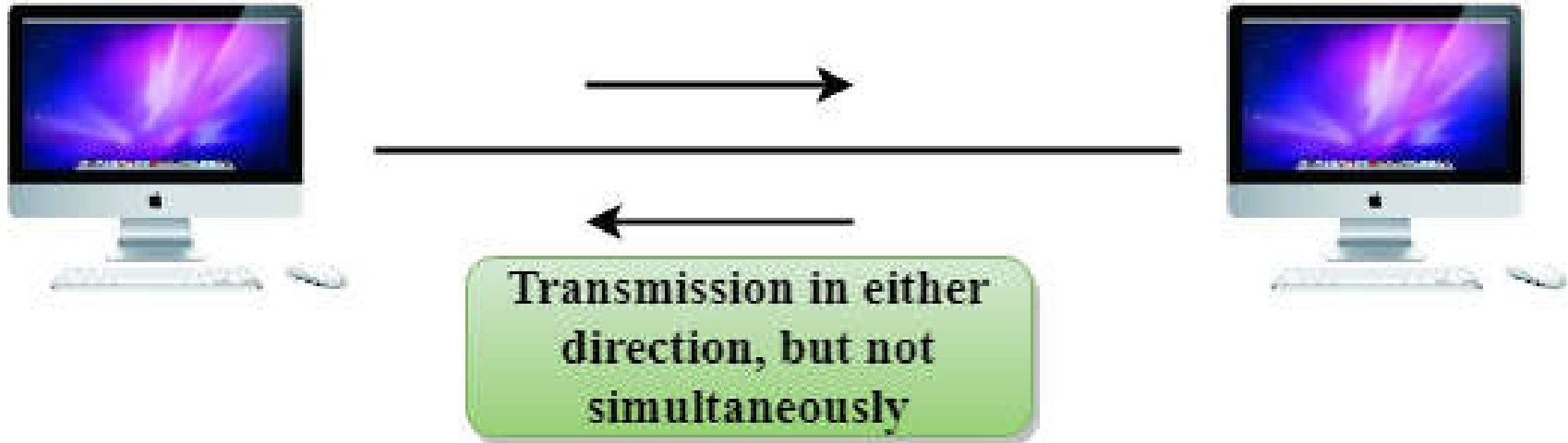
<b>Method</b>	<b>First cost</b>	<b>Scan rates</b>	<b>Reliability</b>	<b>Maint. Effort</b>	<b>Expand-ability</b>	<b>Compati-bility</b>
Coaxial	High	Fast	Excellent	Min.	Unlimited	Unlimited
Twisted pair	High	Medium	Very good	Min.	Unlimited	Limited
Radio frequency	Medium	Fast but limited	Low	High	Very limited	Very limited
Microwave	Very high	Very fast	Excellent	High	Unlimited	Unlimited
Telephone	Very low	Slow	Low to high	Min.	Limited	Limited
Fibre optics	High	Very fast	Excellent	Min.	Unlimited	Unlimited

# Transmission modes of computer network

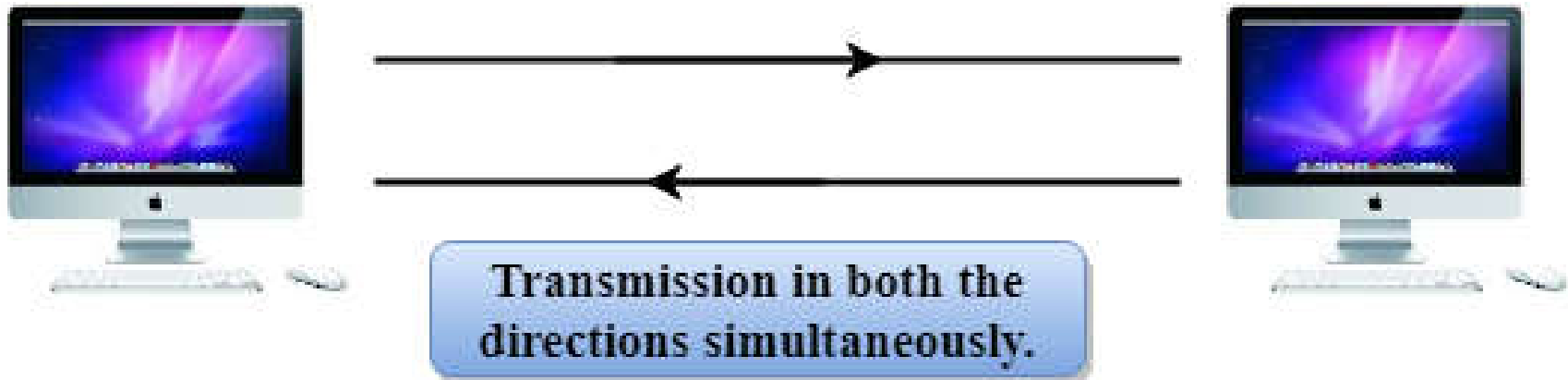
(a) Simplex mode



(b) Half-duplex mode



(c) Full-duplex mode





# Transmission methods

- MODEM = modulator/demodulator
  - Communicate between field panels & controllers
  - Impose info in binary form onto carrier waves

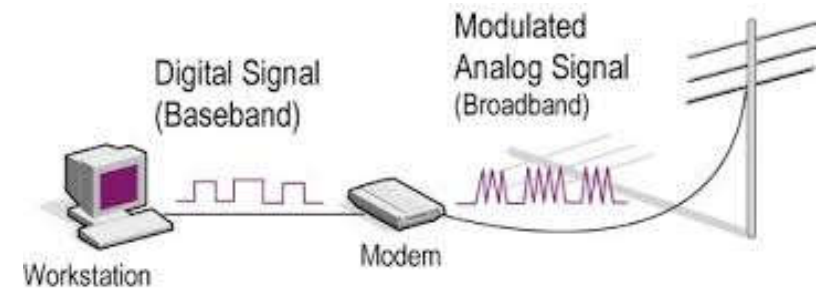
- Two classifications:

- Baseband

- Using differential current pulses for transmission
    - Short range: 2-3 miles

- Broadband

- Frequency, amplitude, or phase characteristics are modulated



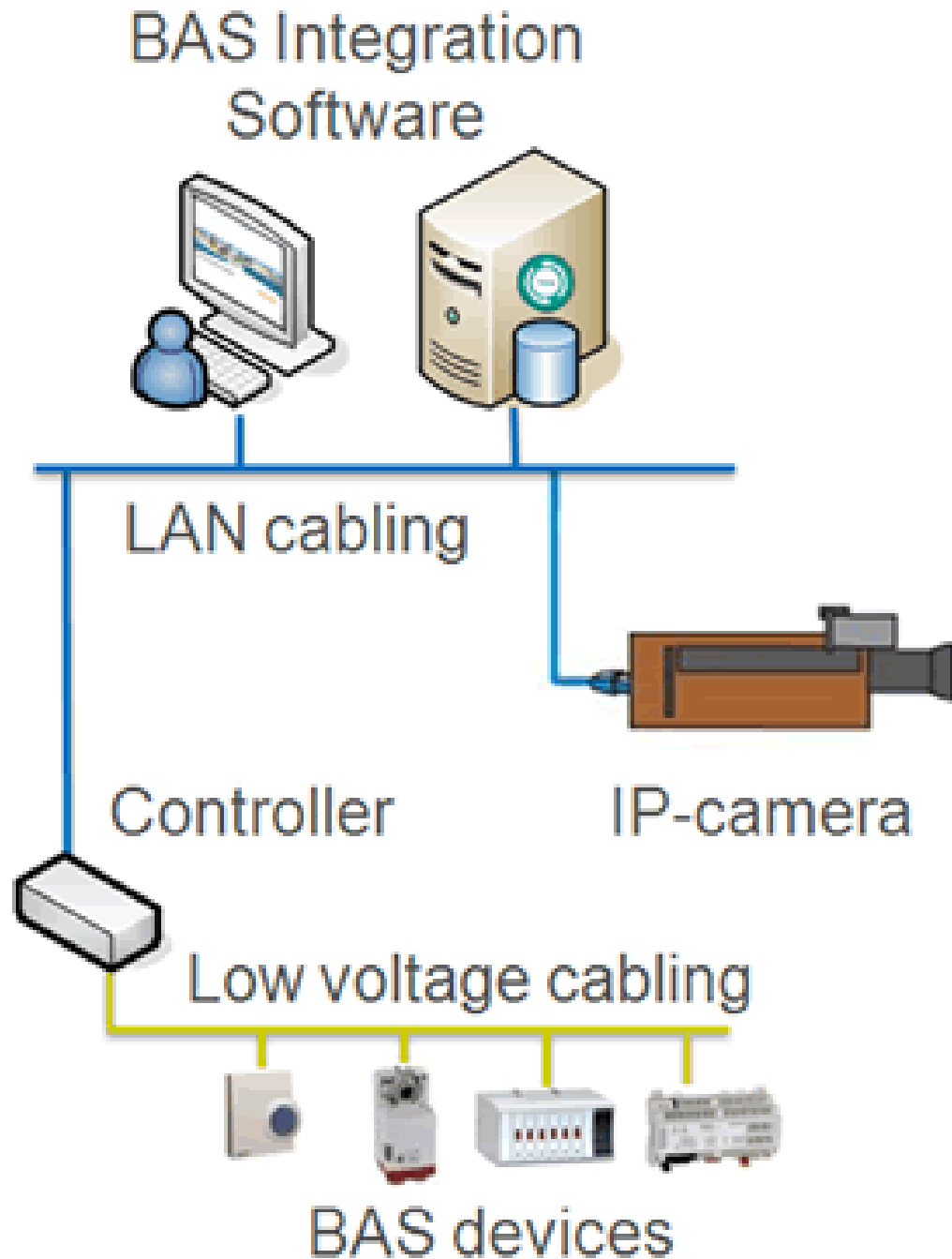


# Networking infrastructure



- Networking infrastructure and BAS
  - It enables effective, efficient & secure communication between people, devices, and the network
  - Because a network is capable of communicating with more devices, operators can more easily & quickly be alerted to failures or potential failures and data can be gathered to evaluate maintenance and operational effectiveness

# Integrate LAN cabling with BAS devices in a converged network



Structured LAN cabling connections, represented by **blue lines**, from a BAS server to an IP-enabled camera and a controller in a basic converged cabling example.

