Telecommunication Services

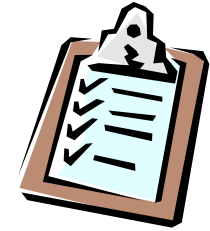*Ir Dr. Sam C. M. Hui*

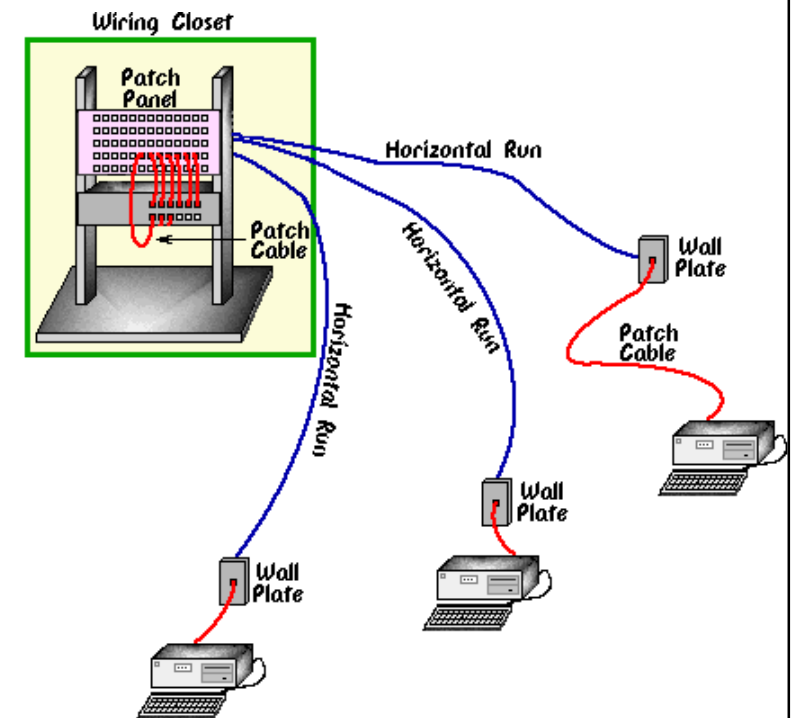E-mail: sam.cmhui@gmail.com

http://ibse.hk/cmhui/

Jan 2023

Contents

- Basic concepts

- Design issues

- Cabling management

- Networking

- Transmission methods

- In-building wireless systems

Basic concepts

- Telecommunication 電訊
  - Communication at a distance ("Tele")
  - Transmission, emission, or reception of signs, signals, writing, images, sounds, or information of any nature by wire, radio, optical, or other electromagnetic systems
- Telecommunication system 電訊系統
  - Uses electricity, light (visible & infrared), or radio waves to transmit signals that carry voice & data transmissions (may be analog or digital)

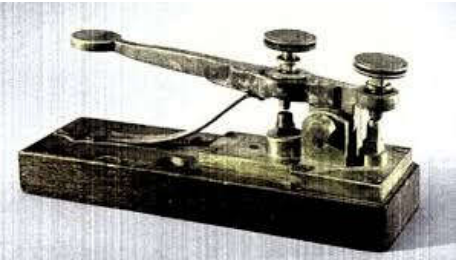# Basic concept of telecommunication system
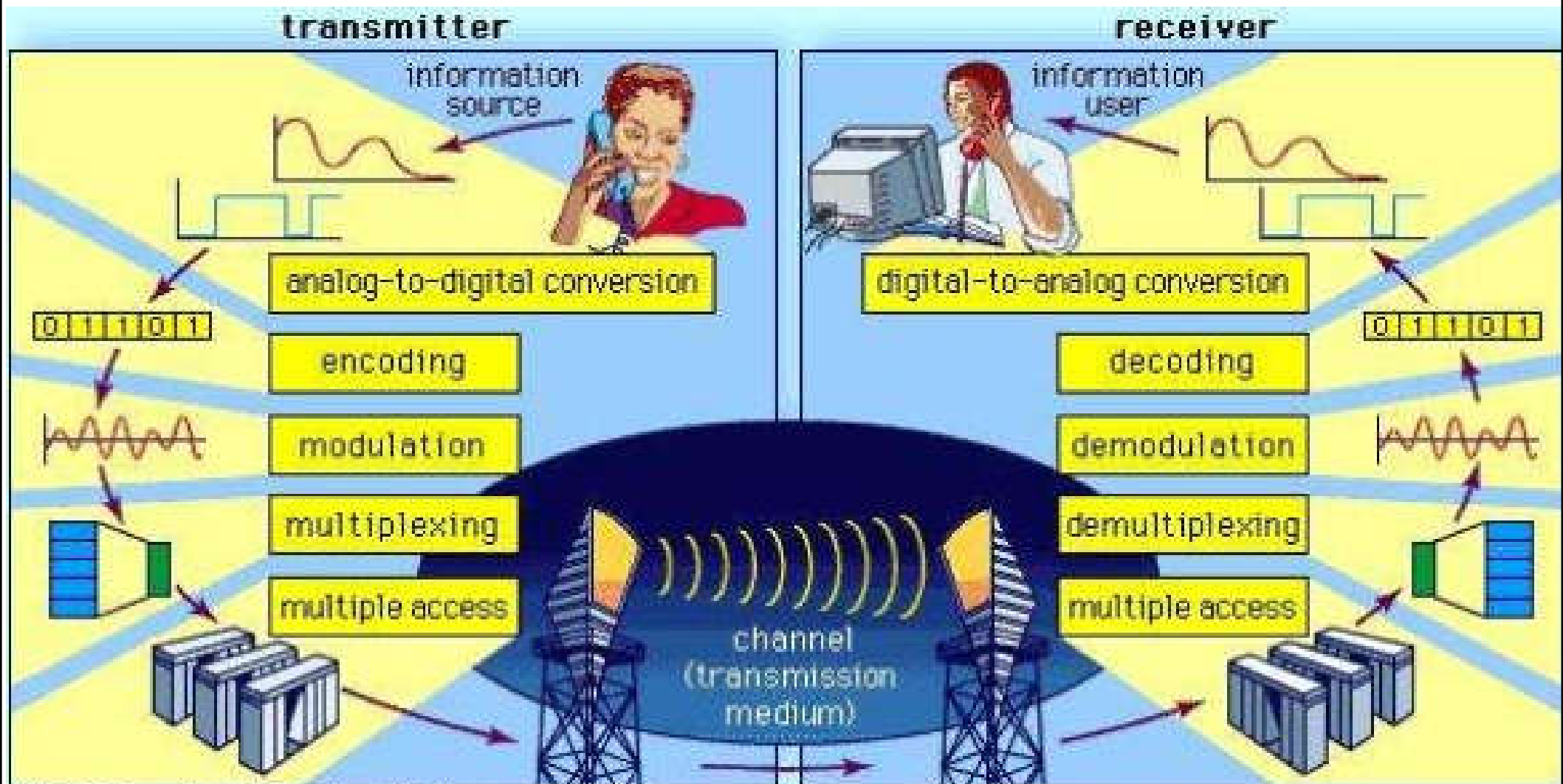
© 1999 Encyclopædia Britannica, Inc.

- "Tele" means "at a distance"
- The short form of telecommunications is "telecom"
- All telecomm systems consist sender, channel and receiver
- The data are transmitted in the form of carrier waves (analog or digital signals)

Historical development of telecommunications systems & services

Abbreviations:

WAN = Wide Area Network
LAN = Local Area Network
WLAN = Wireless LAN
WWW = World Wide Web
ADSL = Asymmetrical
   Digital Subscriber Line
ISDN = Integrated Services
   Digital Network
AM = Amplitude Modulation
FM = Frequency Modulation
IP = Internet Protocol
CS = Circuit Switched
PS = Packet Switched
VoD = Video on Demand

Telegraph
Wireless telegraph
Telephone
Telex
Slow WAN   Fast WAN   ADSL
LAN   WLAN
Internet   WWW
e-mail
Cable modems
Telefax
Cordless telephones
ISDN   Telefax Gr 4
AM radio   FM radio   Stereo radio   Digital radio
Radio   TV   Color TV   Stereo TV   Digital TV
Telephone   VoD
Cellular Telephone   Mobile
Paging   Digital   Data
         Cellular
         Telephone   Mobile
                     IP

1850   1930   1970   1990   2000   2005   Time/year

(Source: Anttalainen T., 2003. *Introduction to Telecommunications Network Engineering*, Second Edition, Artech House, Boston & London.)

Basic concepts

- Telecommunication network 電訊網絡
  - A collection of communication equipment & devices that are interconnected so they can communicate in order to share data, hardware, and software or perform an electronic function
  - The network includes a series of connecting points called nodes (e.g. a terminal like a telephone receiver or computer) that are interconnected with cables (wiring)

Communications supply arrangement
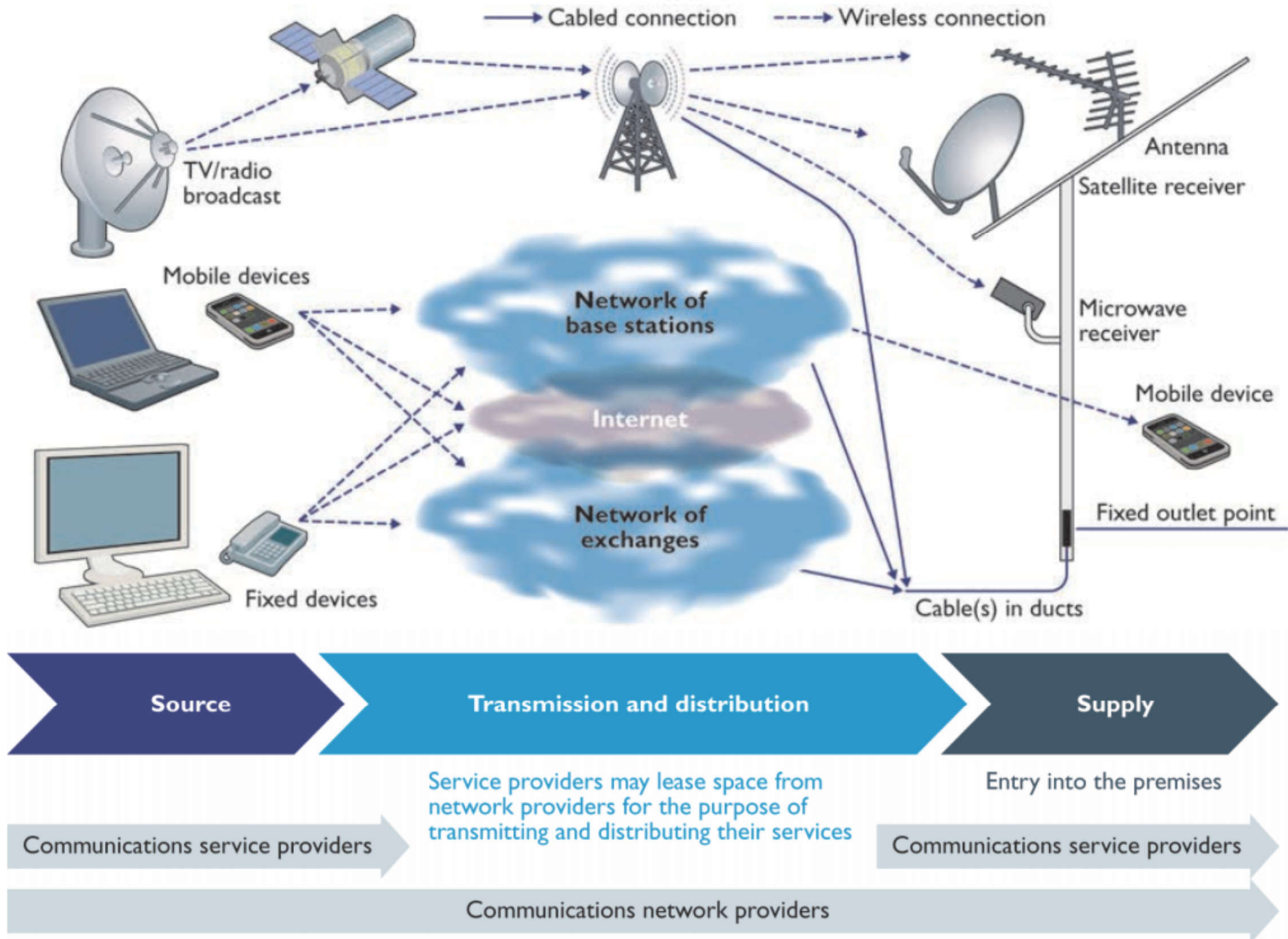
(Source: Portman J. & Bleicher D., 2011. *Utility Connections and Diversions: Planning, design and installation*, BG 37/2011.)

Basic concepts

- Telecommunications & information technology (IT)
  - Influence people & many aspects of our life
  - Affect building design & requirements
  - Require the setting up of information systems
- Information systems
  - 1. User (voice, text, image & data networks)
  - 2. Building (bldg. mgt., energy, fire, security)
  - 3. Miscellaneous (public address, CCTV, etc.)

User Information Technology
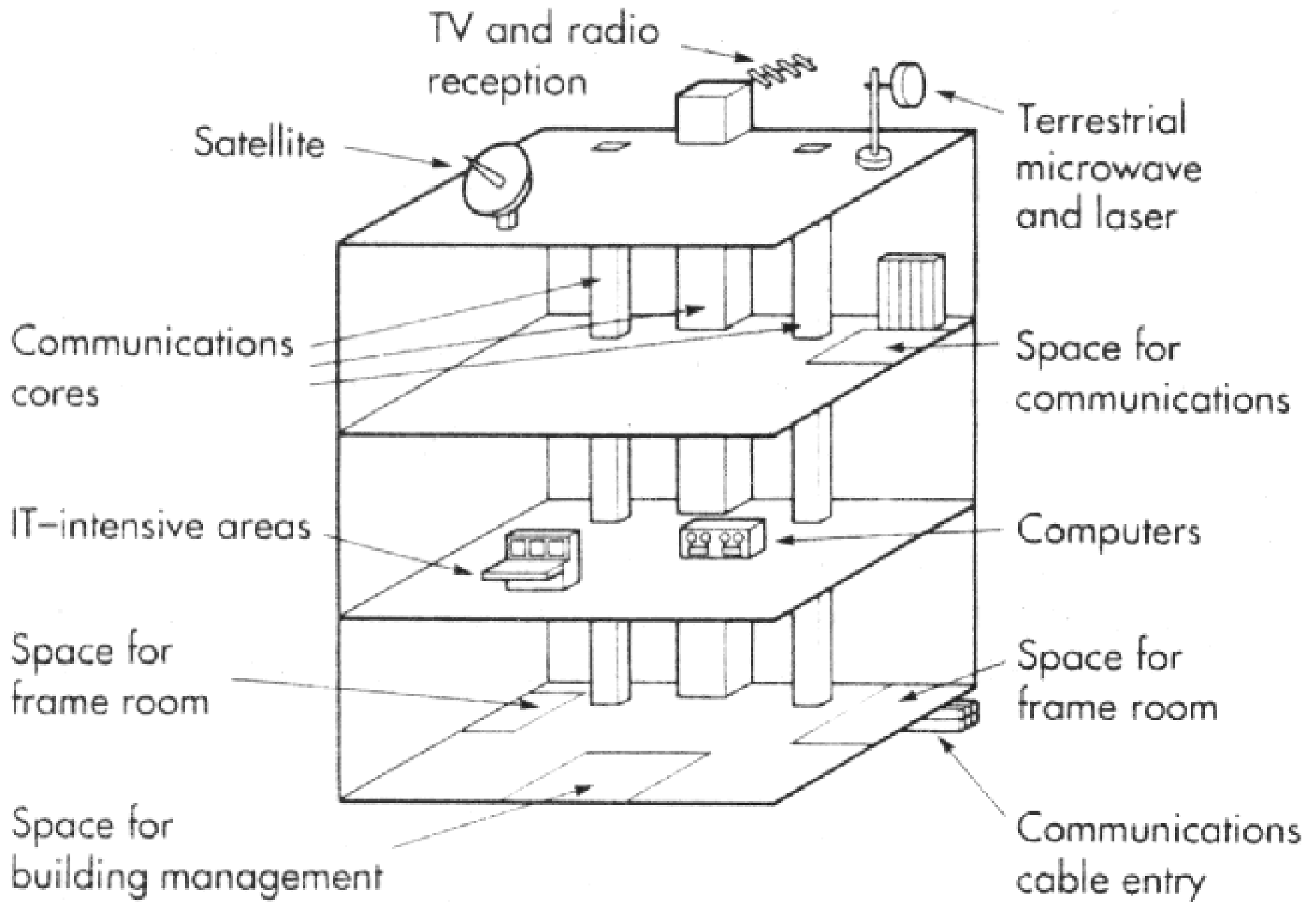
Voice and data networking
PABX and telephones
Information feeds
External communications links
Paging and messaging
Video distribution
Public address
Electronic signage
Access, movement control & security
Energy management system
Building automation system

Building Information Systems

More user oriented

More building oriented

(Source: CIBSE, 1992. Information Technology and Buildings)

Examples of IT & telecommunication systems in a building

TV and radio reception

Satellite

Terrestrial microwave and laser

Communications cores

Space for communications

IT-intensive areas

Computers

Space for frame room

Space for frame room

Space for building management

Communications cable entry

(Source: CIBSE, 1992. Information Technology and Buildings)

Basic concepts

- Information Technology (IT) in buildings
  - Systems of structured cable & wireless information technologies relating to buildings & building occupants
    - **<u>Building systems</u>** -- HVAC, lighting, daylighting control, energy monitoring, security access, and fire/smoke detection and alarm
    - **<u>Telecommunications</u>** -- voice, data, graphics, and audio/video
  - Properly designed pathways & spaces are needed to accommodate the IT systems
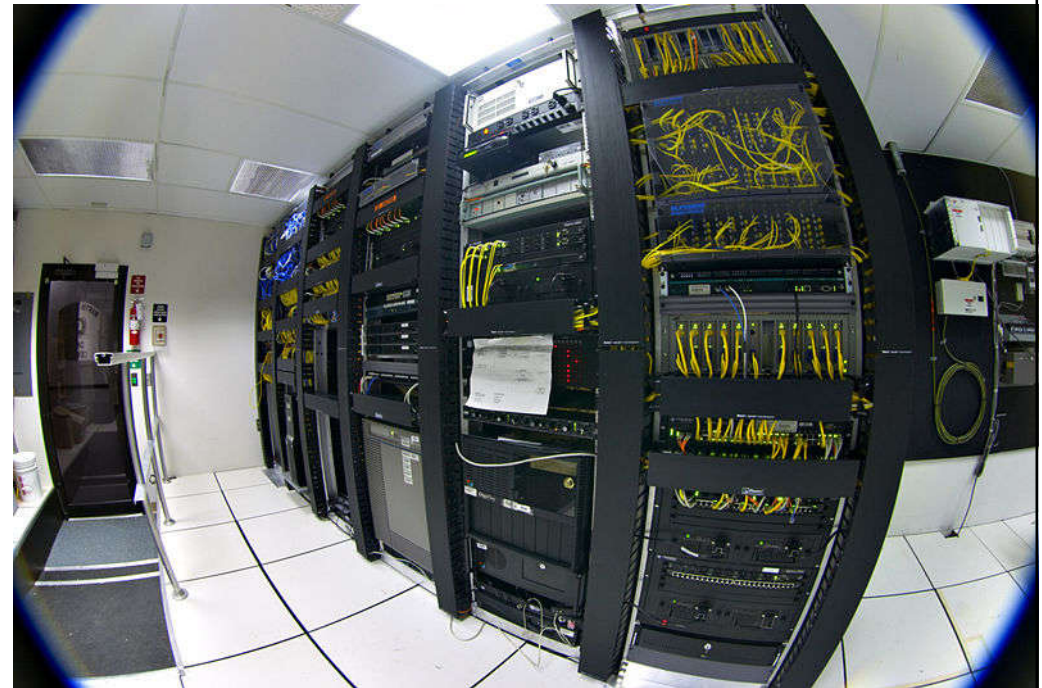
Basic concepts

- The density & demand of IT equipment in buildings increase many times

  - A robust and secure infrastructure is needed to support the growing & evolving demands of business & organisations (e.g. server rooms)

- Key factors for buildings to accommodate IT

  - Space requirements (for equipment & distribution)

  - Power requirements (electricity supply)

  - Environmental requirements (e.g. temperature)

Basic concepts

- Major considerations
  - Flexibility
  - Accessibility
  - Life cycle
  - Cost-benefit
- Flexibility
  - Building & IT infrastructure design must be flexible & adaptable to accommodate future new technologies (e.g. by scalable IT infrastructure)
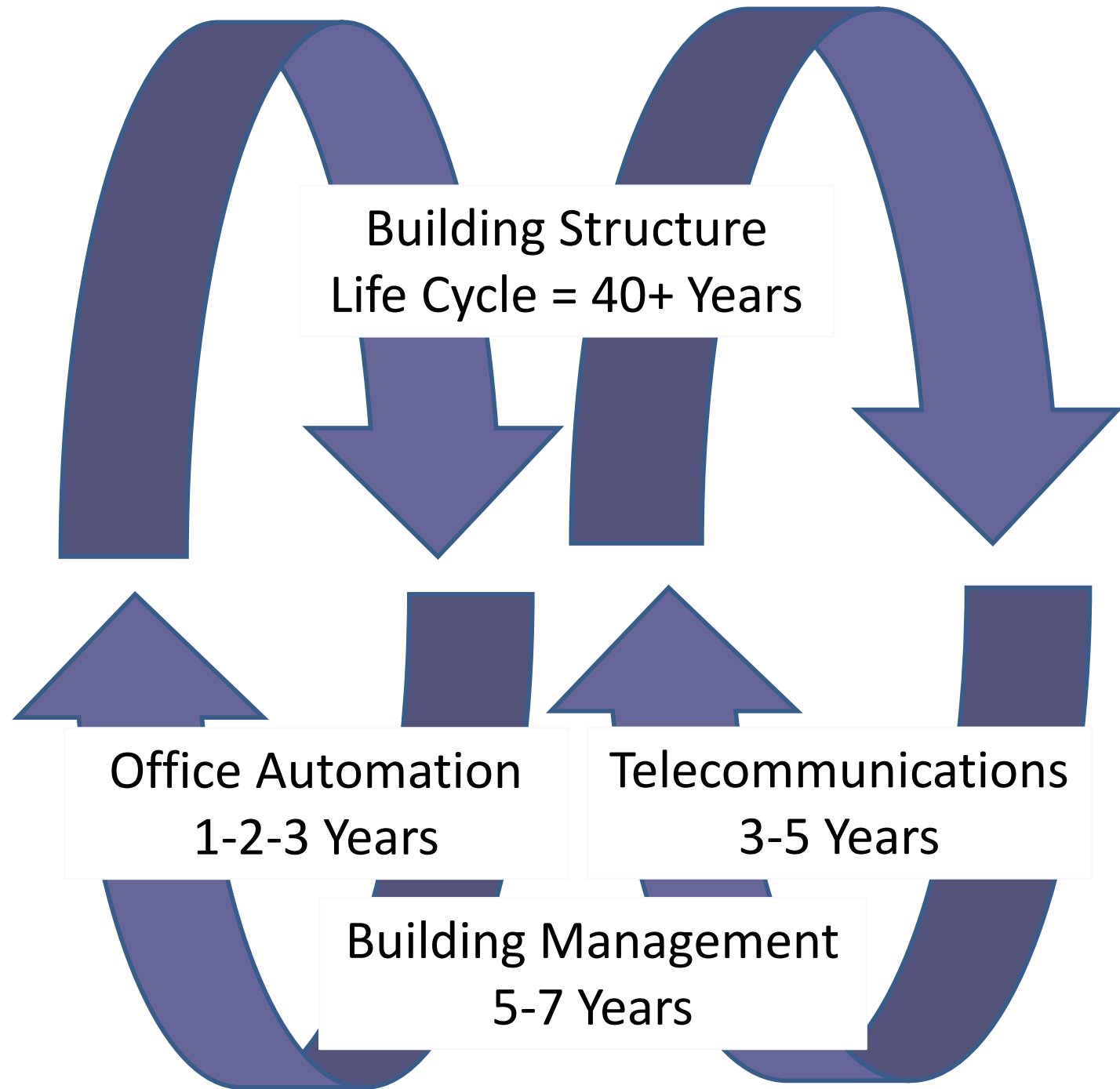
Basic concepts

- Design for IT flexibility should consider:
    - Adequate power for future building/system expansion
    - Adaptable power & telecommunication cores, adaptable dedicated electrical & telecommunications spaces
    - HVAC delivery to dedicated IT spaces
    - Network security (vulnerabilities & reliability)
    - Strategically located branch takeoffs & utility stubs
    - Adaptable plenum systems -- either overhead or underfloor, coordinated with space needs for building services systems
    - Overhead exposed cable trays integrated with building services systems (HVAC, power, lighting, fire protection)

Basic concepts

- IT systems take up space, e.g.
  - In basements where cables enter, on desks, in risers, above ceilings, under carpets, in special equipment areas, on roofs and in car parks
- Life cycle considerations
  - The frames of buildings have lives of many decades during which the IT systems contained will be updated & replaced several times
  - With proper planning, it is not necessary to provide new cabling every time systems are changed or upgraded (cost savings)

Life Cycle Diagram

Building Structure
Life Cycle = 40+ Years

Office Automation
1-2-3 Years

Telecommunications
3-5 Years

Building Management
5-7 Years

Basic concepts

- Planning for IT (a dynamic process)
  - Consider carefully its own "information needs"
    - Present & anticipated use of information
    - Standard of service: speed of transfer, availability, error rates & user-friendliness
    - Corporate view of the rate of IT introduction
    - Geographical distribution of IT
    - Likely growth of, and 'churn' within, the organisation
    - Existing & proposed use of building stock
    - Assessment of the suitability of building stock for IT

Basic concepts

- Example: Planning and designing your IT Infrastructure
  - Part I: Networking
    - https://synyx.de/blog/planning-and-designing-your-it-infrastructure-part-i-networking/
      - Networking hardware and your needs
      - LAN, WAN or CAN infrastructure
      - Network applications and bandwidth
      - Number of users and networked devices
      - Office layout, hardware & software components
      - Budget for the installation and maintenance

Basic concepts

- <u>Example</u>: Planning and designing your IT Infrastructure (cont'd)
  - Part II: Evaluating your requirements and designing your data center
    - https://synyx.de/blog/planning-and-designing-your-it-infrastructure-part-ii-evaluating-your-requirements-and-designing-your-data-center/
      - Evaluate what you want and what you really need
      - Don't overbuild; Don't plan for now, plan for the future!
      - Cost of Ownership (vs. webhosting, cloud solutions)
      - Select a proper data center site

Basic concepts

- Following planning, the subsequent phases are important for implementing the IT:
    - 1. Design & procurement of systems and cabling
    - 2. Installation, testing & commissioning
    - 3. Operation, management, maintenance & modification
    - 4. Removal & recovery of redundant systems
- Critical for buildings with high IT demands
    - Such as data centres, high-tech offices

Basic concepts

- Emerging issues
  - Integrated building design practice
    - Use the same cable network for different systems
  - Interoperability across all systems
    - Among user IT and building operating systems
  - Building Information Modeling (BIM)
    - A master, intelligent data model to design & manage
  - Wireless communication technologies
  - Smart & intelligent buildings

(* See also: Information Technologies Engineering (WBDG) http://www.wbdg.org/design/dd_infotecheng.php)

Infrastructure and systems for "intelligent building"

Infrastructure		
Sensors, Structured cabling, IP network, Wireless*, Plant rooms, Data rooms, Server rooms, Communications rooms, etc.		
Building systems (ICS)†	**ICT systems†**	**Business systems‡**

Building management
HVAC controls
Access control
Lighting control
Intruder alarm
Security/CCTV
Fire alarm
Water management
Waste management
Utilities
Stand-by generators
UPS
	Office automation
	(email, data, Internet)
	
	Media/multi-media
	(voice, video, music)
	
	Telephony
	(voice, fax, video
	conferencing, SMS,
	pagers)
	
	IP-based applications§
		Enterprise resource
		  planning (ERP)
		Material requirements
		  planning (MRP)
		Customer relationship
		  management (CRM)
		Integrated command-and-
		  control centre
		Integrated service/
		  helpdesks

* The term 'wireless' is used as a generic term to cover communications and data links that do not require a physical connection; technologies employed include WiFi, Bluetooth, ZigBee, radio, NFC, RFID

† ICS – Industrial Control Systems; ICT = information and communication technology