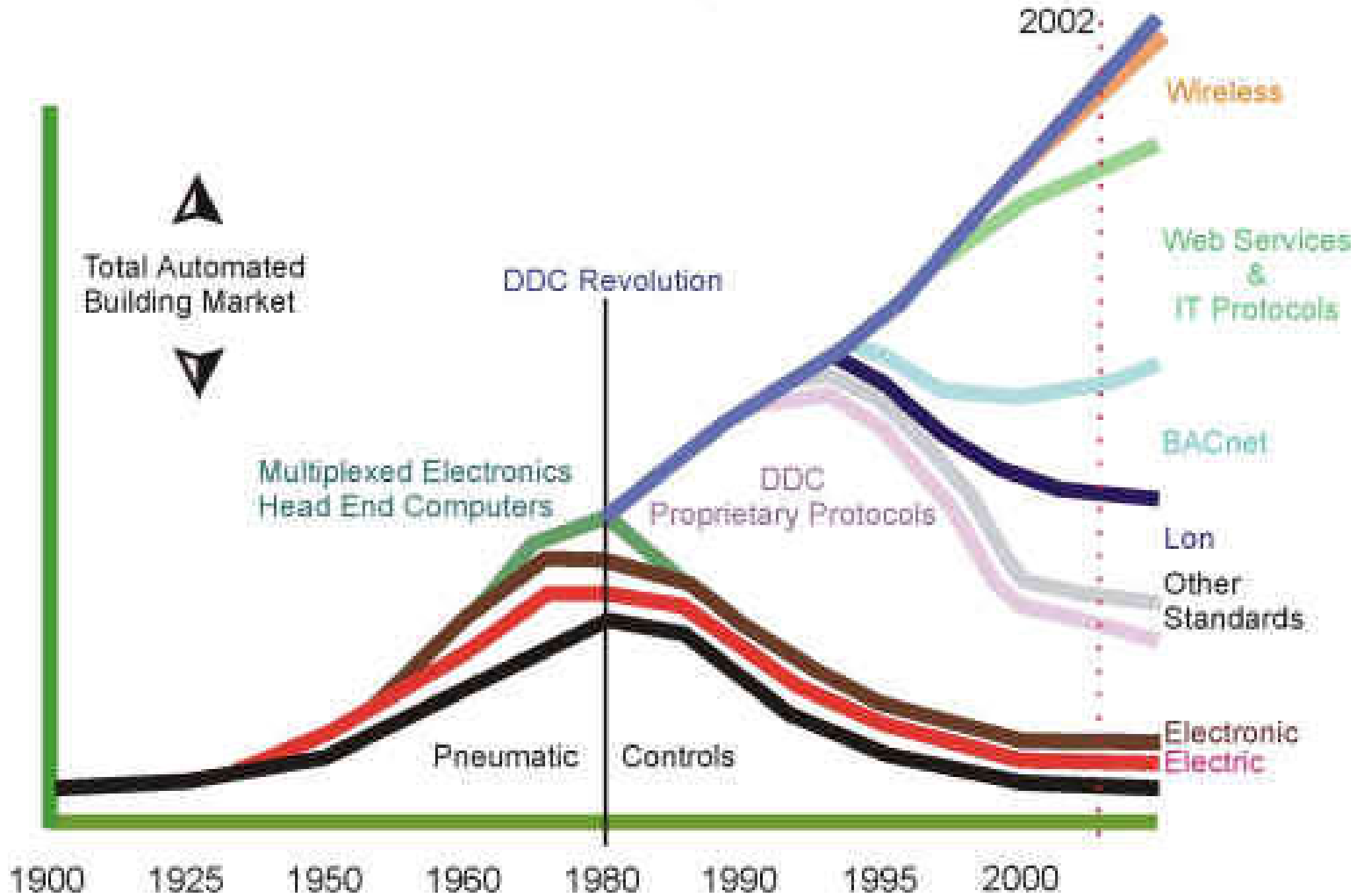
The cabling from the controller to the BAS devices, represented by **green lines**, is typically application dependent low voltage wiring.

# Networking infrastructure



- Advantages of network-based systems
  - Easier & more convenient monitoring
  - Improved energy efficiency
  - Simplified system maintenance
  - Self-balancing & self-setup
- Integrated facility networks (IFNs)
  - To streamline building O&M (operation & maintenance) activities
  - To monitor & control the systems/equipment

# Automated Buildings Evolution



# Networking infrastructure



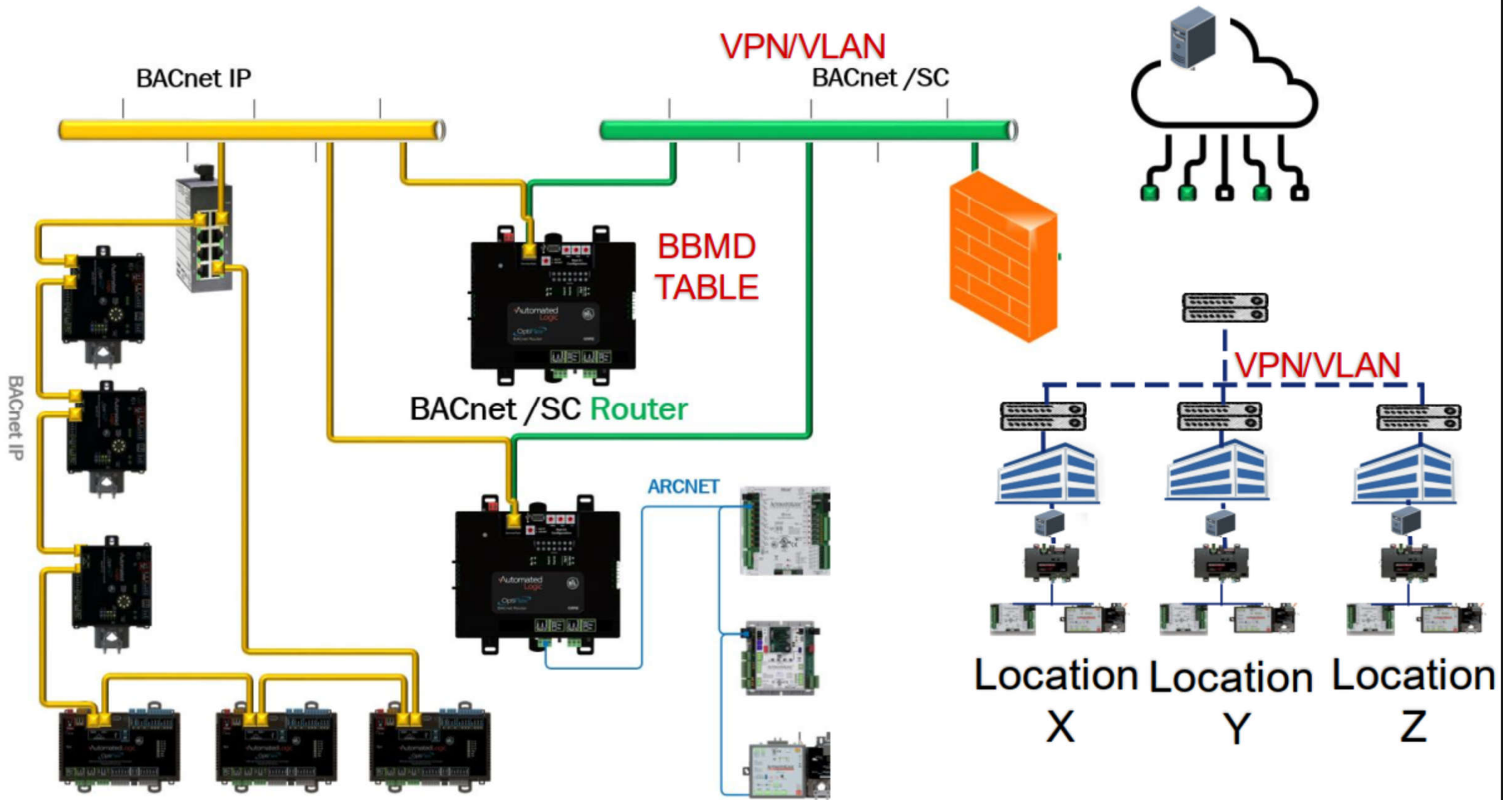
- History of building automation (BA)
  - Early 1600s: Invention of the thermostat
  - 1884: Invention of the modern light switch
  - Early 20th century: Homes go electric
  - Around 1925: Invention of the heat regulator
  - 1960s: Networking of buildings
  - 1969: The advent of digital control
  - 1979/1980: BA goes digital DDC, high-speed data transfer
  - 1986: Building information modelling (BIM)
  - 1987 and 1990: The advent of non-proprietary standards
  - 1998/1999: Global networking (The Internet & Wi-Fi)

# Networking infrastructure



- History of building automation (BA) (cont'd)
  - 2005: Home automation gains momentum in Germany
  - 2007: Smartphones propel a great leap forward
  - 2008: Building automation joins the cloud (cloud-based services)
  - 2009: Wireless control of lighting
  - 2010: Always on the go, always online
  - 2014: Text-to-speech (TTS) technology
  - 2016: The Internet of Things (IoT) networks building technology
  - 2018: A “brain” for buildings
  - 2020: Turnkey artificial intelligence (AI) & intelligent video techno.
  - The near future: A boom in cloud-based services

# An example of BAS topologies with Cloud



BACnet = Building Automation and Control Networks

IP = Internet Protocol

SC = Secure Connect

VLAN = virtual local area network

VPN = virtual private network

# Networking infrastructure



- Telecommunication services and systems in HK (HK: the Facts – telecommunications

<http://www.gov.hk/en/about/abouthk/factsheets/docs/telecommunications.pdf>

- Local Fixed Carrier Services
- Fixed Broadband Services
- External Telecommunications Services
- External Telecommunications Facilities
- Mobile Services



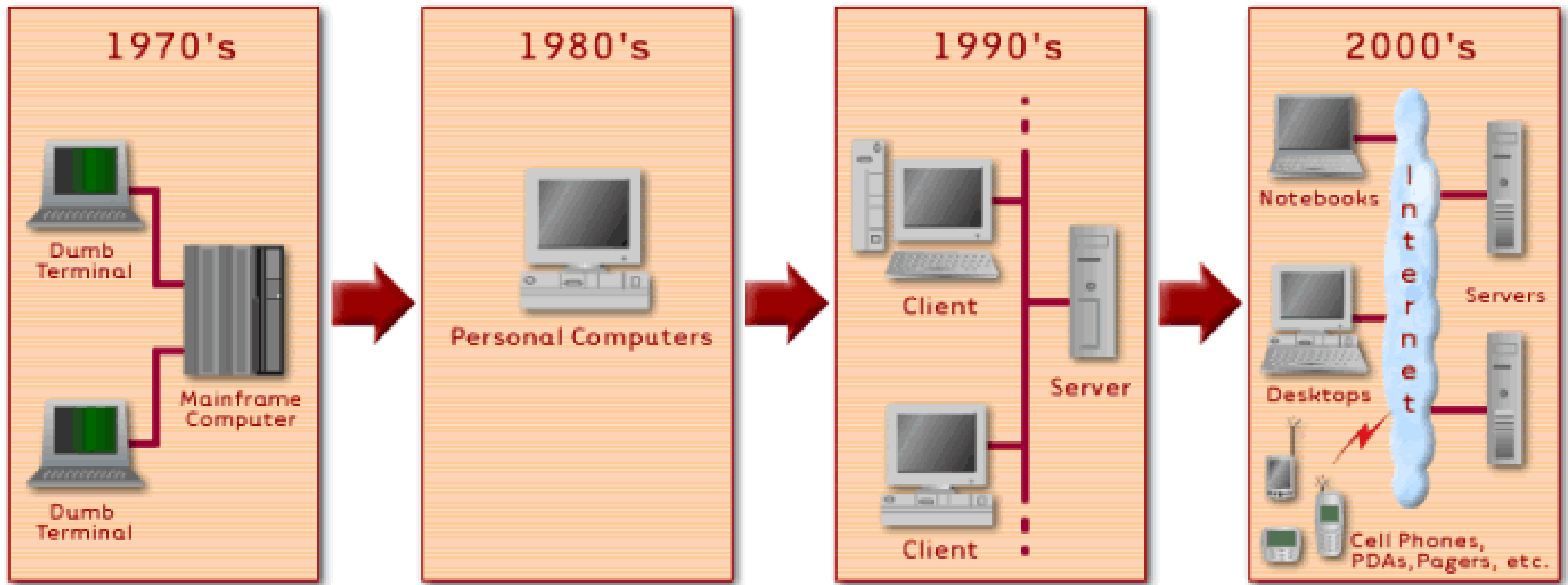


# Key Telecommunications Statistics (Hong Kong)

<b>Telecommunications Services</b>	<b>Quantity</b>
Mobile network operators (Aug 2023)	5
Mobile virtual network operators (Aug 2023)	23
Local fixed network operators (Aug 2023)	26
External fixed telecommunications services operators (Aug 2023)	190
- Facility-based external fixed network operators (Aug 2023)	39
- Services-based external telecommunications services operators (Aug 2023)	151
Residential fixed line penetration rate (Jun 2023)	71.5%
Mobile subscriber penetration rate (Jun 2023)	301.9%
Mobile subscriptions (Jun 2023)	23,179,949
Mobile broadband subscriptions (Jun 2023)	23,166,222
<b>Internet Services</b>	<b>Quantity</b>
Internet service providers (Aug 2023)	296
Registered subscriptions with broadband access (estimated) (Jun 2023)	2,988,907
Household broadband penetration rate (Jun 2023)	99.2%
Fire-to-the-home/building (FTTH/B) household penetration rate (June 2023)	85.1%
- FTTH (69.6%) and FTTB (15.4%)	
Public Wi-Fi access points (as at August 2023)	86,880

(Source: [https://www.ofca.gov.hk/en/news\\_info/data\\_statistics/key\\_stat/](https://www.ofca.gov.hk/en/news_info/data_statistics/key_stat/))

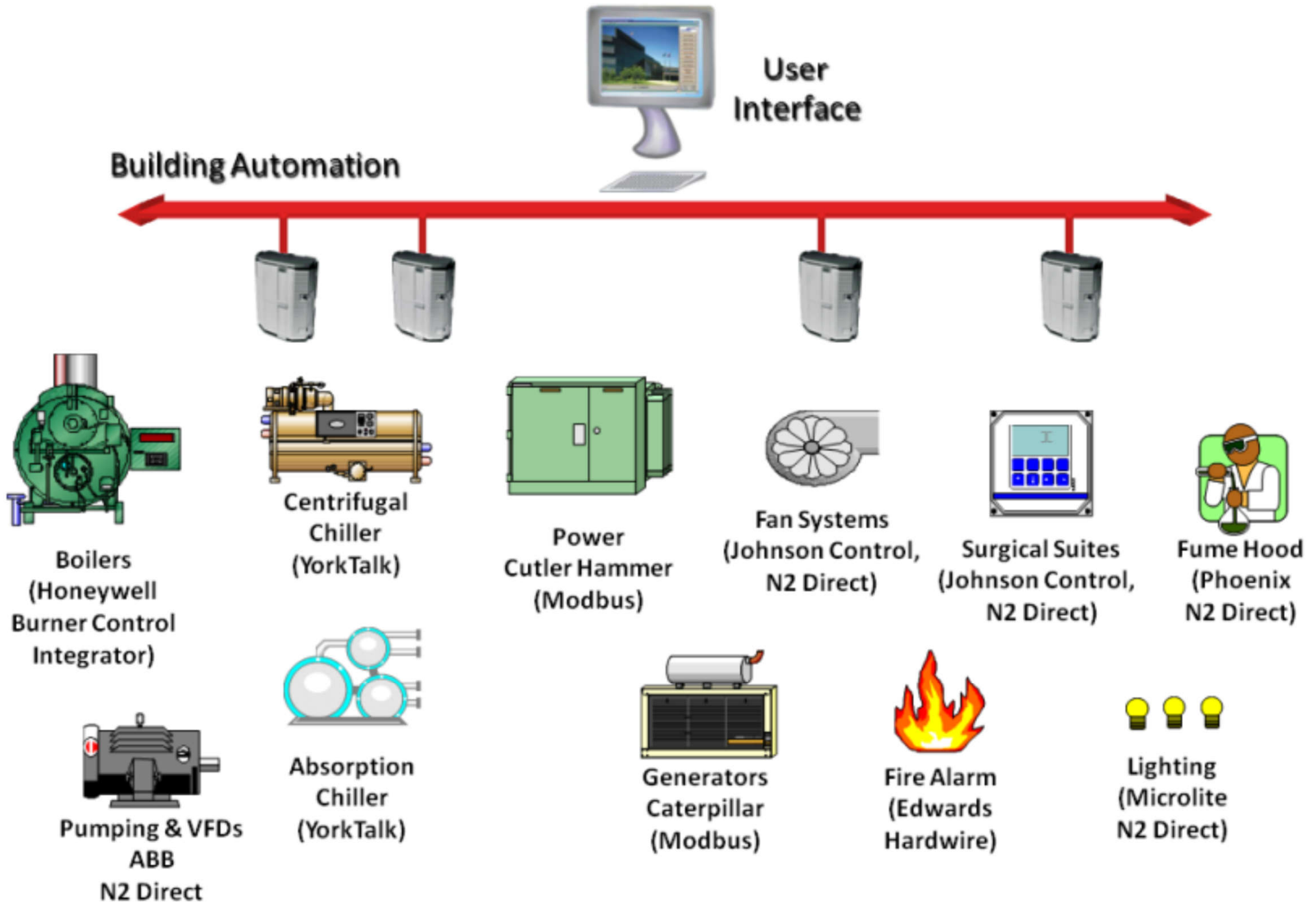
# Evolution of Information Technology and trends of Web revolution



The trends of IT and Web revolution:

1. Content is becoming dynamic - The first web pages were static. Today, sites provide up-to-the-minute content.
2. Bandwidth is getting cheaper – There will be enough bandwidth for a full-motion video channel. Bandwidth is growing exponentially cheaper year after year.
3. Storage is getting cheaper - The capacities of hard drives, DVDs, CD-ROMs, and removable storage media are far greater than they were a few years ago.
4. Enterprise computing is becoming more important - Integrate information from desktop PCs with mobile phones on the low-end and with mini and mainframe-based corporate information systems on the high-end is increasing.