‡ Only included to the extent that they are integrated with building systems, for example CRM – Access Control, ERP/MRP – Supply Chain Management
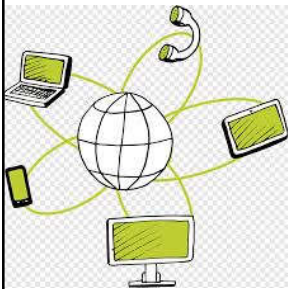
§ Relevant where they interact with building systems or sensors, for example RFID for tracking location of material or assets

(Source: The Institution of Engineering and Technology)
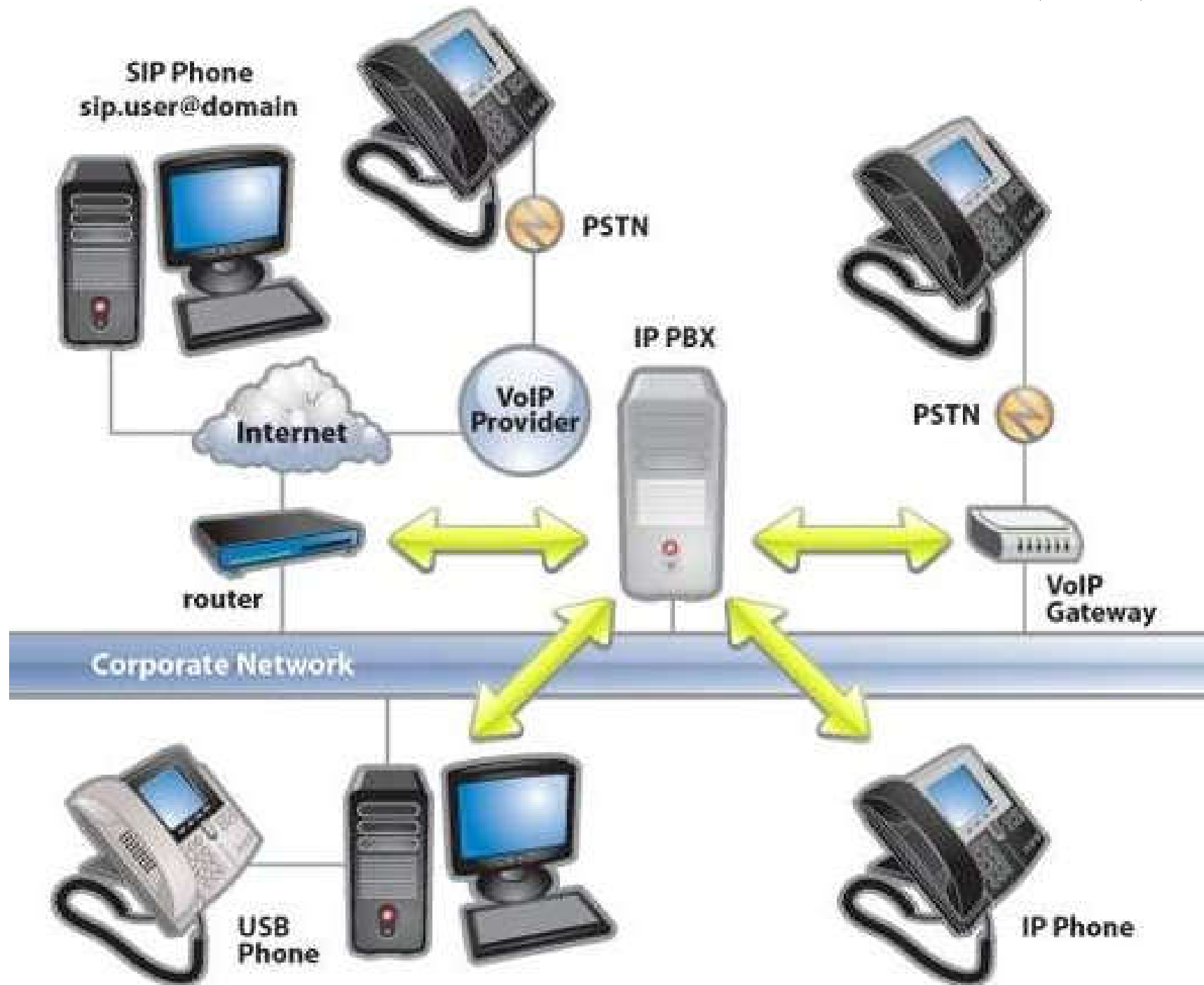
Basic concepts

- Internet Protocol (IP) Telephony
    - Use of IP-based networks to build, provide and access voice, data or other forms of telephonic communications
    - Replace the telecommunications' infrastructure of circuit switched public data networks (CSPDN) and public switched telephone networks (PSTN) with packet switched IP communication networks
    - Voice over IP (VoIP) is a popular implementation which only supports voice communication over IP

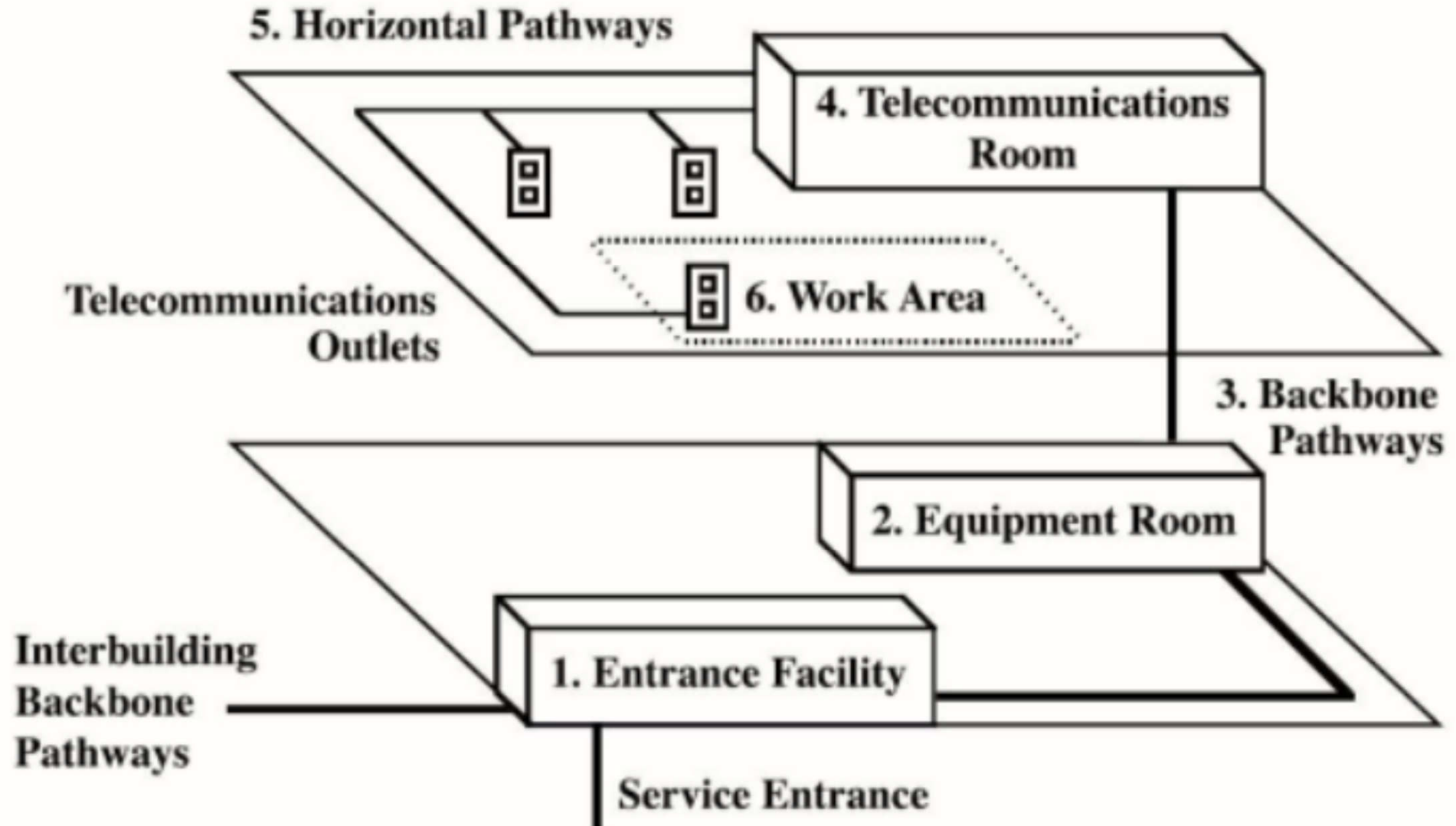# Internet Protocol (IP) Telephony and Voice over IP (VoIP)

SIP Phone
sip.user@domain

PSTN

VoIP Provider

IP PBX

PSTN

Internet

router

VoIP Gateway

Corporate Network

USB Phone

IP Phone

Design issues

- Design requirements
  - Plant & equipment rooms, spaces & pathways
  - Electrical power, bonding & earthing/grounding
  - Environmental requirements (e.g. cooling)
  - Fire safety issues
- Typical telecommunication room facilities
  - Room lighting, air conditioning, fire protection
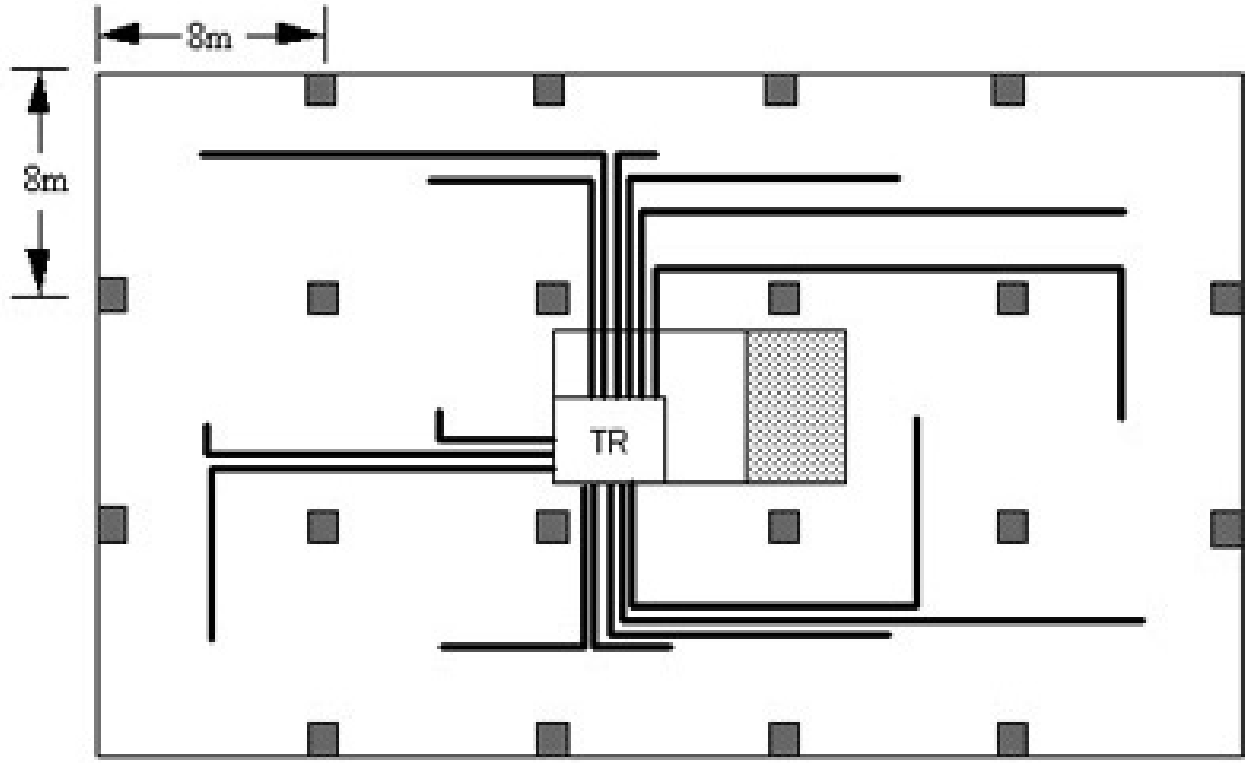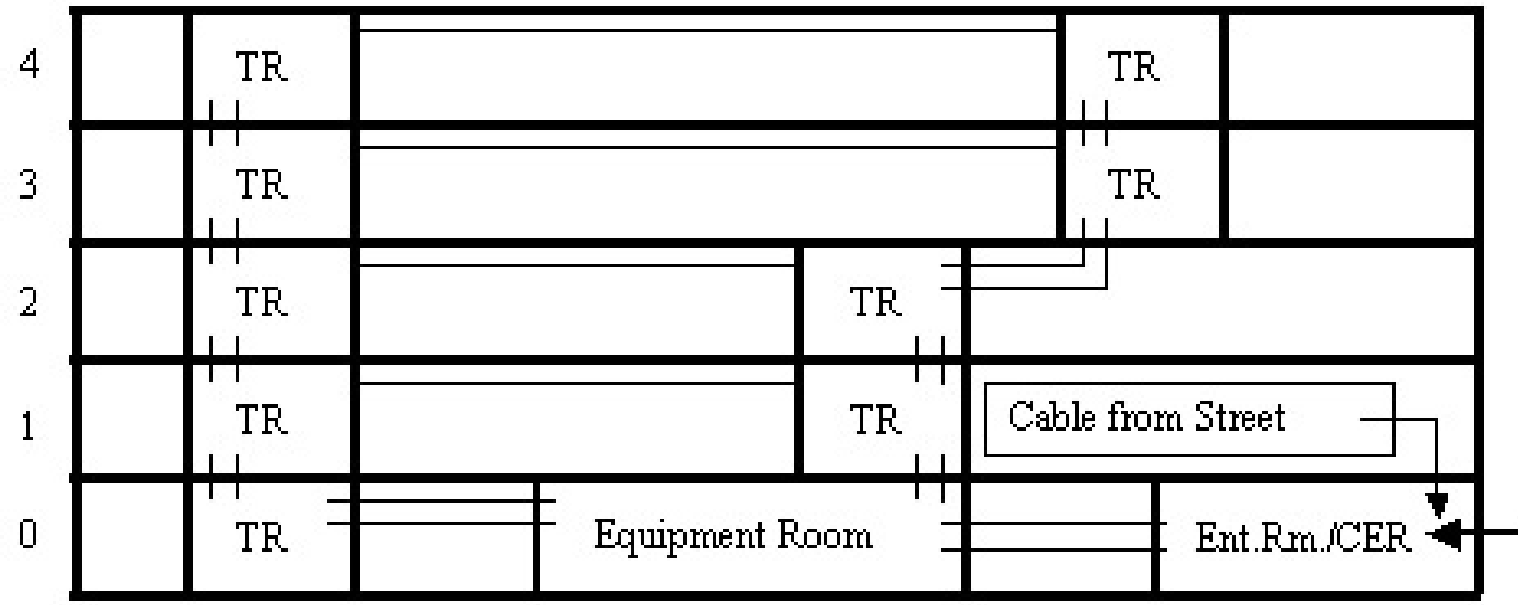 - Temperature senor, raised floor, AC power supply, station earthing, working tables & chairs
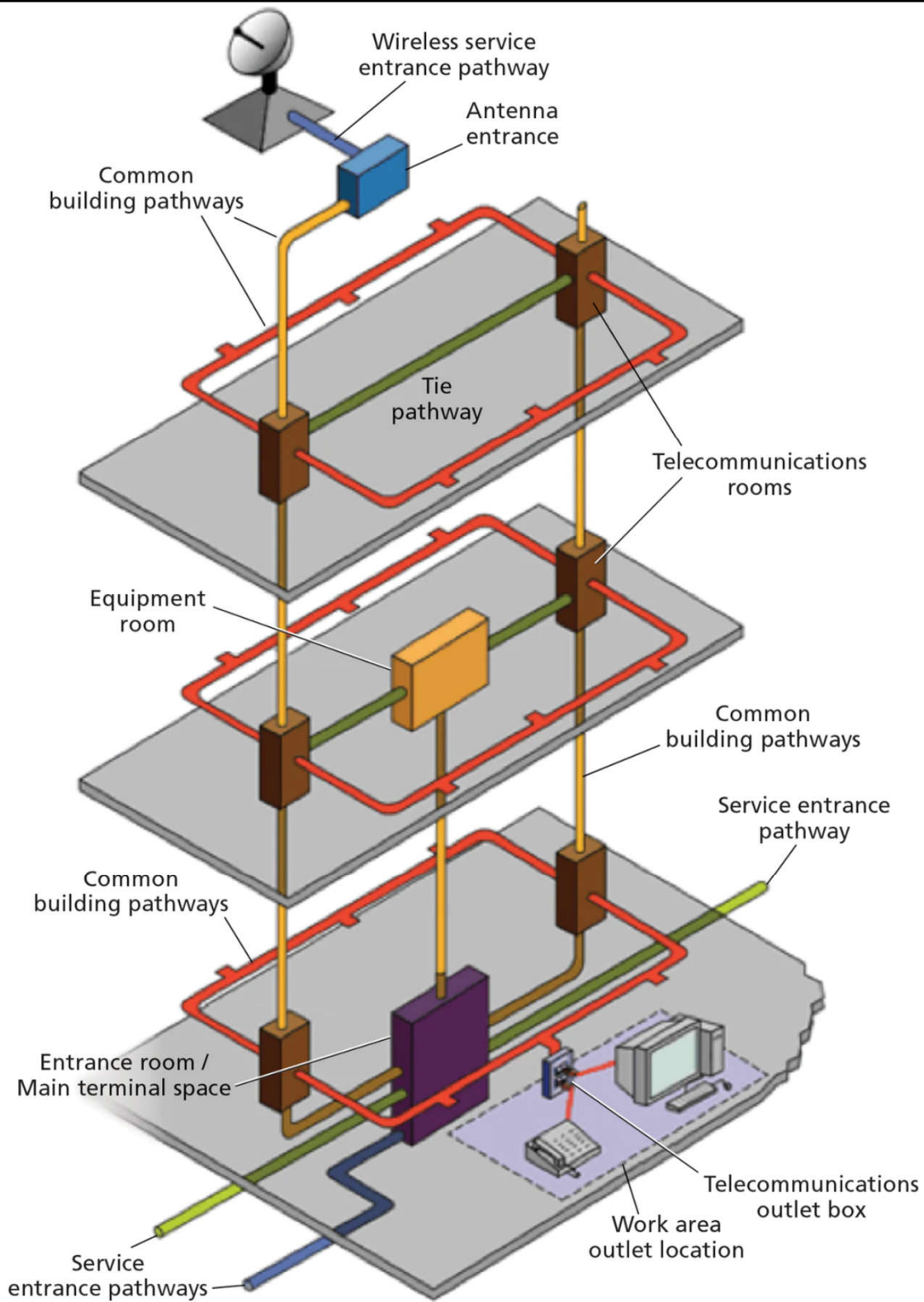
Telecommunication spaces