# The need to integrate different sub-systems of BAS

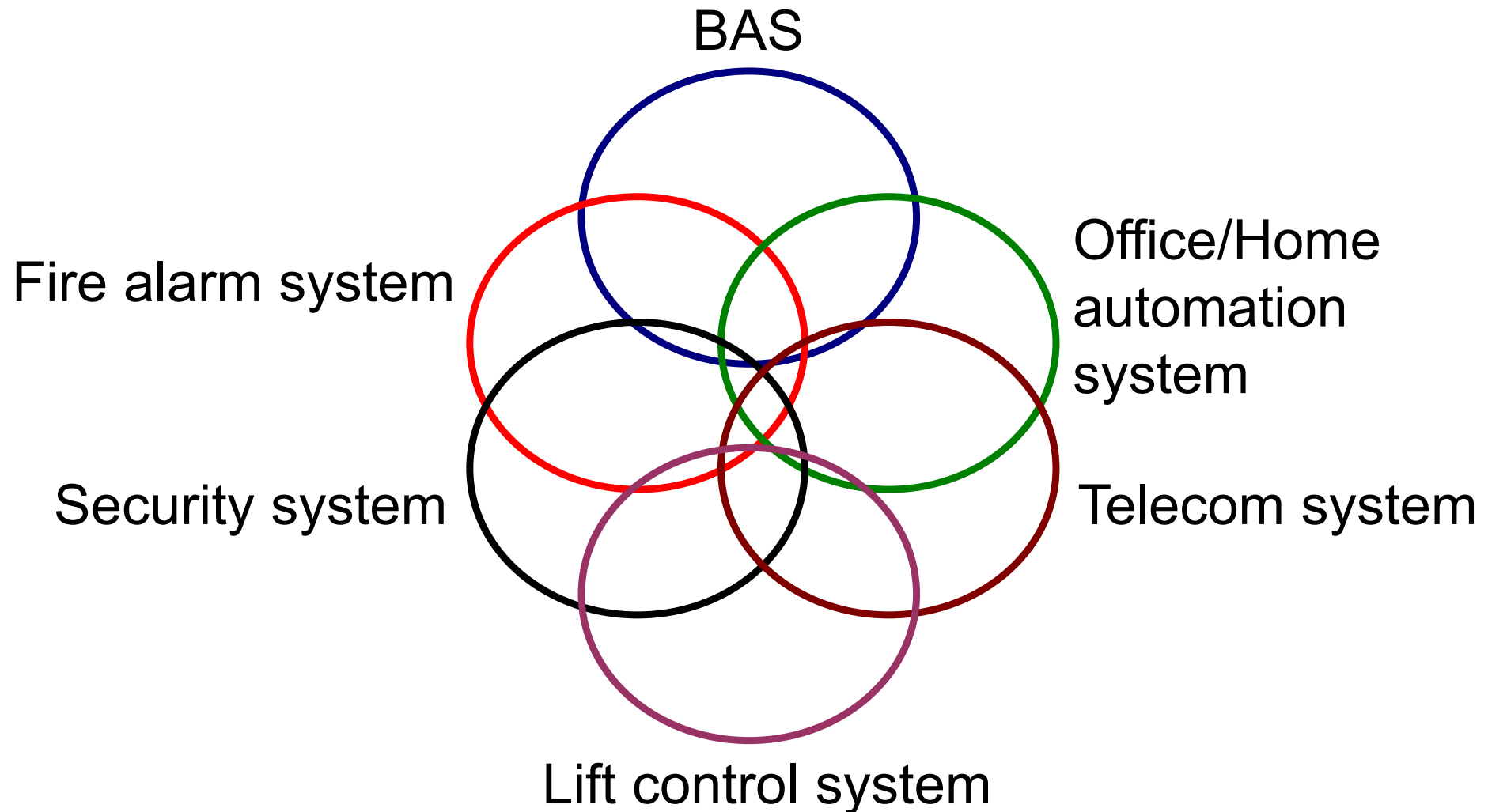


# Networking infrastructure



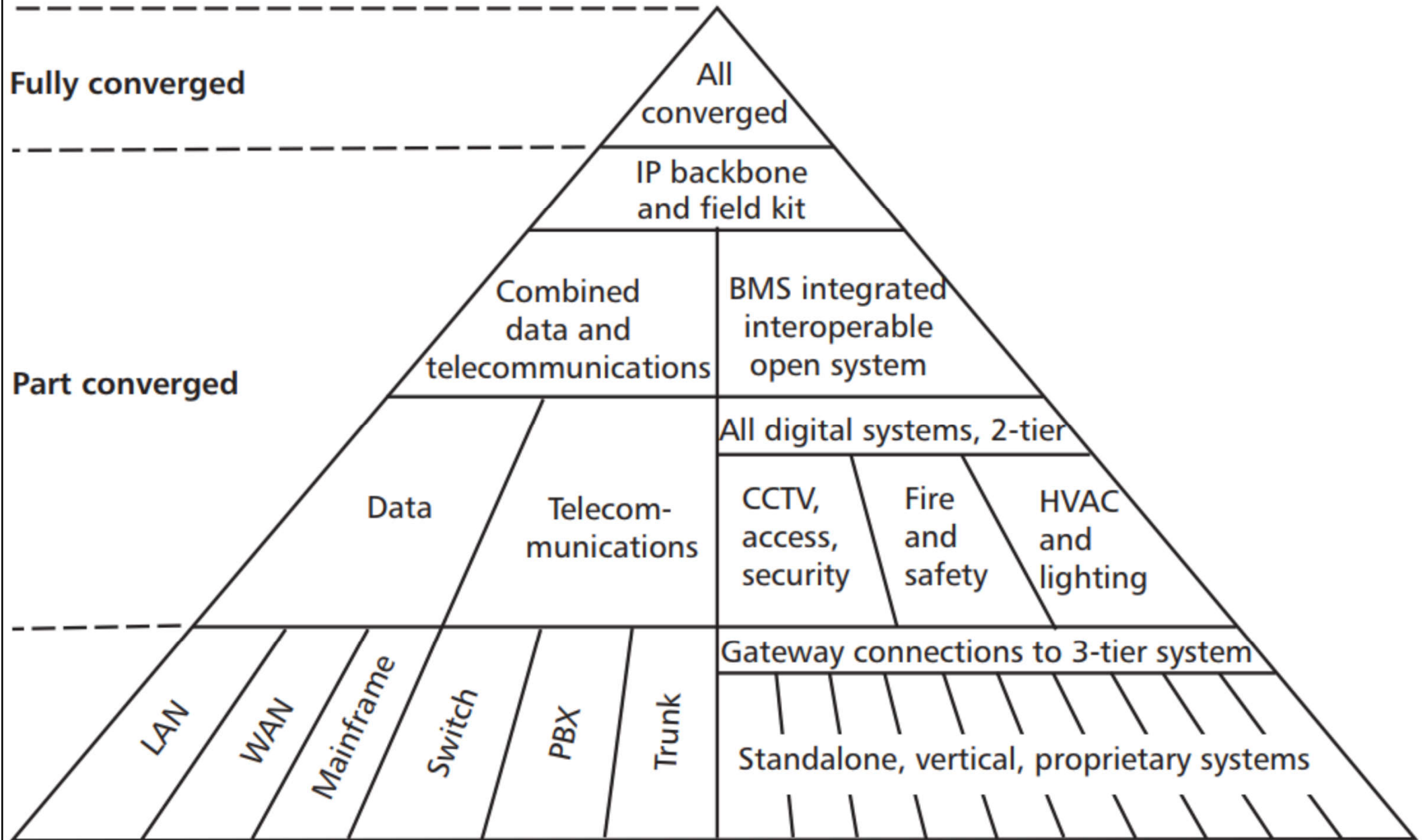
- What can be integrated for BAS?
  - HVAC
  - Lighting
  - Security
  - Fire (alarm & control)
  - Emergency generator
  - Uninterruptable power supply (UPS)
  - Lifts & escalators
  - .....

# Potential overlap of microprocessor-based systems

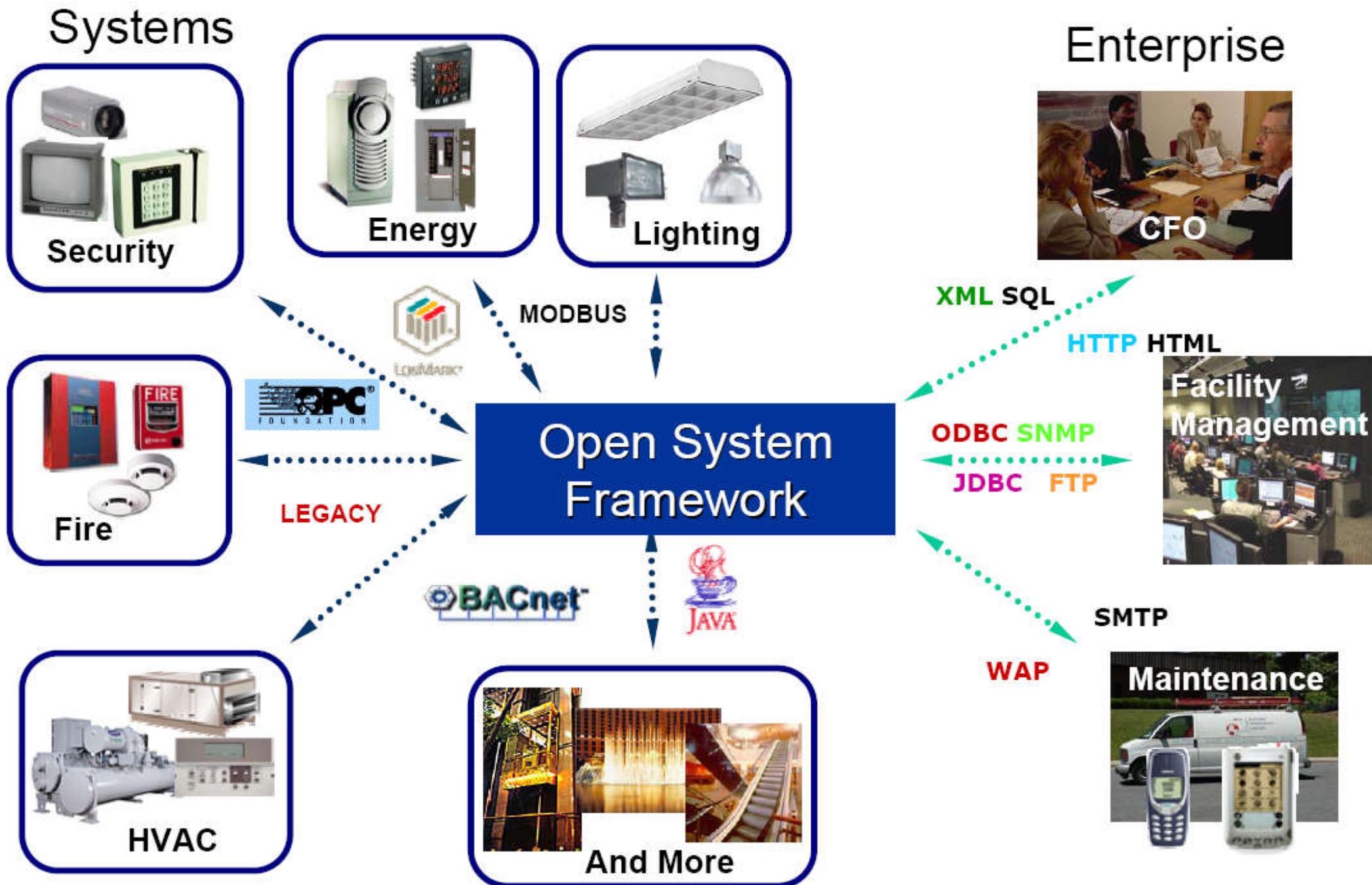


Building Services Engineer needs to integrate all the systems

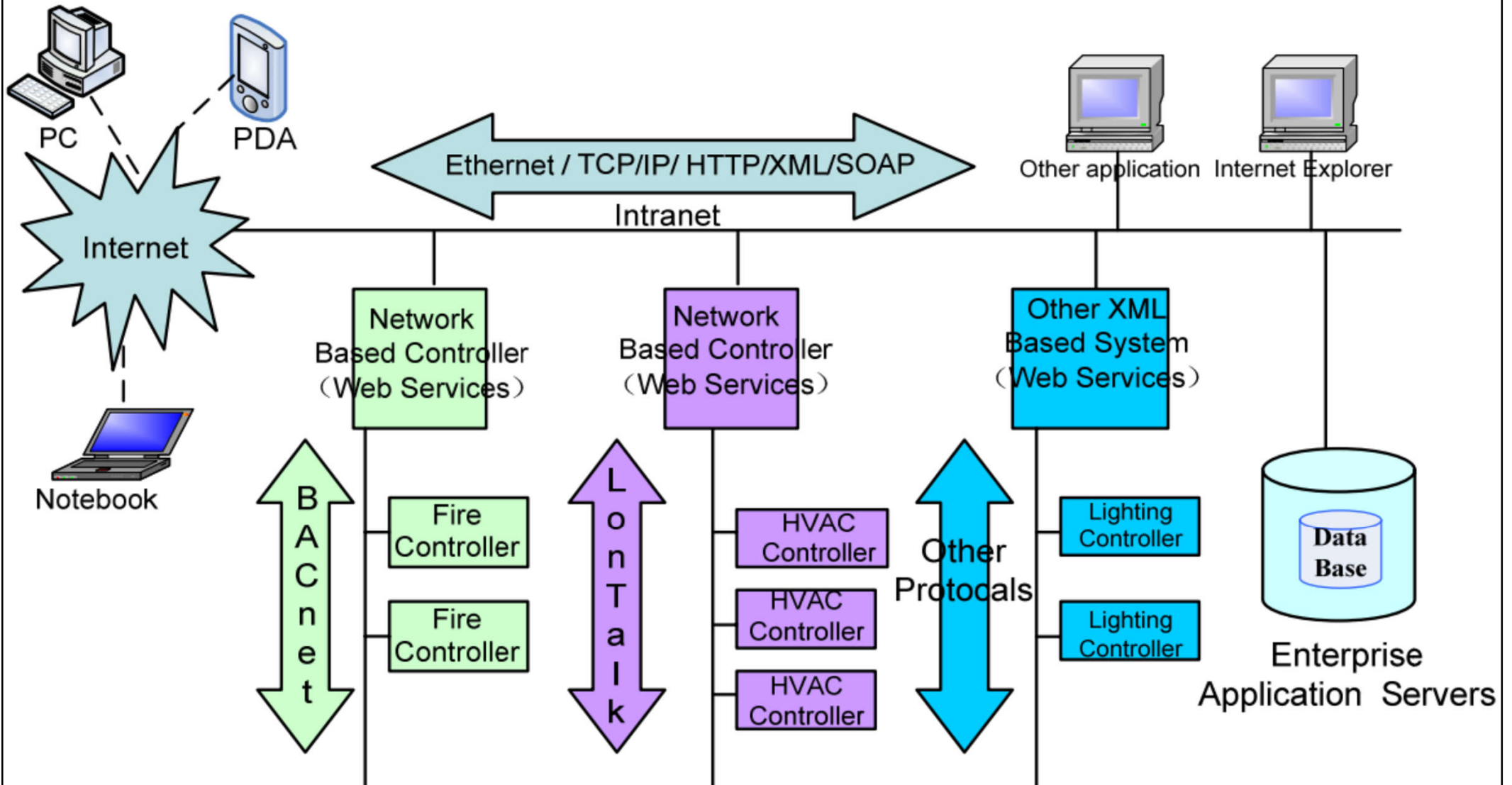
# Controls and information technology (IT) integration hierarchy



# Integration of building automation and enterprise information systems



# Integration between BASs and enterprise applications based on Web Services



TCP = Transmission Control Protocol  
 IP = Internet Protocol  
 HTTP = HyperText Transfer Protocol

XML = Extensible Markup Language  
 SOAP = Simple Object Access Protocol





# Wireless networks

- Wireless communication
  - Transfer of information between two or more points that are not connected by an electrical conductor, such as radio & infrared controller
- Modern wireless technologies
  - Digital devices that communicate without wires
    - Such as mobile phones & wireless networking
    - 4G LTE (long-term evolution), LTE-Advanced, 5G
    - Wi-Fi, Bluetooth, Zigbee, EnOcean



# Evolution of mobile phone communications

1980

1990

2000

2010

2020

2030

● First UK mobile phone call



**1G - TACS**



**2G - GSM/GPRS/EDGE**

● 3G spectrum auction



**3G - WCDMA/HSPA/HSPA+**

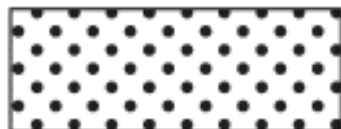
● 4G spectrum auction

● 2.3 GHz & 3.4 GHz auction



**4G - LTE/LTE Advanced**

**5G**



research &  
standardisation

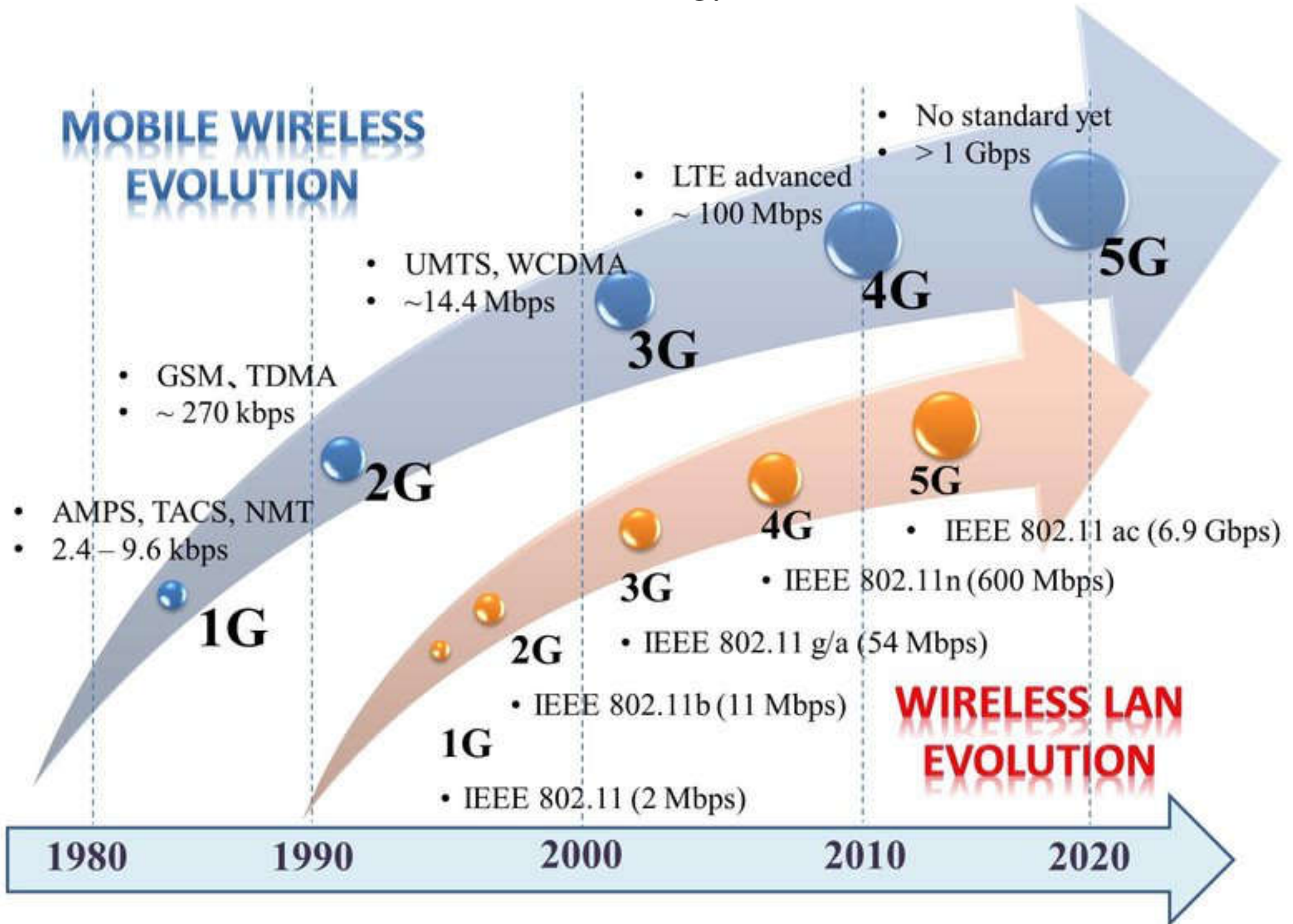


commercialisation

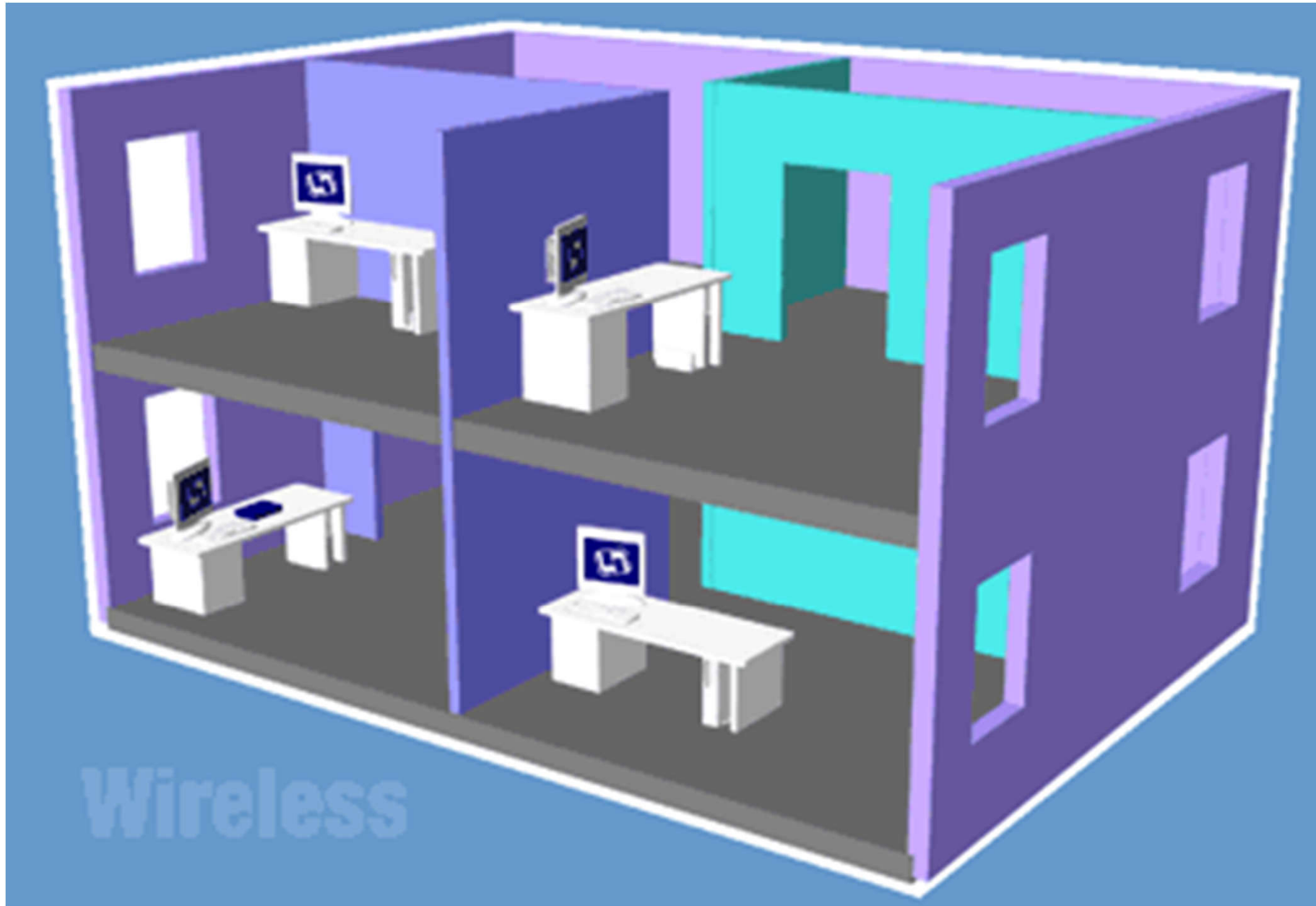
# Fixed wireless network evolution



# Wireless technology evolution



# Wireless transmission in buildings





# Wireless networks

- Common wireless network standards

- IEEE wireless local area network (WLAN)

- 802.11(b) – Wi-Fi, over short distances, up to 11Mbps
- 802.11(g) or (a) – up to 54 Mbps



- Bluetooth wireless technology













- Originally designed for mobile devices
- Does not require a large power source
- Allows personal area networks (PANs) (mini-instant network) using radio frequency identification (RFID)
- Communicate w/o a server or a single point of routing
- Connect up to 8 devices at a time (PicoNet)
- ‘Invisible’ technologies: user acceptance?