5. Horizontal Pathways

4. Telecommunications Room

Telecommunications Outlets

6. Work Area

3. Backbone Pathways

2. Equipment Room

Interbuilding Backbone Pathways

1. Entrance Facility

Service Entrance

1. Building Entrance Facility
2. Equipment Rooms
3. Backbone Pathways

4. Telecommunication Rooms
5. Horizontal Pathways
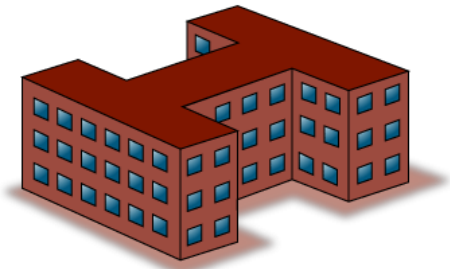6. Work Areas

Telecommunications spaces and pathways

TR = telecommunications room
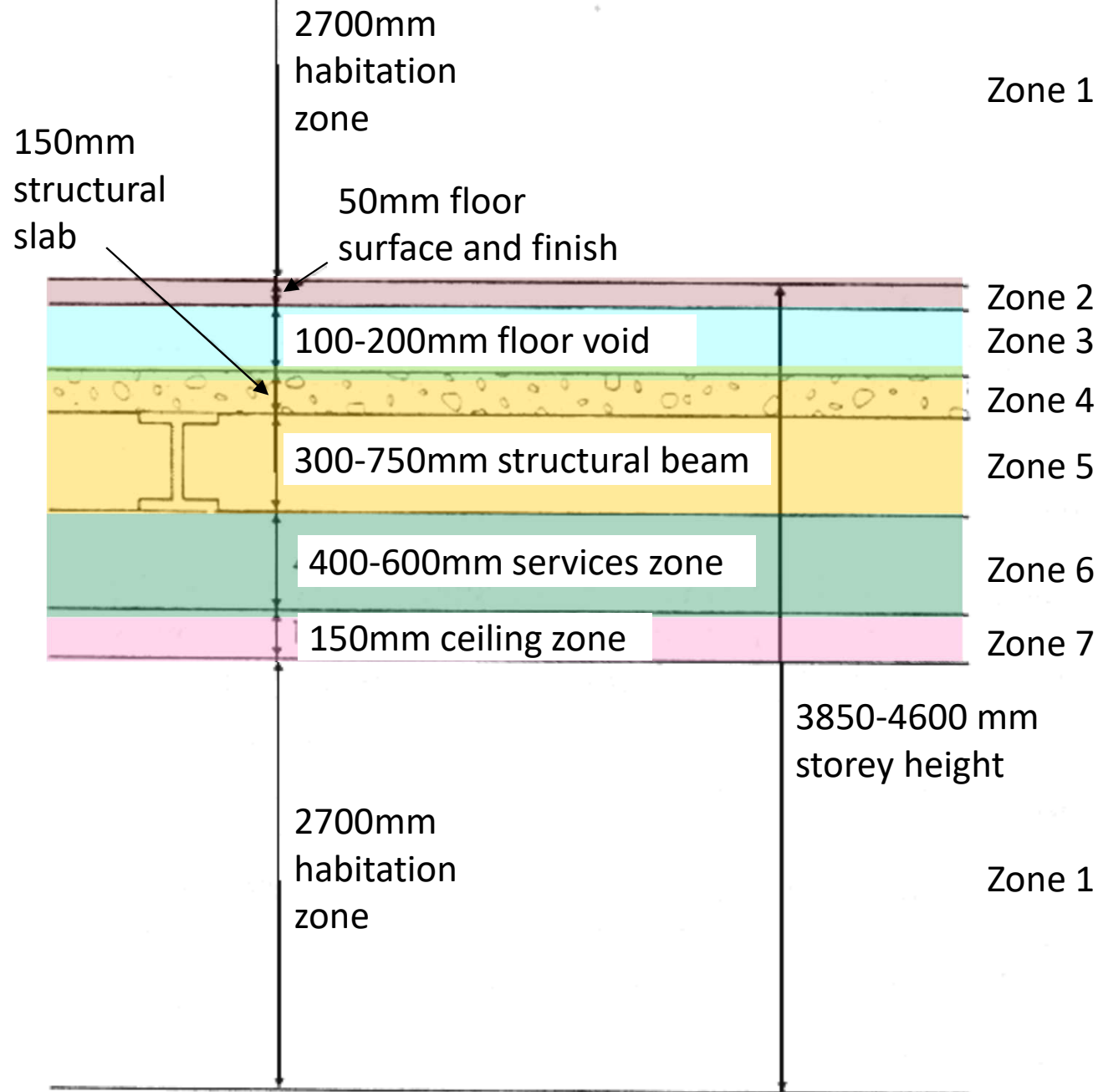Ent. Rm/CER = Entrance Room/Common Equipment Room

(Source: https://www.tpsgc-pwgsc.gc.ca/biens-property/sngp-npms/bi-rp/tech/telecommunications/espaces-spaces-eng.html)

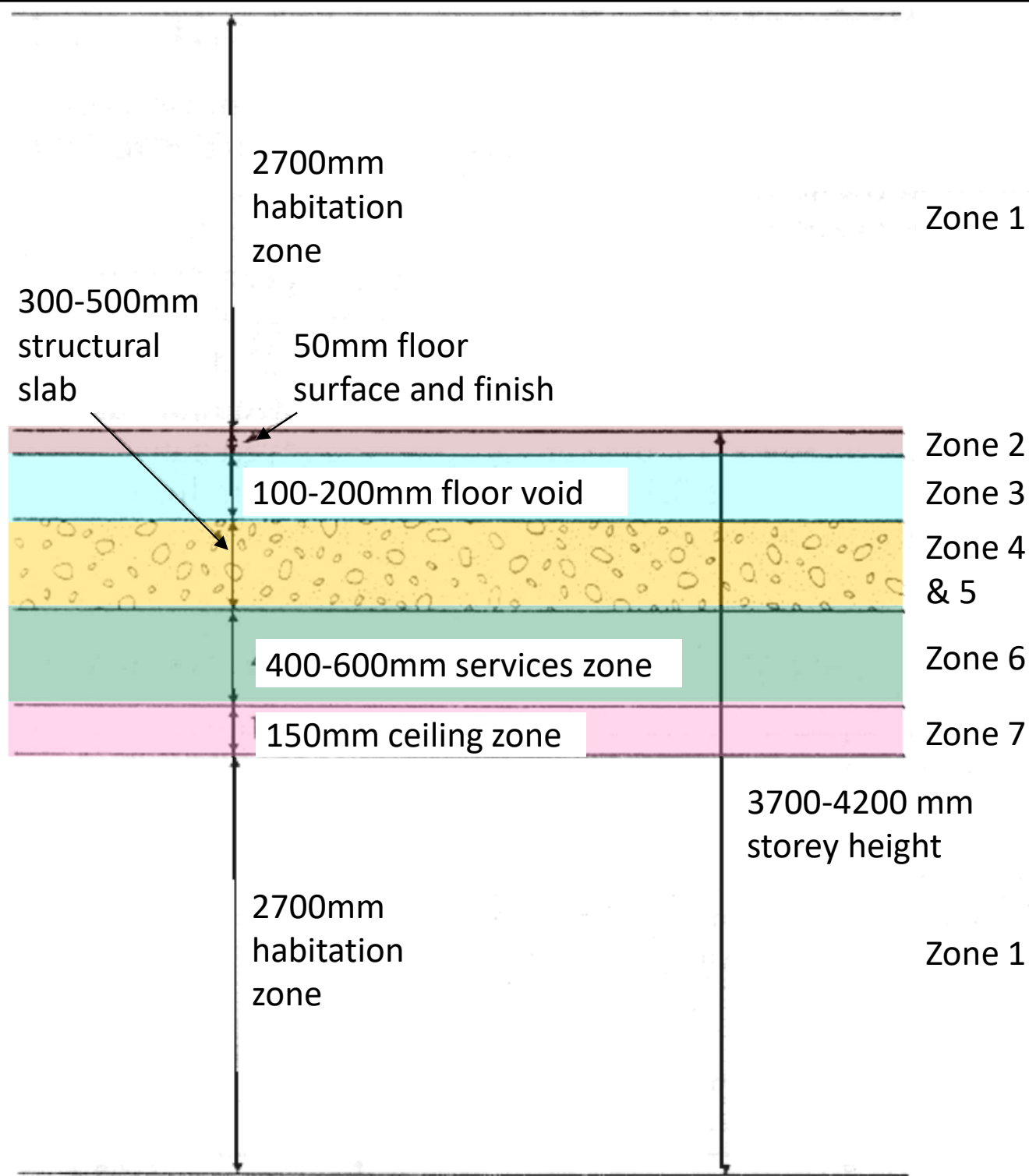Vertical & horizontal distribution for telecommunication networks

Design issues

- Structural requirements
  - Integration of architecture, building services & structural engineering
- Vertical cable distribution
  - Designated cable ducts or riser space
- Horizontal distribution
  - Raised access floor if IT usage is high
  - Typical heights for zoning (Zone 1 to 7)
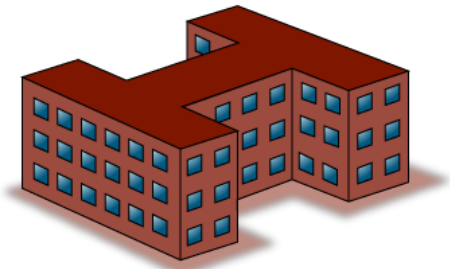   - Steel frame
    - Concrete frame

2700mm habitation zone — Zone 1

150mm structural slab

50mm floor surface and finish — Zone 2

100-200mm floor void — Zone 3

Zone 4

300-750mm structural beam — Zone 5

400-600mm services zone — Zone 6

150mm ceiling zone — Zone 7

3850-4600 mm storey height

2700mm habitation zone — Zone 1

Steel frame (3.85-4.6m storey height)

(Source: CIBSE, 1992. Information Technology and Buildings)