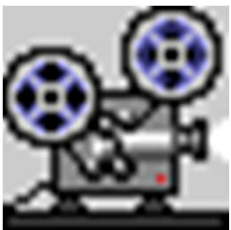
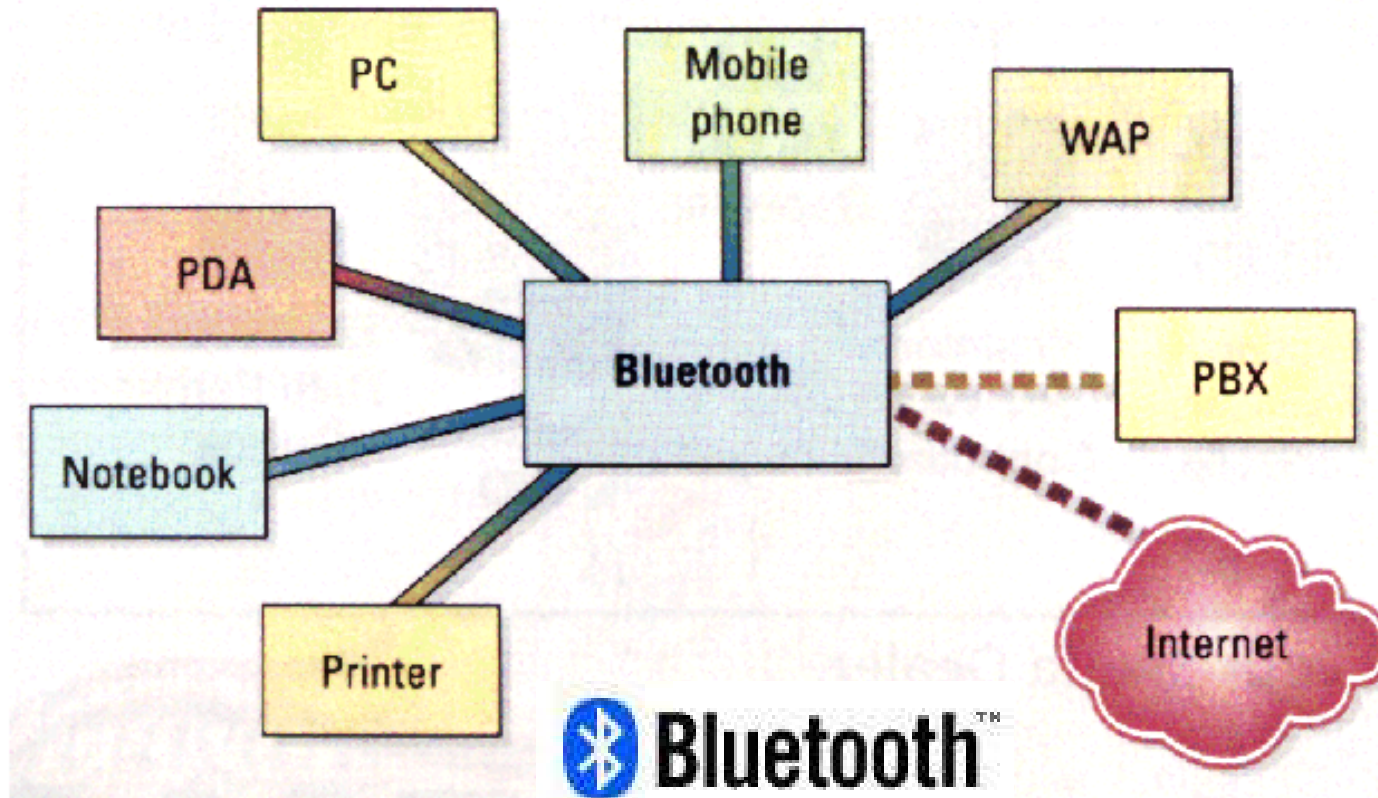
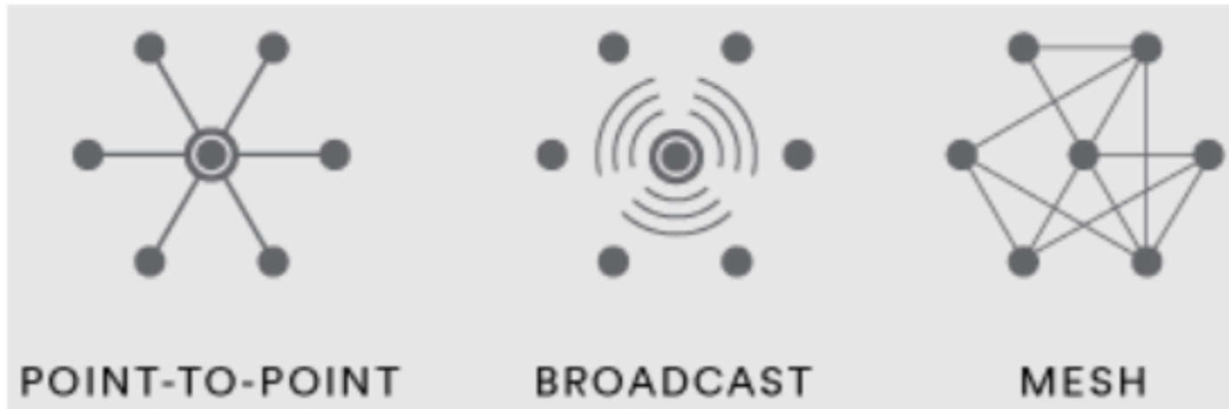
# Comparing IEEE wireless local area network standards

## Why Choose? A vs B vs G

### Wireless Technology Comparison Chart

Wireless Standard	802.11b	802.11a	802.11g
Popularity	 Widely adopted. Readily available everywhere.	 New technology.	 New technology with rapid growth expected.
Speed	<b>11 Mbps</b> Up to 11Mbps (note: cable modem service typically averages no more than 4 to 5Mbps).	<b>54 Mbps</b> Up to 54Mbps (5X greater than 802.11b).	<b>54 Mbps</b> Up to 54Mbps (5X greater than 802.11b).
Relative Cost	 Inexpensive.	 Relatively more expensive.	 Relatively inexpensive.
Frequency	<b>2.4 GHz</b> More crowded 2.4GHz band. Some conflict may occur with other 2.4GHz devices like cordless phones, microwave ovens, etc.	<b>5 GHz</b> Uncrowded 5GHz band can coexist with 2.4 GHz networks without interference.	<b>2.4 GHz</b> More crowded 2.4GHz band. Some conflict may occur with other 2.4GHz devices like cordless phones, microwave ovens, etc.
Range	 Good Range. Typically up to 100-150 feet indoors, depending on construction, building materials, room layout.	 Shorter range than 802.11b & 802.11g. Typically 25 to 75 feet indoors.	 Good Range. Typically up to 100-150 feet indoors, depending on construction, building materials, room layout.
Public Access	 The number of public "hotspots" is growing rapidly, allowing wireless connectivity in many airports, hotels, college campuses, public areas, and restaurants.	 None at this time.	 Compatible with current 802.11b hotspots (at 11Mbps). Also, it is expected that most 802.11b hotspots will quickly convert to 802.11g.
Compatibility	<b>OK</b> 802.11b Widest adoption.	<b>OK</b> 802.11a Incompatible with 802.11b or 802.11g.	<b>OK</b> 802.11b 802.11g Interoperates with 802.11b networks (at 11Mbps). Incompatible with 802.11a.

# Bluetooth wireless technology

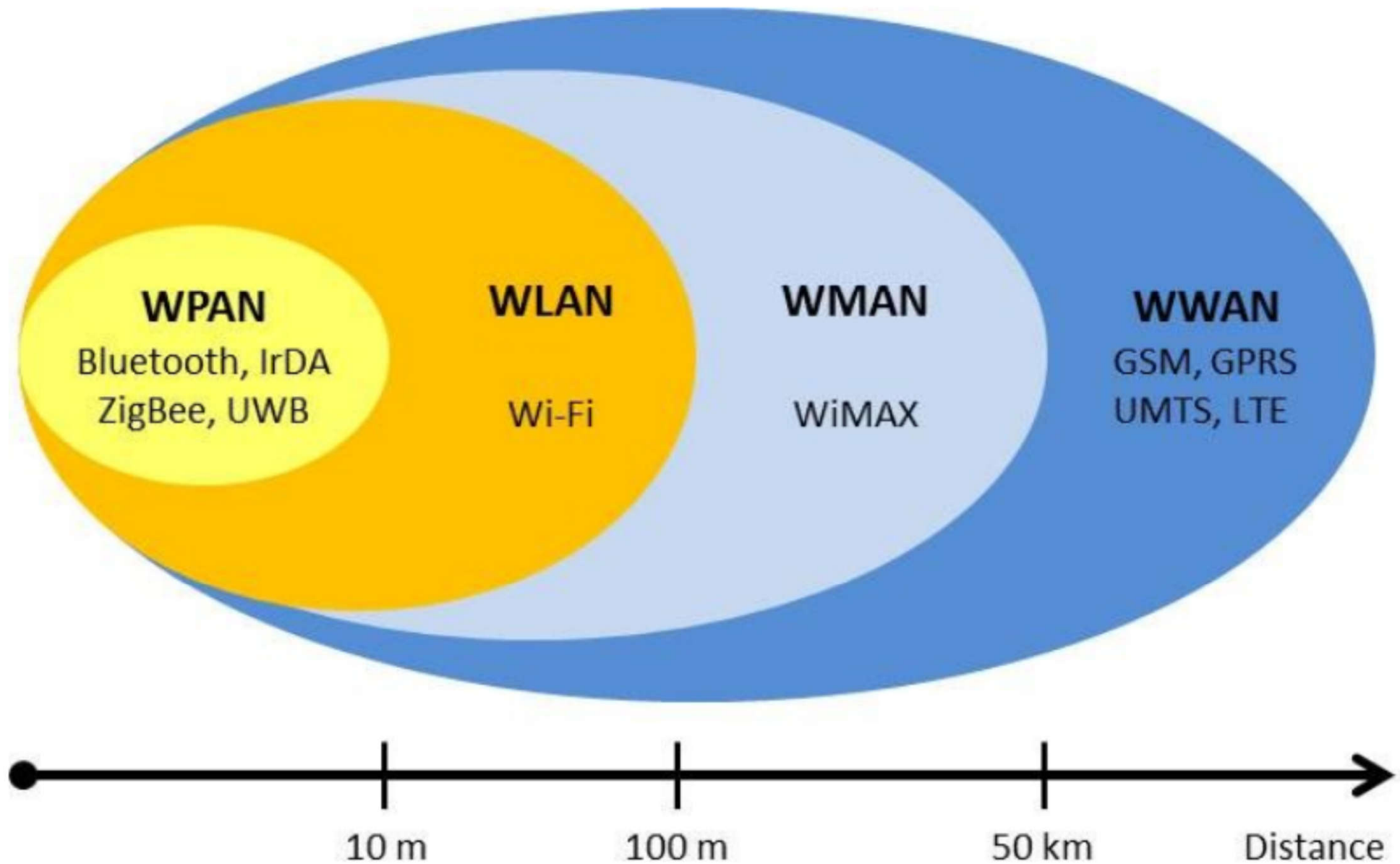


Video: Bluetooth vs WiFi - What's the difference? (4:40)

<https://youtu.be/mPMGRILsOVk>



# Wireless networks classification according to the signal range



WPAN = Wireless Personal-Area Network

WMAN = Wireless Metropolitan-Area Network

WLAN = Wireless Local-Area Network

WWAN = Wireless Wide-Area Network



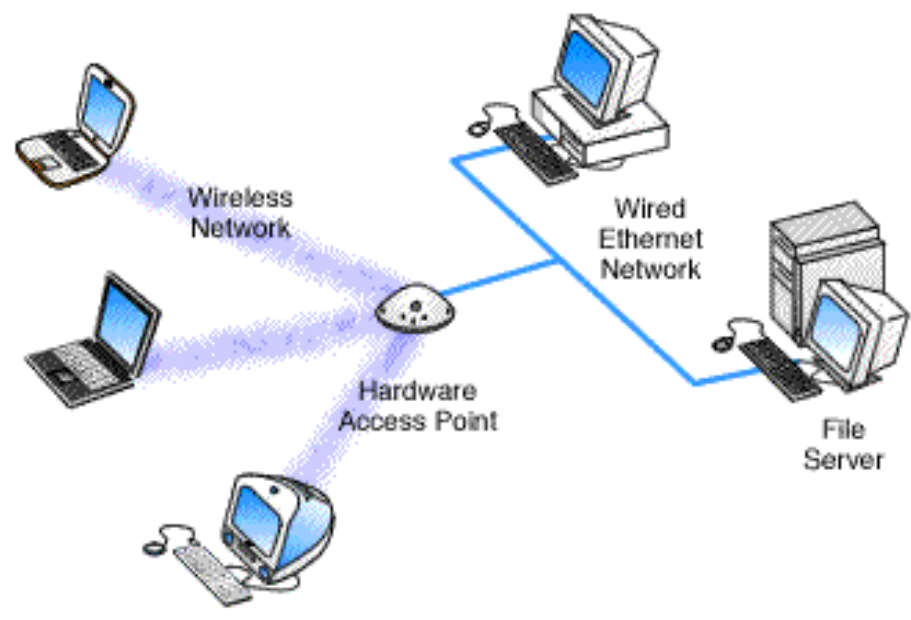
# Wireless networks

- Two kinds of wireless networks
  - Ad-hoc mode (ad-hoc or peer-to-peer)
    - Computers with wireless interface can communicate directly with each other
  - Infrastructure mode (access point or base station)
    - Acts like a hub, providing connectivity for the wireless computers/devices
    - (a) Dedicated hardware access points
    - (b) Software access points

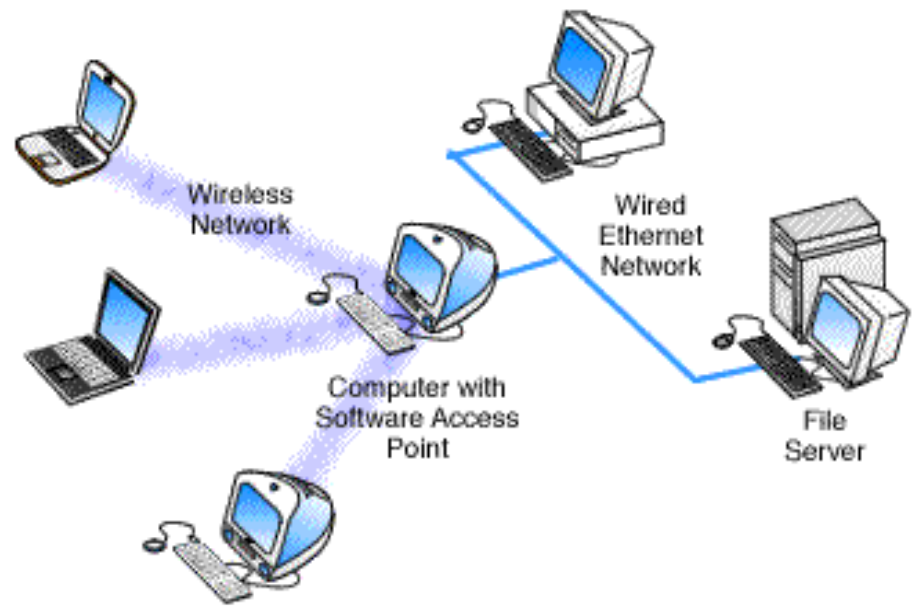
# Different types of wireless networking



Ad-hoc or peer-to-peer networking



Hardware access point



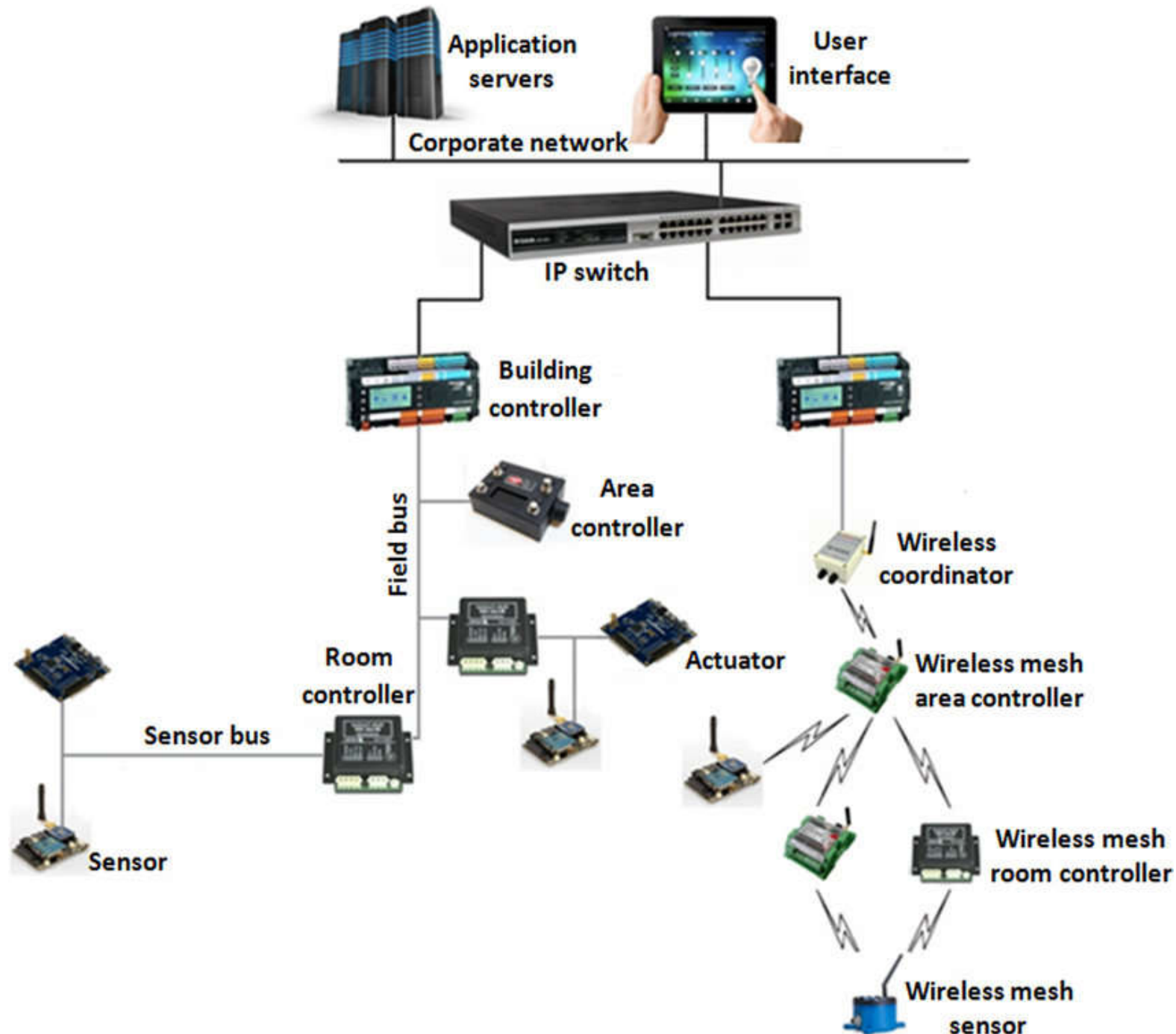
Software access point



# Wireless networks

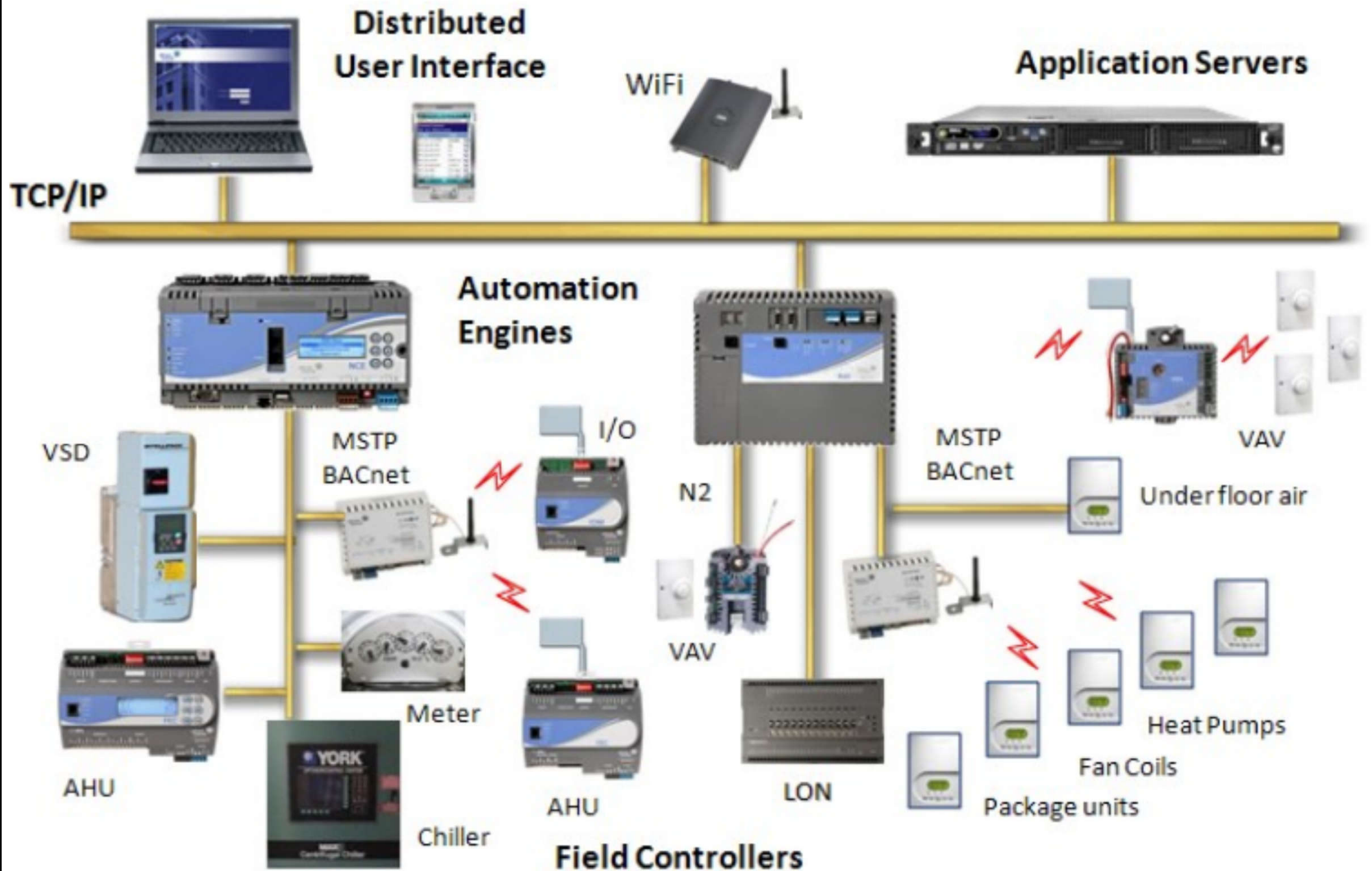
- Advantages of wireless networks for BAS
  - Lower installation & maintenance costs
  - Greater flexibility & scalability (no wiring is needed)
  - Easier integration with existing infrastructure
  - Support the deployment of more sensors & actuators, which can provide more granular and accurate data for BAS optimization & automation
  - Enable BAS to communicate and collaborate with other wireless devices (e.g. smartphones, tablets, wearables) to provide personalized and interactive services for building occupants