2700mm habitation zone — Zone 1

300-500mm structural slab

50mm floor surface and finish — Zone 2

100-200mm floor void — Zone 3

Zone 4 & 5

400-600mm services zone — Zone 6

150mm ceiling zone — Zone 7

3700-4200 mm storey height

Re-inforced concrete frame (3.7-4.2m storey height)

2700mm habitation zone — Zone 1

(Source: CIBSE, 1992. Information Technology and Buildings)
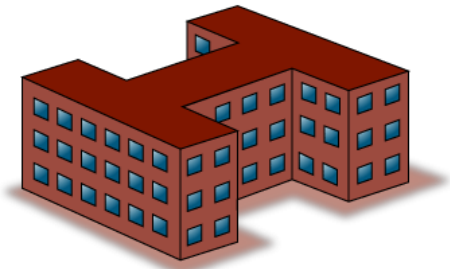
Design issues

- [Floor loading](#)
  - Usually IT equipment will not exceed the floor loads, except where equipment densities are high
  - Where point loads are high, load spreading must be used, such as for power equipment
  - High volume of papers (very heavy!)
  - Loads of raised floors
  - Access areas
  - Weight of power or radio equipment on roofs

Design issues

- **IT equipment rooms**
  - Project planning
    - Detailed knowledge of IT equipment often not known
   - May consult the public telephone/network operators & equipment suppliers
  - Design considerations
    - Voice and data services
    - Distributed equipment rooms
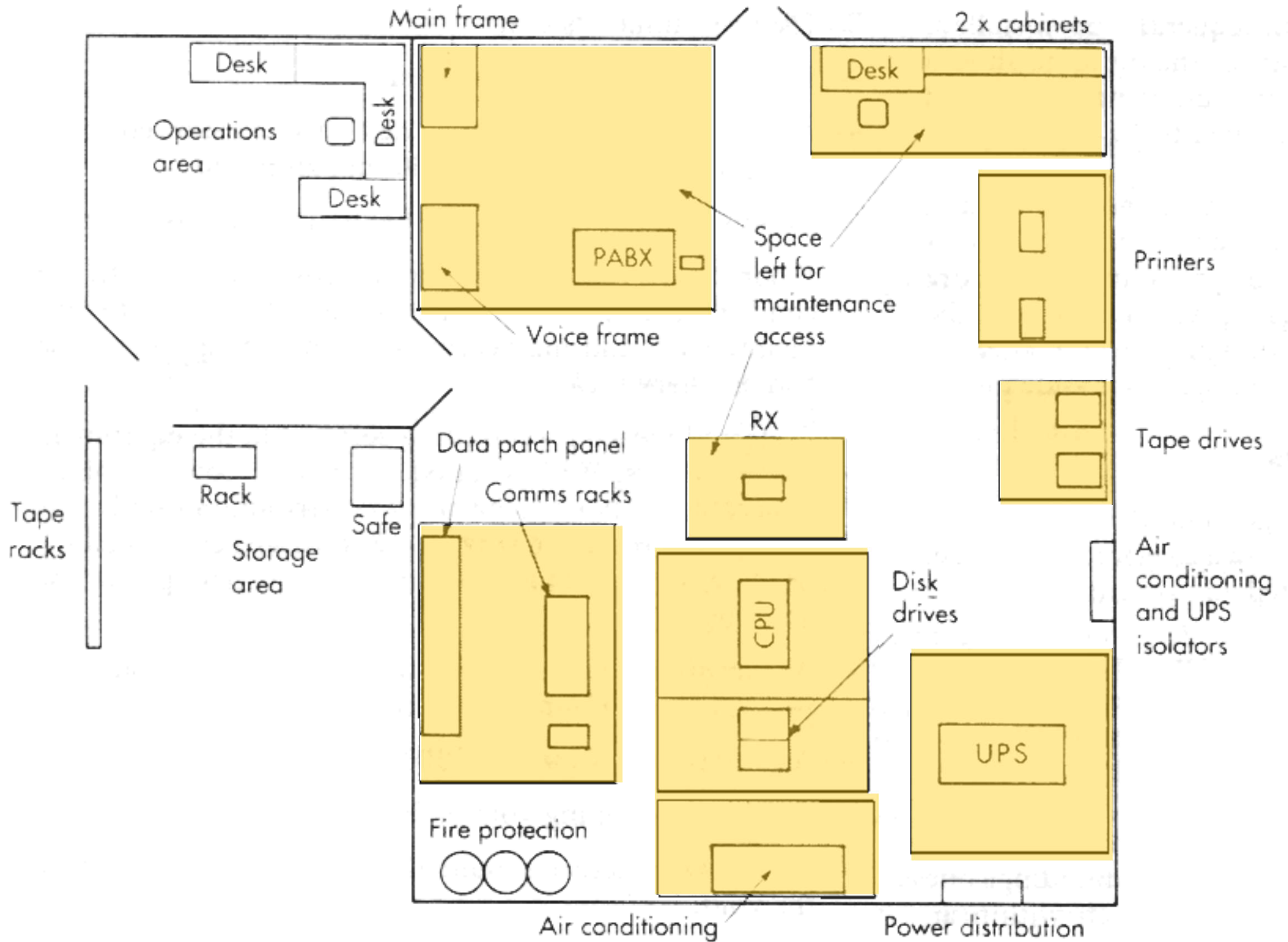   - Components of IT systems

Components of IT systems

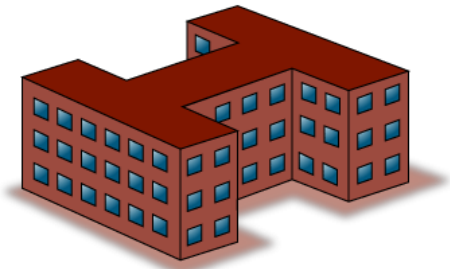| System	External service	Equipment	Internal distribution
Telephone	Telephone lines	PABX	Extension wiring Network links
Central computer	Network links	CPU	Terminal wiring
Departmental computer	Network links	CPU	Terminal wiring plus network
Local area network	Gateway or data link	Distributed processing	Internal wiring Bridge links
Information system	Network link to service	Controller wiring	Display terminal provider
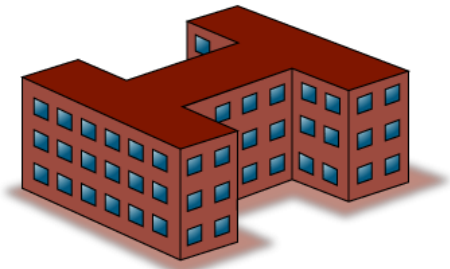
Design issues

- <u>General equipment rooms</u>: design considerations
  - Minimum room height, floor void, ceiling void
  - Sufficient floor loadings
  - Access for installing, operating and maintenance of equipment
  - Environment suitable for operating the equipment
  - Room finishes easily cleaned
  - Floor areas allowed for all equipment, staff, services, storage, etc

Main frame

2 x cabinets

Desk

Operations area

Desk

Desk

Desk

PABX

Space left for maintenance access

Voice frame

Printers

RX

Data patch panel

Comms racks

Tape drives

Tape racks

Rack

Safe

Storage area

CPU

Disk drives

Air conditioning and UPS isolators

UPS

Fire protection

Air conditioning

Power distribution

(Source: CIBSE, 1992. Information Technology and Buildings)
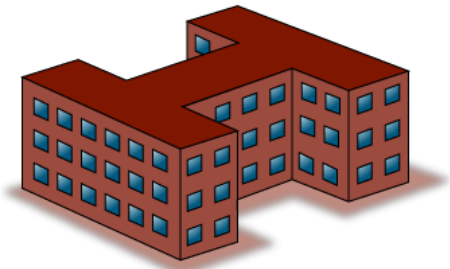
Design issues

- General equipment rooms: design considerations (cont'd)
    - Future expansion allowance
    - Access for equipment deliveries
    - Preferred methods of locating services
        - Within raised floor void: power cabling, data cabling, HVAC pipework, air distribution supply, fire detection/protection services
        - Within suspended ceiling: lighting, air distribution return, fire detection/protection services
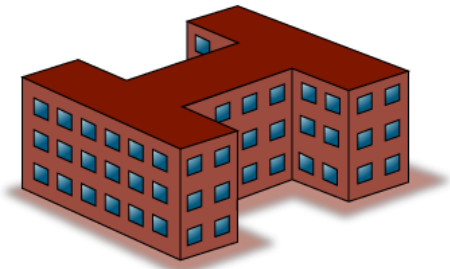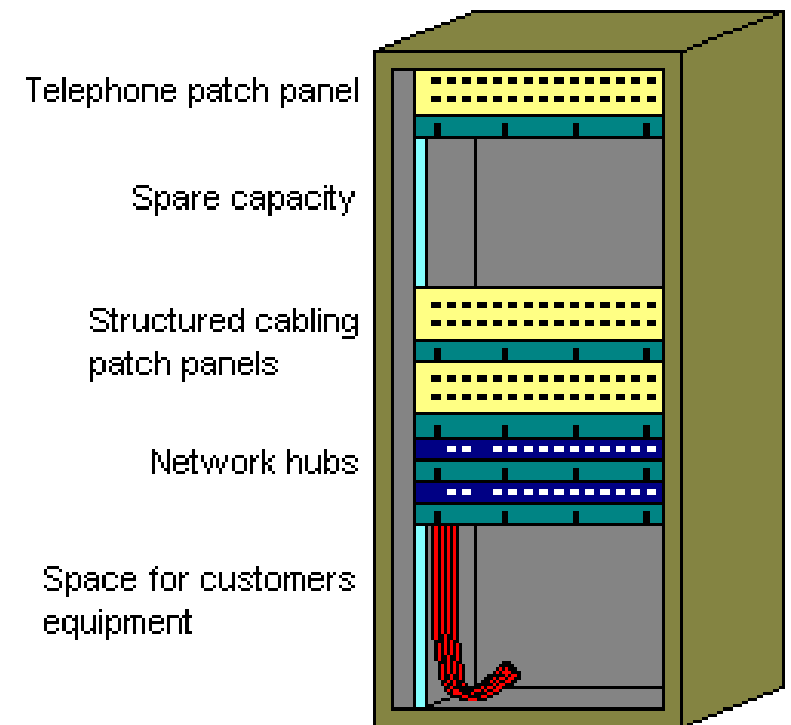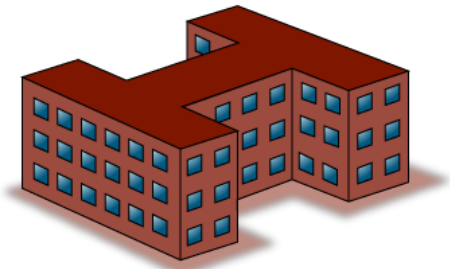
Design issues

- Major sub-systems:
  - Lead-in or entrance facilities, including cable entry and cable entry chamber
  - Telecommunications and broadcasting equipment (TBE) room [*Equipment room*]
  - Secondary TBE room [*Telecomm room*]
  - Vertical riser (backbone)
  - Horizontal distribution facilities

Design issues

- Major sub-systems: (cont'd)
  - Telecommunications closets
  - Accommodation for subscription TV receiving system
  - TV/FM outlets
  - Telephone sockets
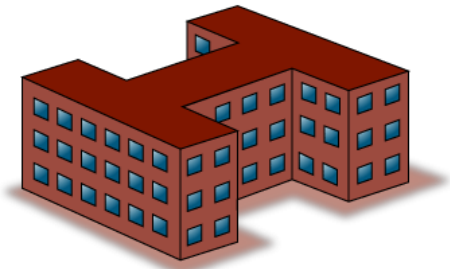 - Cables
  - Rooftops (antennas)

Telephone patch panel

Spare capacity

Structured cabling patch panels

Network hubs

Space for customers equipment

Design issues

- Space planning
    - IT fit-out: equipment is known
    - "Speculative" building: equipment not known
    - Electrical closets & communication closets
    - Minimum areas for equipment
        - Consult telecom operators or follow standards
- Hong Kong telecommunication services:
    - Communication Authority (CA) 通訊事務管理局
      https://www.coms-auth.hk/
        - Codes of Practice/Guidelines https://www.coms-auth.hk/en/policies_regulations/cop_guidelines/telecomm/

Design issues

- Entry points and equipment rooms
  - Entry points for cables & services
    - Multiple routing to reduce risk of disruption
  - Radio systems (e.g. antenna mounting)
  - Frame rooms (may also houses the PABX)
- Maintenance access
  - Areas for maintenance and safety
    - Consult telephone operators & suppliers
  - Access
    - Clearly separate groups, compartments or rooms
    - Used by operating staff and maintenance staff

Typical telecom cabling system
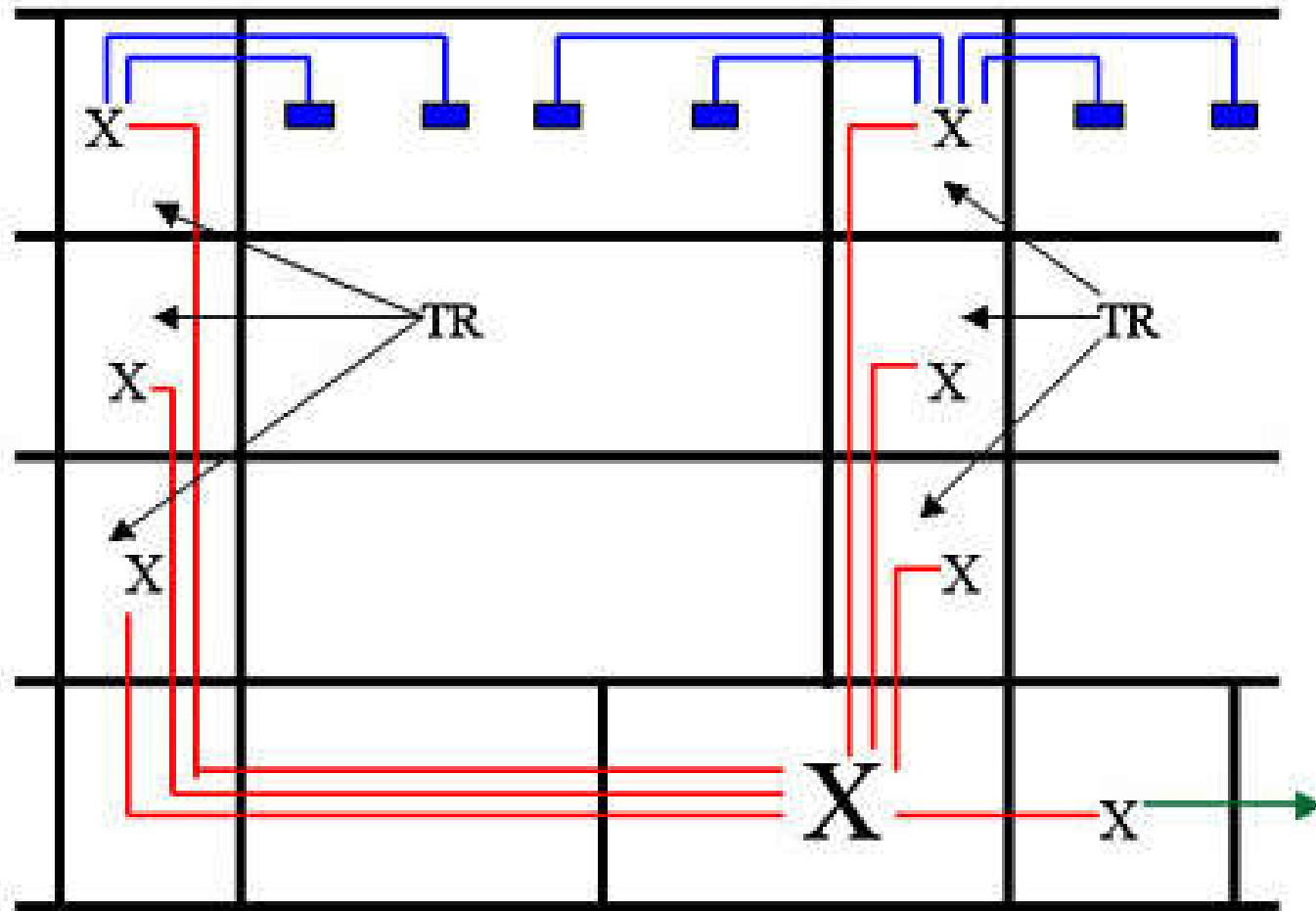
MT/ER   ER

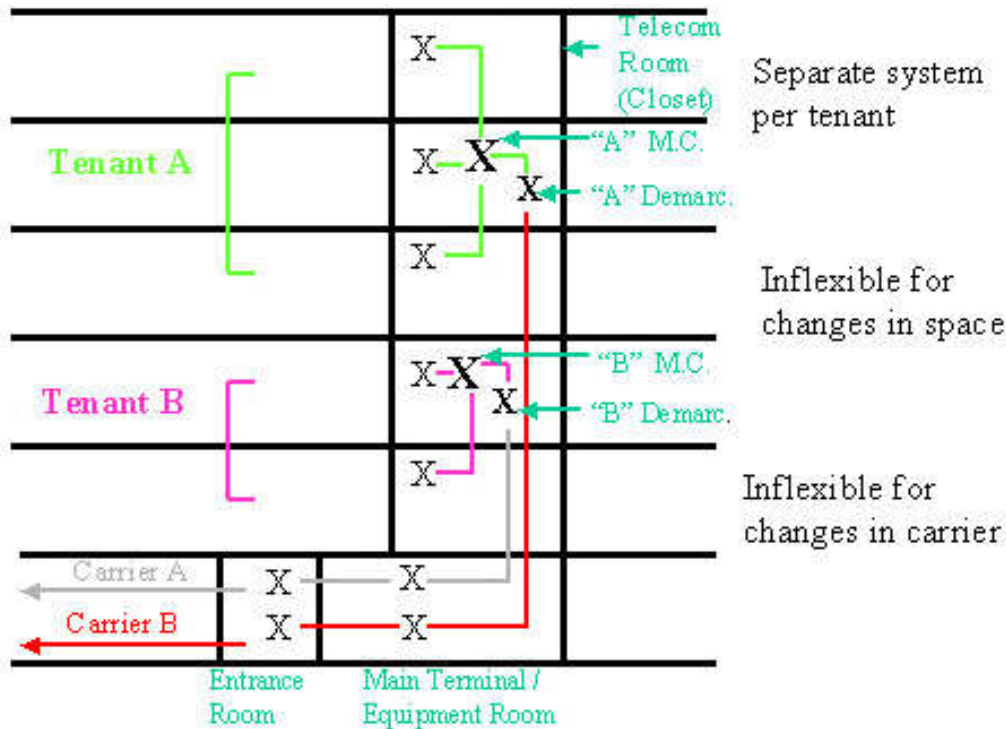|			
▬▬▬	Horizontal Cables	TR:	Telecommunications Room
▬▬▬	Backbone Cables	MT/ER:	Main Terminal / Equipment Room
⟶	Carrier cables from Street	ER:	Entrance Room
X	Cross-connect	▪	Work-area jacks (voice, data)

Multi-tenant building: legacy approach and holistic approach

(a) Legacy approach
Each tenant creates its own main cross-connect, installs pathways & backbone cables connecting each of the floor telecom room, and establishes a point of demarcation with the facilities of the telecom carriers.
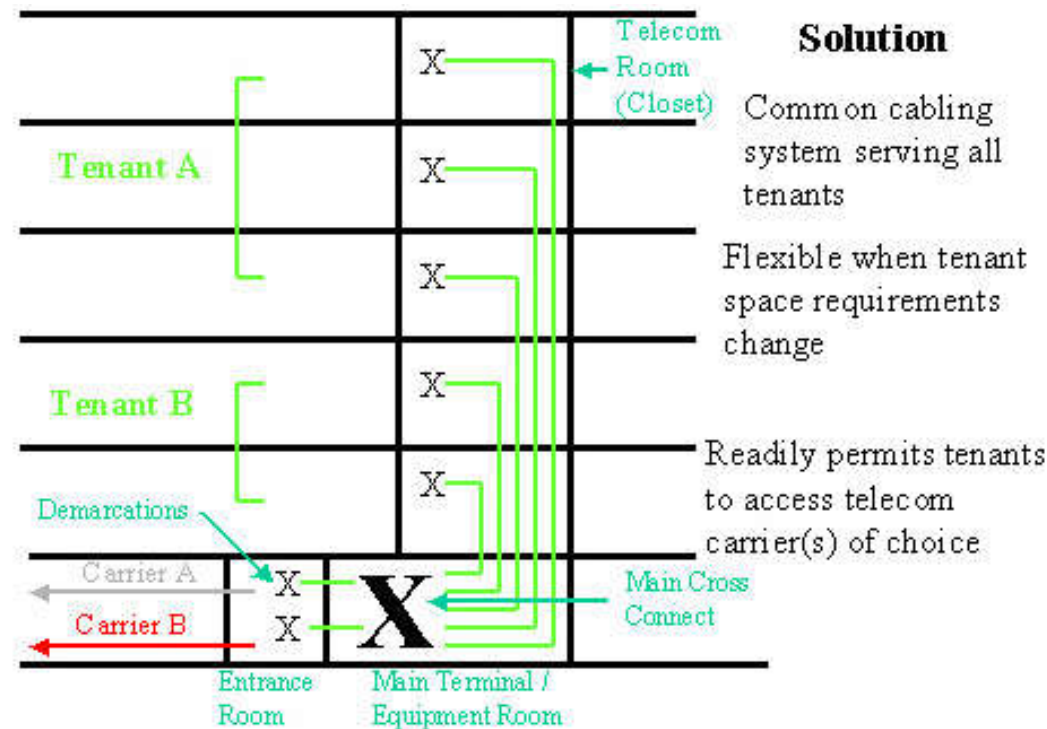
(b) Holistic approach
Adapts to changes in space allocations between tenants or the addition of new tenants. It accommodates fluctuations between single and multiple occupancy of the building & readily permits tenants to select their telecomm common carriers.

Example of a basic data centre topology

Access Providers ── **Entrance Room** (Carrier Equip & Demarcation) ── **Access Providers**

Offices, Operations Center, Support Rooms

Computer Room

Backbone cabling

Horizontal cabling

Telecom Room (Office & Operations Center LAN switches)

Backbone cabling

Main Dist Area (Routers, Backbone LAN/SAN Switches, PBX, M13 Muxes)

Backbone cabling

Horiz Dist Area (LAN/SAN/KVM Switches)

Horiz Dist Area (LAN/SAN/KVM Switches)

Horiz Dist Area (LAN/SAN/KVM Switches)

Horiz Dist Area (LAN/SAN/KVM Switches)

Horizontal cabling

Zone Dist Area

Horizontal cabling

Equip Dist Area (Rack/Cabinet)

Horizontal cabling

Equip Dist Area (Rack/Cabinet)

Horizontal cabling

Equip Dist Area (Rack/Cabinet)

Horizontal cabling

Equip Dist Area (Rack/Cabinet)

(Source: ANSI/TIA-942-2005 Telecommunications Infrastructure Standard for Data Centers)
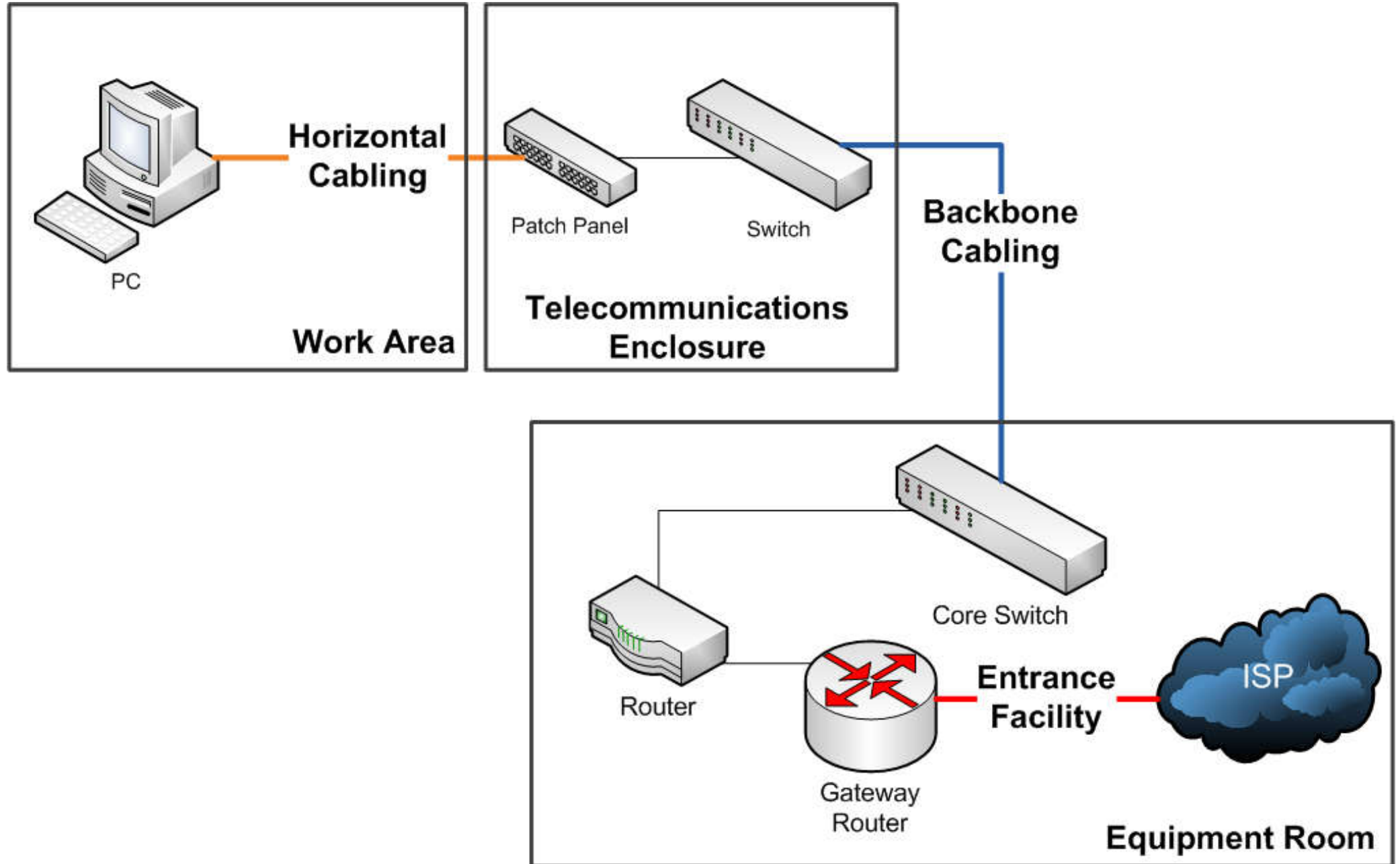
Cabling management

- <u>Structured cabling system (SCS)</u>
  - A set of cabling and connectivity products that integrates the voice, data, video, and various management systems of a building (e.g. safety alarms, security access, energy systems, etc.)
    - Give saturation wiring & flexibility
    - Radial architecture connection (back to closet)
    - Suitable patching to facilitate maintenance
  - Once the main components of the system is installed, it do not change