# Wired and wireless topological hierarchy of BAS



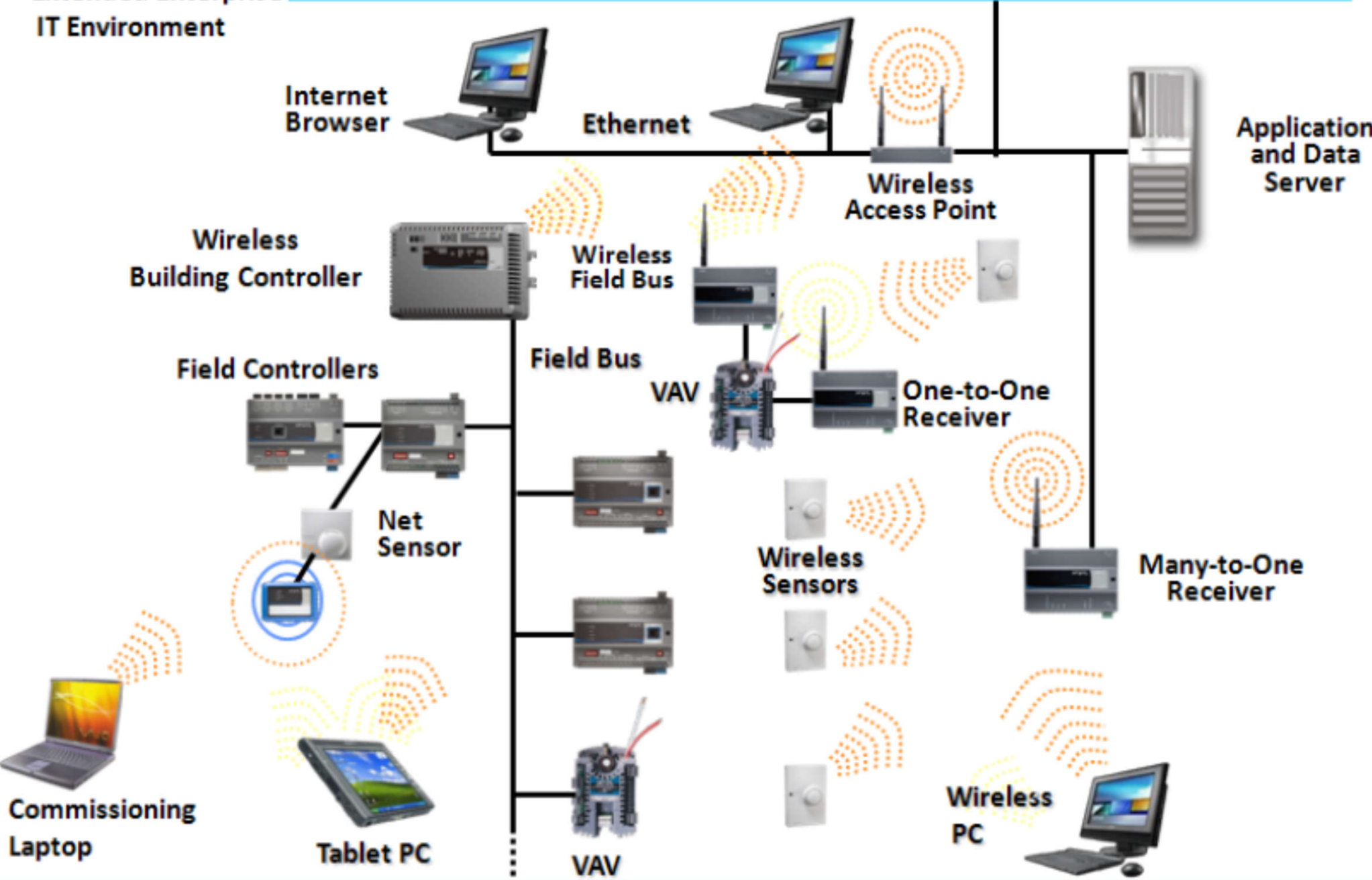
(Source: Maatoug A., Belalem G. & Mahmoudi S., 2019. Fog computing framework for location-based energy management in smart buildings, Multiagent and Grid Systems – An International Journal, 15: 39-56. <https://doi.org/10.3233/MGS-190301>)

# An example of wireless network BAS architecture



# Integration of BAS wireless network and enterprise IT environment

Extended Enterprise  
IT Environment



[Source: <https://docplayer.net/5893734-Chapter-5-introduction-to-building-automation-system-bas.html>]



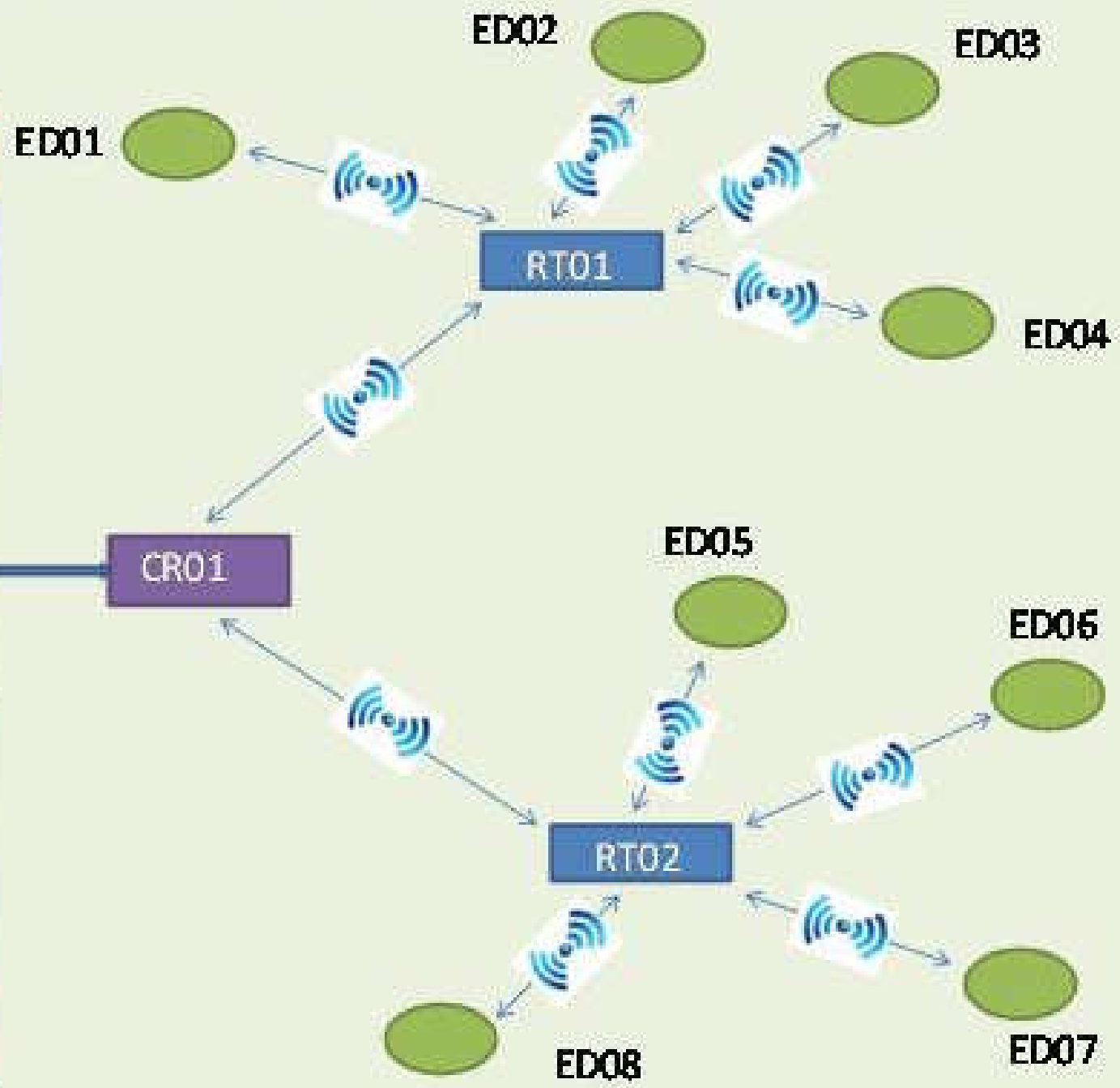
# Wireless networks

- BAS with **wireless sensor networks (WSN)**
  - Consist of small sensor nodes that sense the environment, perform computations, and communicate with other nodes using the onboard radio module
  - Sensor nodes transport the measured data to a base station using multi-hop communication
  - The size of sensor nodes is close to a matchbox
  - Wiring is avoided and both installation & operational costs significantly reduced



# Basic concept of wireless sensor network (WSN)

## WSN Monitoring System





# Further reading

- Hui S. C. M., 2007. Latest trends in building automation and control systems, In *Proceeding of the CAI Symposium 2007 on Intelligent Facility Management and Intelligent Transport*, 28 March 2007, Hong Kong, 10 p. [http://ibse.hk/cmhui/CAI-2007\\_SamHui.pdf](http://ibse.hk/cmhui/CAI-2007_SamHui.pdf)
- Video: Network Topologies (Star, Bus, Ring, Mesh, Ad hoc, Infrastructure, & Wireless Mesh Topology) (8:57) <https://youtu.be/zbqrNg4C98U>