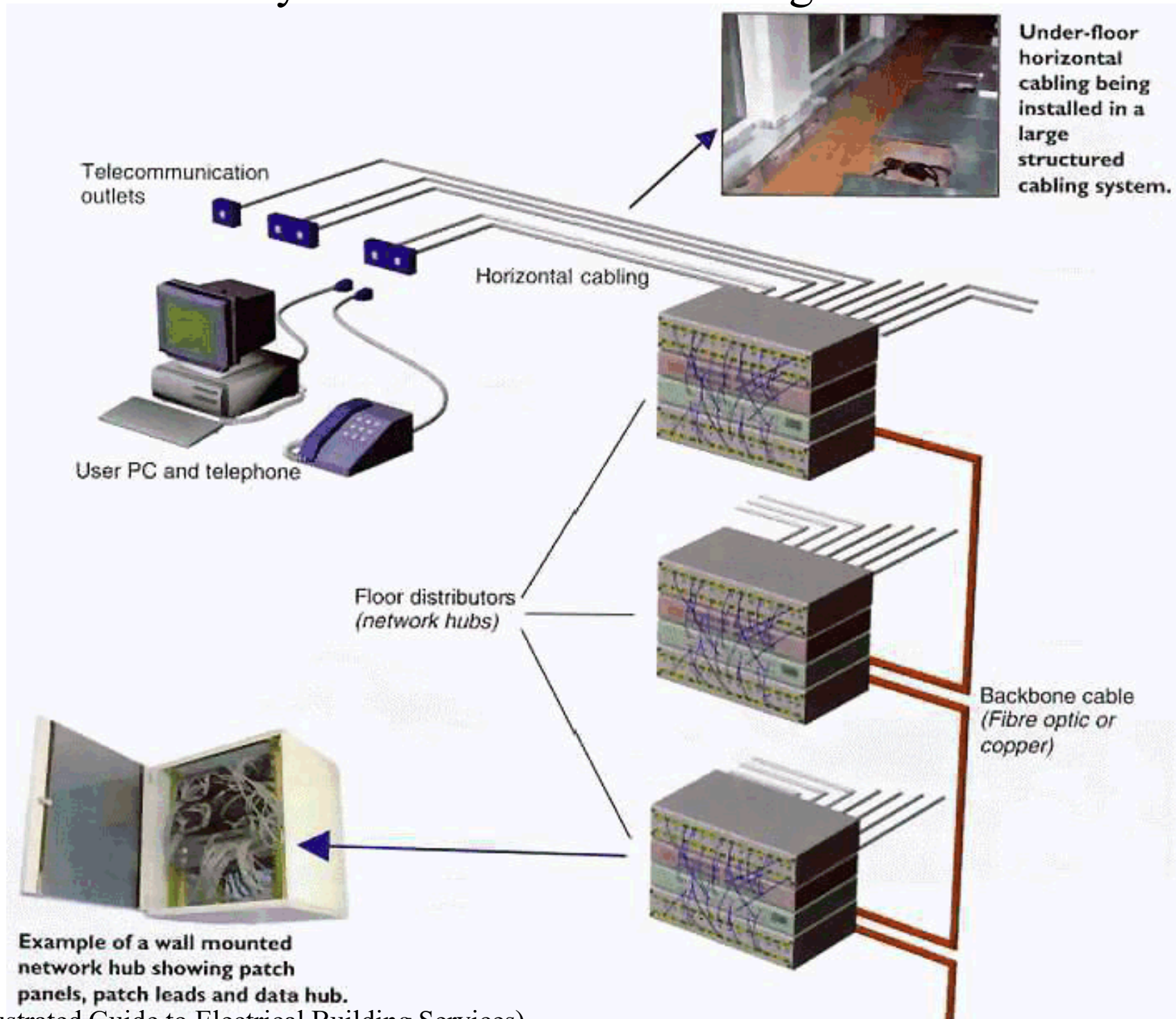結構化佈線系統

Cabling management

- Industry <u>standards</u> to address the cabling and cable-delivery methods (pathways & spaces)
  - Such as EIA/TIA 568, ISO/IEC 11801
  - Based on a structured subsystem architecture
- 4 key components of structured cabling
  - Telecommunication outlets
  - Horizontal cabling
  - Patch panels and floor distributors (data hub)
  - Backbone cable

Structured cabling network diagram

Work Area: PC — Horizontal Cabling

Telecommunications Enclosure: Patch Panel — Switch

Backbone Cabling

Equipment Room: Router, Gateway Router, Core Switch — Entrance Facility — ISP

Basic layout of a structured cabling installation

Under-floor horizontal cabling being installed in a large structured cabling system.

Telecommunication outlets

Horizontal cabling

User PC and telephone

Floor distributors (network hubs)

Backbone cable (Fibre optic or copper)

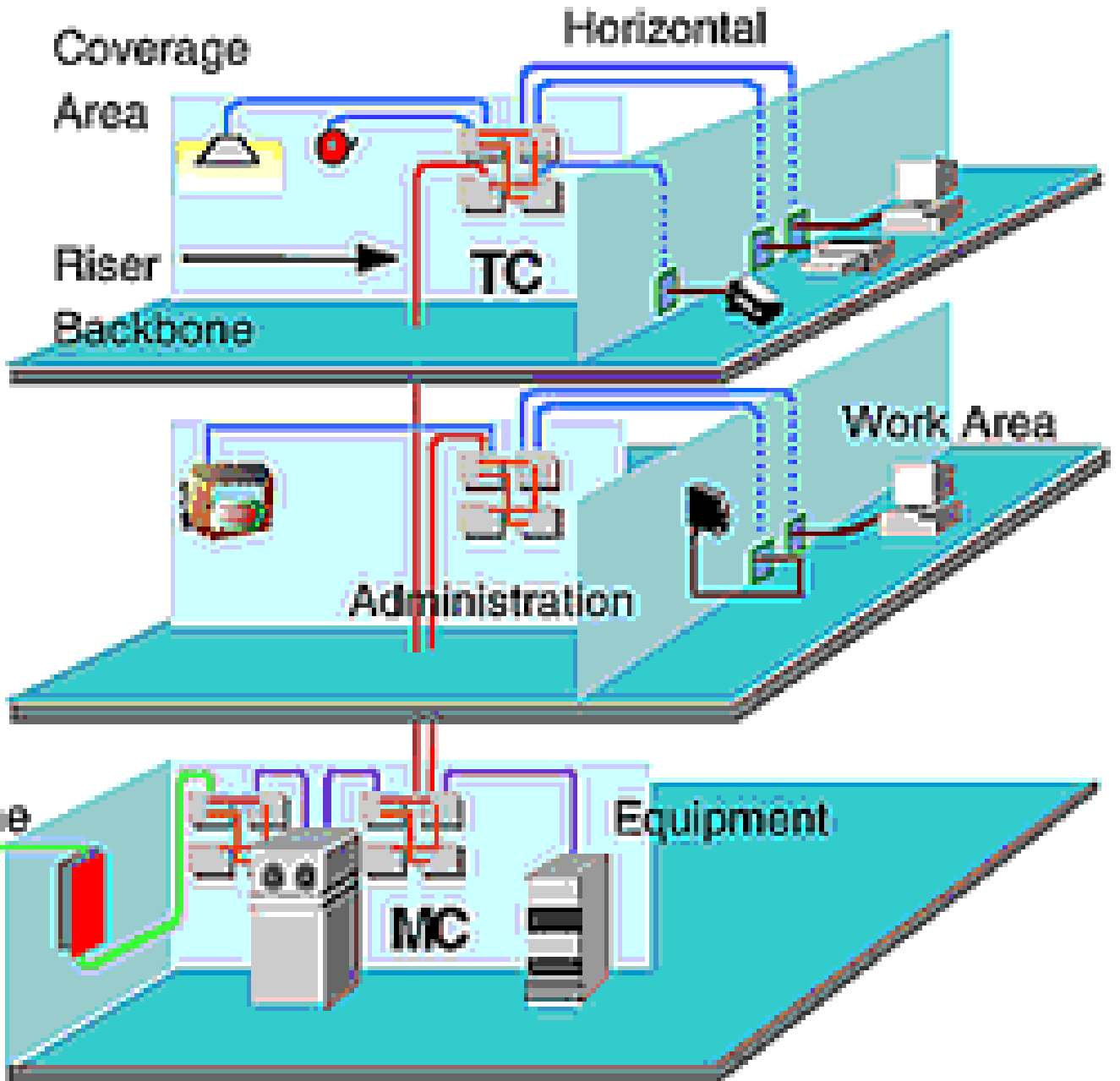Example of a wall mounted network hub showing patch panels, patch leads and data hub.

(Source: Illustrated Guide to Electrical Building Services)

TC = telecomm closet

Structured Cabling Subsystems
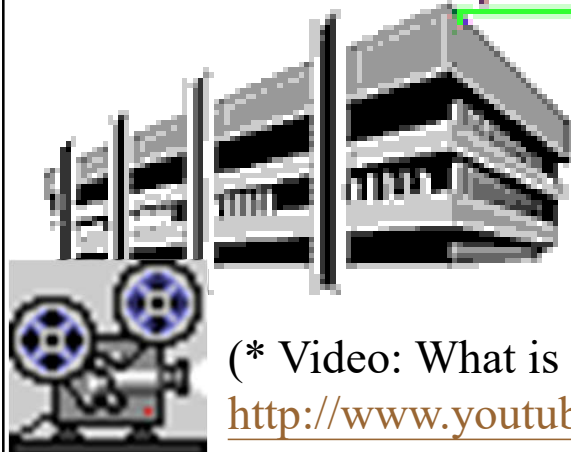
Coverage Area

Horizontal

Riser

TC

Backbone

Work Area

Administration

Campus Backbone

Equipment

MC

# Six subsystems of structured cabling

1. Entrance Facilities The point where the telephone company network ends and connects with the on-premises wiring at the customer premises	**4. Horizontal Cabling** Inside wiring or plenum cabling that connects telecom rooms to individual outlets or work areas on the floor
2. Equipment Rooms House equipment and wiring consolidation points that serve the users inside the building or campus	**5. Telecommunications Rooms or Enclosure** Connects between the backbone cabling and horizontal cabling
3. Backbone Cabling Connects between the equipment/telecom rooms on different floors	**6. Work-Area Components** Connect end-user equipment to outlets of the horizontal cabling system

Video: What are the Structured Cabling System Components? (8:13)
https://youtu.be/xDbiT3IwNpE

Typical structured cabling components
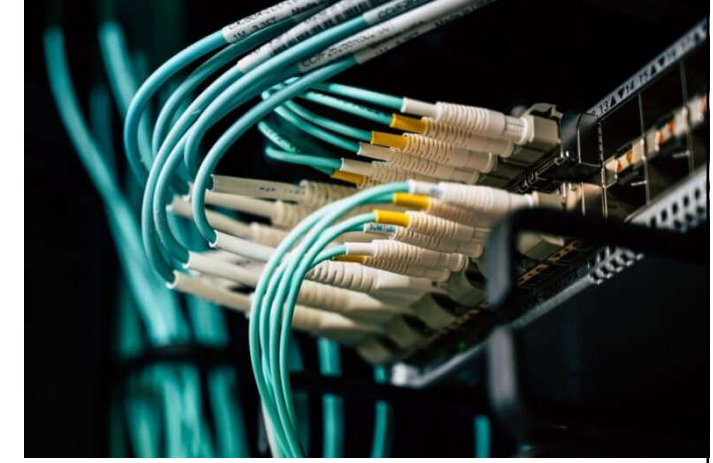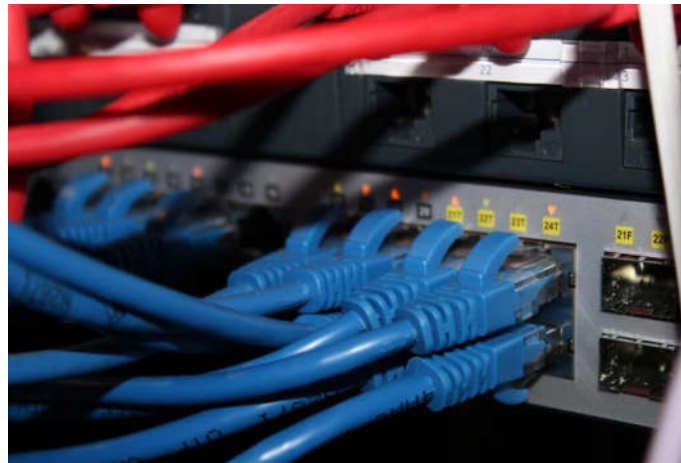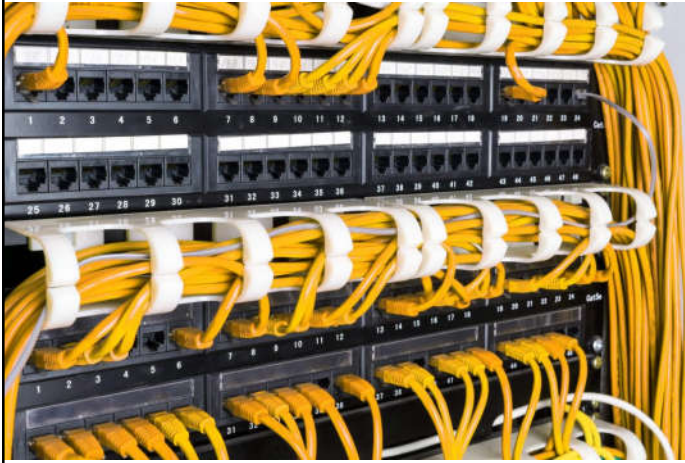
Patch Panels
A patch panel connects cables. They're also called patch bays and are attached to network racks. Patch panels use cords to connect to a switch.

Switches
A switch is a component of the system that receives, processes and sends data. The switch connects your patch panels so you can connect devices to a network and share data and access the internet.
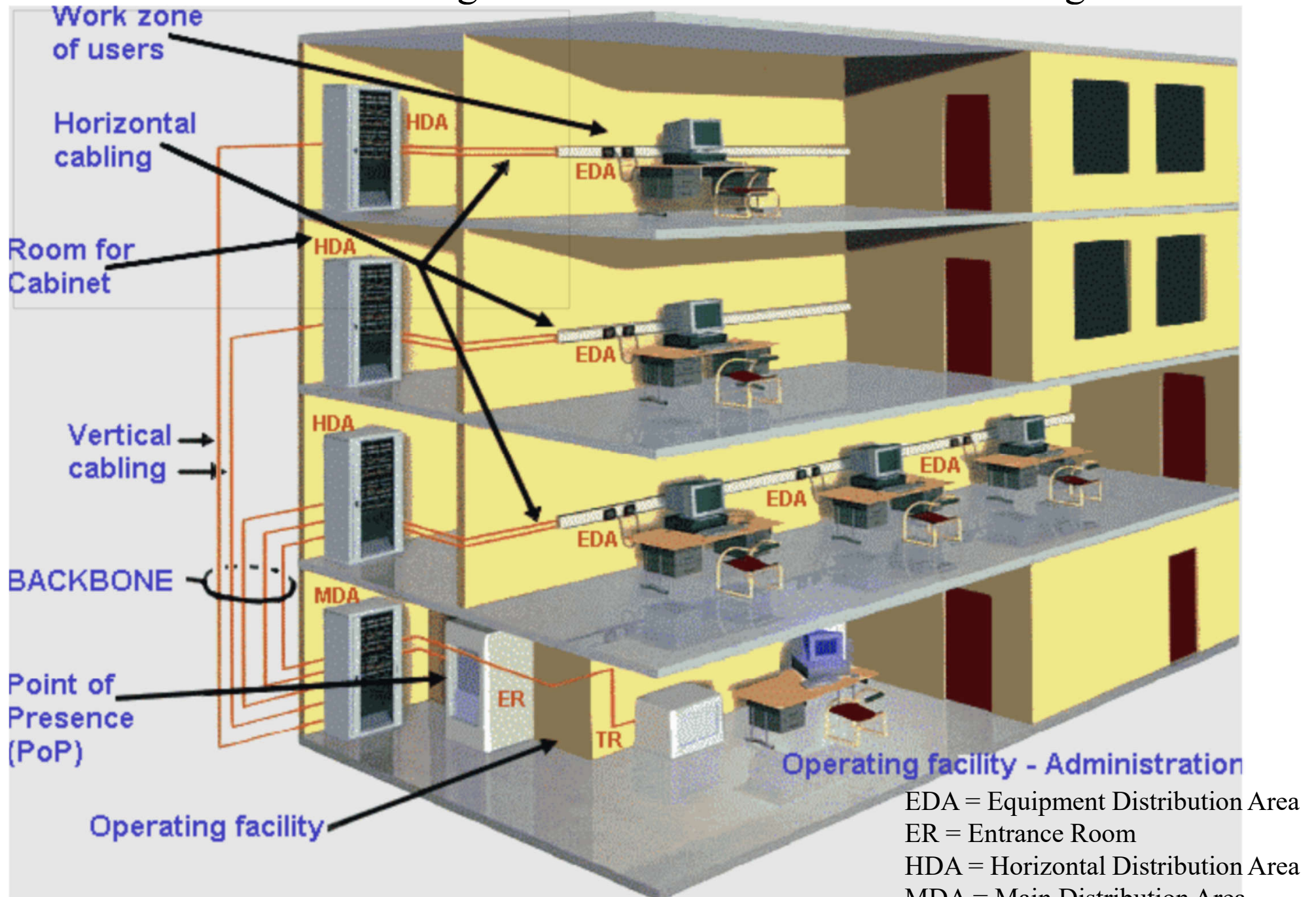
Trunk Cables
A trunk is a cable that connects to patch panels, consolidating the number of wires running from patch panel to patch panel. They're essentially a grouping of wires that are bound into one big cable to keep everything neat and organized.

(Source: https://datalinetechnologies.com/structured-cabling-solutions/)

Typical telecommunication equipment room

Structured cabling for local area network in a building

Work zone of users

Horizontal cabling

Room for Cabinet

Vertical cabling

BACKBONE

Point of Presence (PoP)

Operating facility

HDA

HDA

HDA

MDA

EDA

EDA

EDA

EDA

EDA

ER

TR

Operating facility - Administration

EDA = Equipment Distribution Area
ER = Entrance Room
HDA = Horizontal Distribution Area
MDA = Main Distribution Area
TR = Telecom Room
ZDA = Zone Distribution Area

(Source: https://informatics.buzdo.com/p862-intranet-structured-cabling.htm)

Topological scheme of structured cabling

(Source: https://informatics.buzdo.com/p862-intranet-structured-cabling.htm)
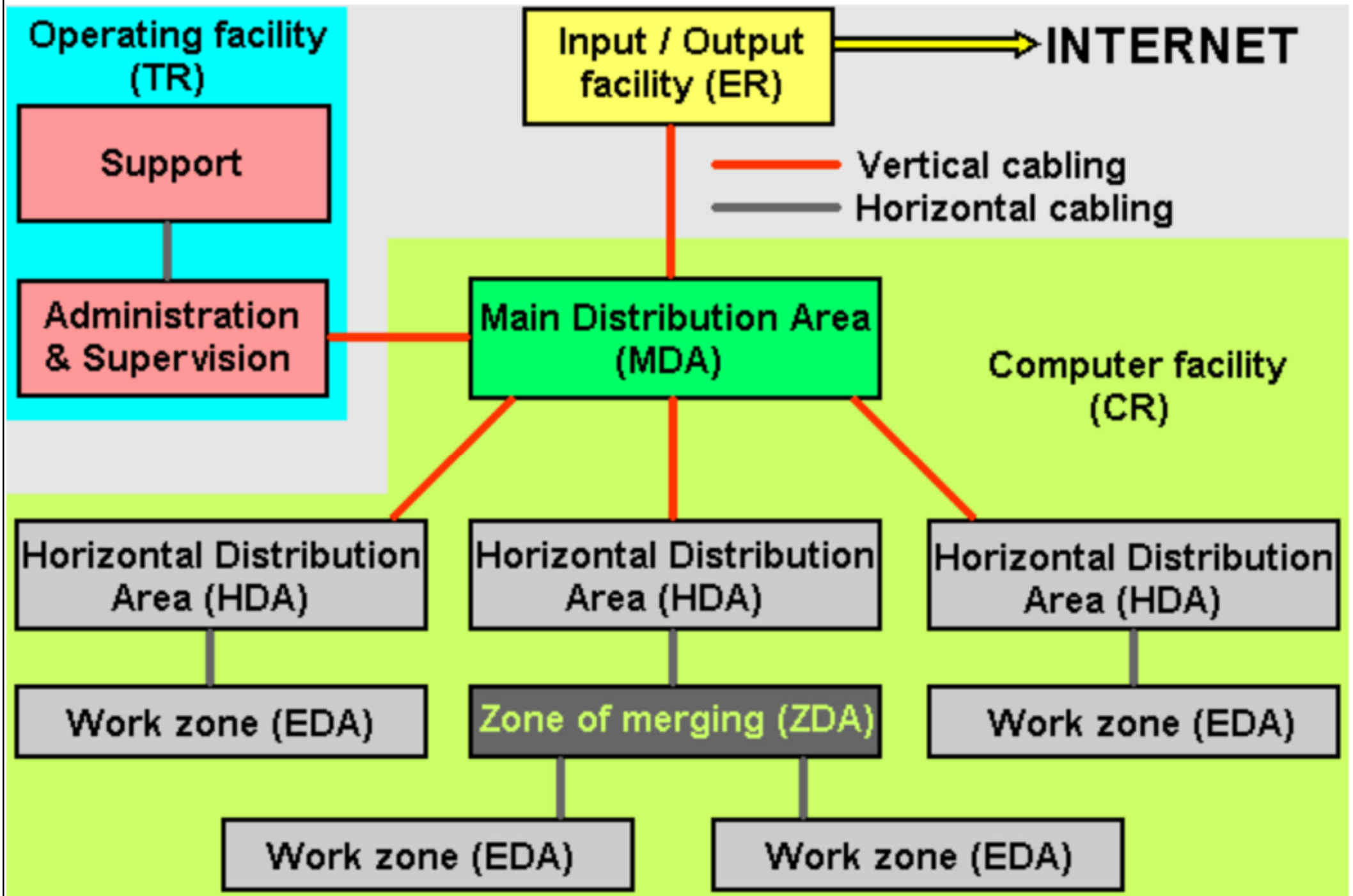
Topological scheme connection of network devices

EDA = Equipment Distribution Area
ER = Entrance Room
HDA = Horizontal Distribution Area
MDA = Main Distribution Area
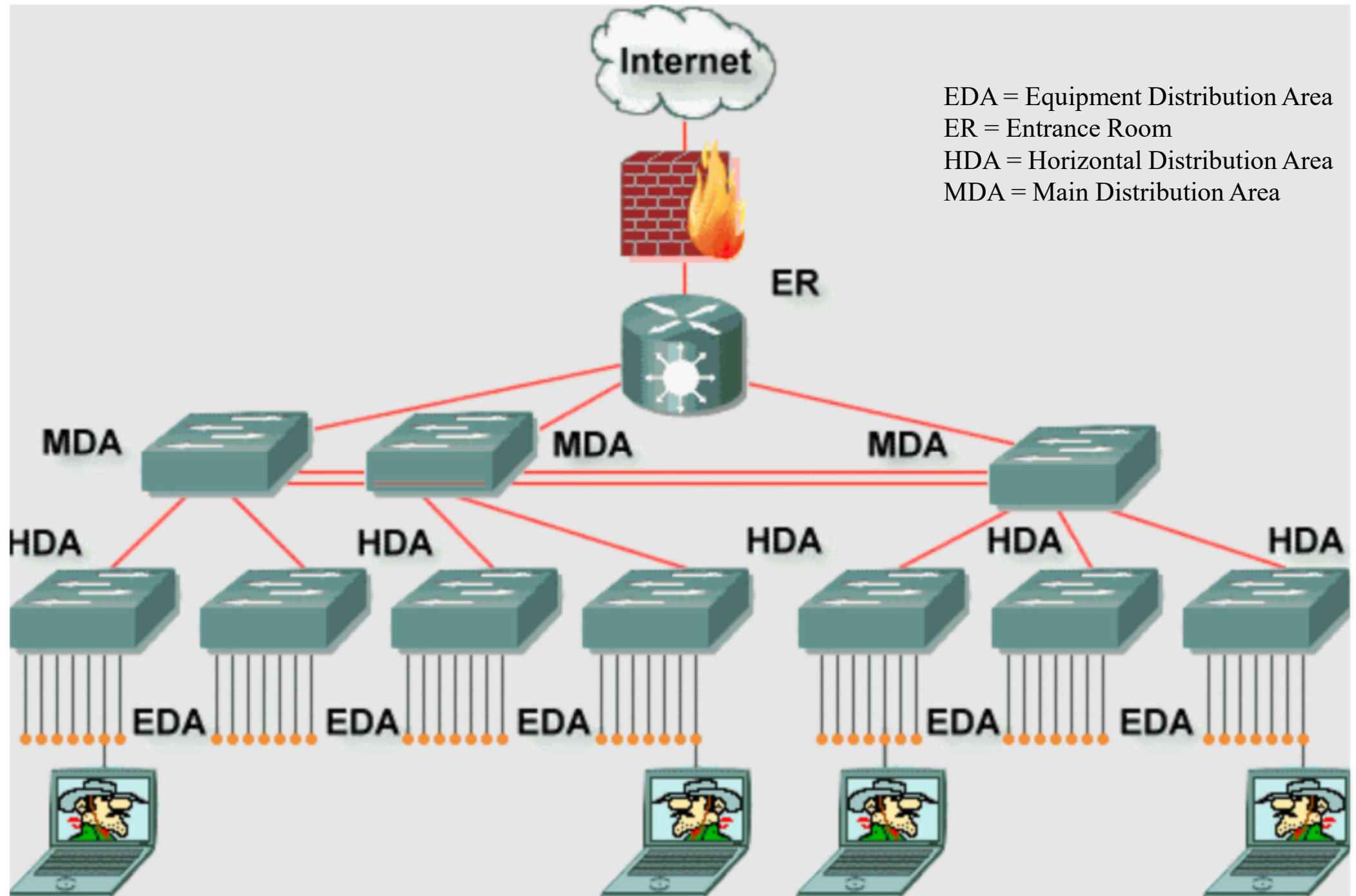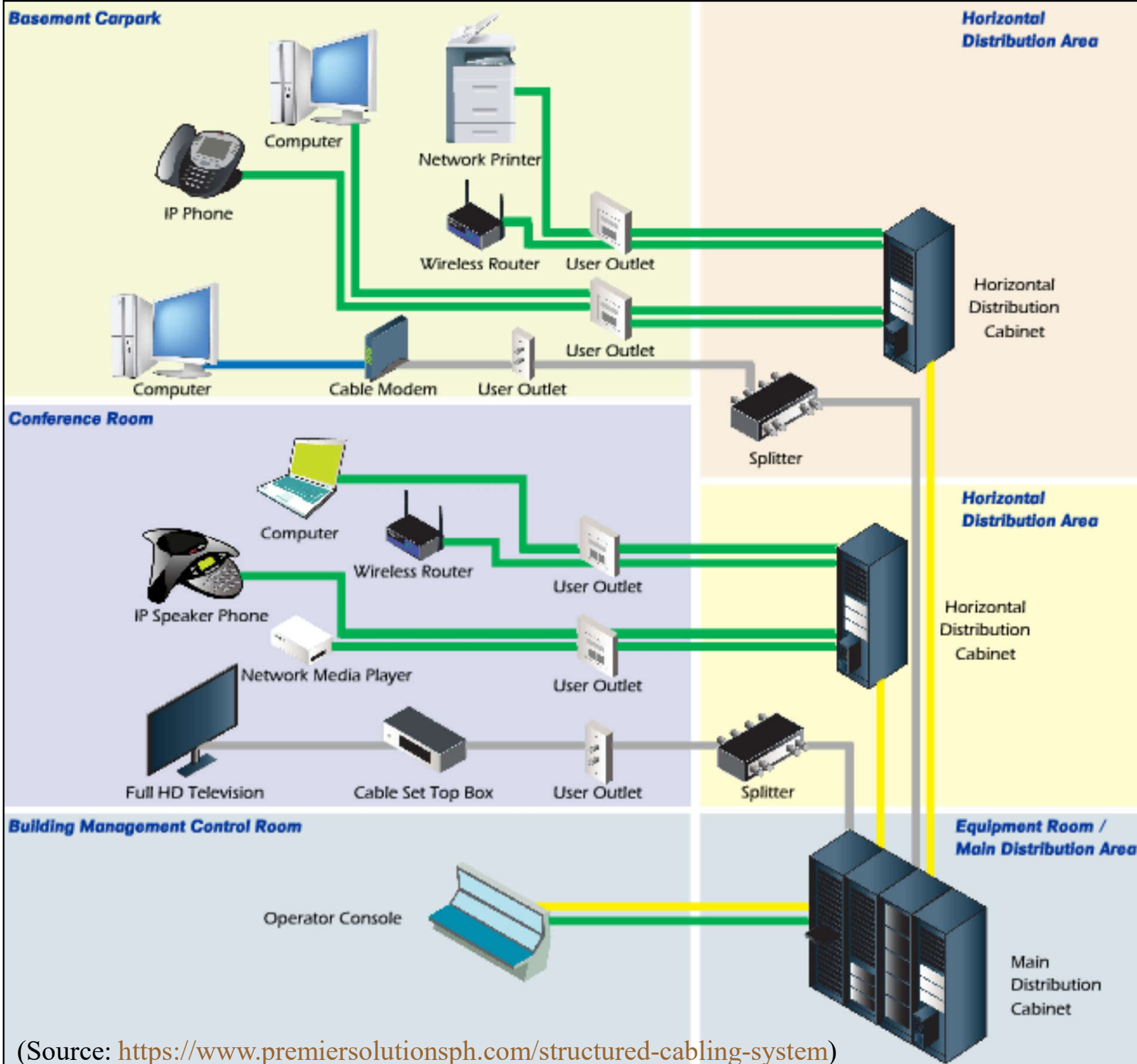
Application example of structured cabling systems

(Source: https://www.premiersolutionsph.com/structured-cabling-system)
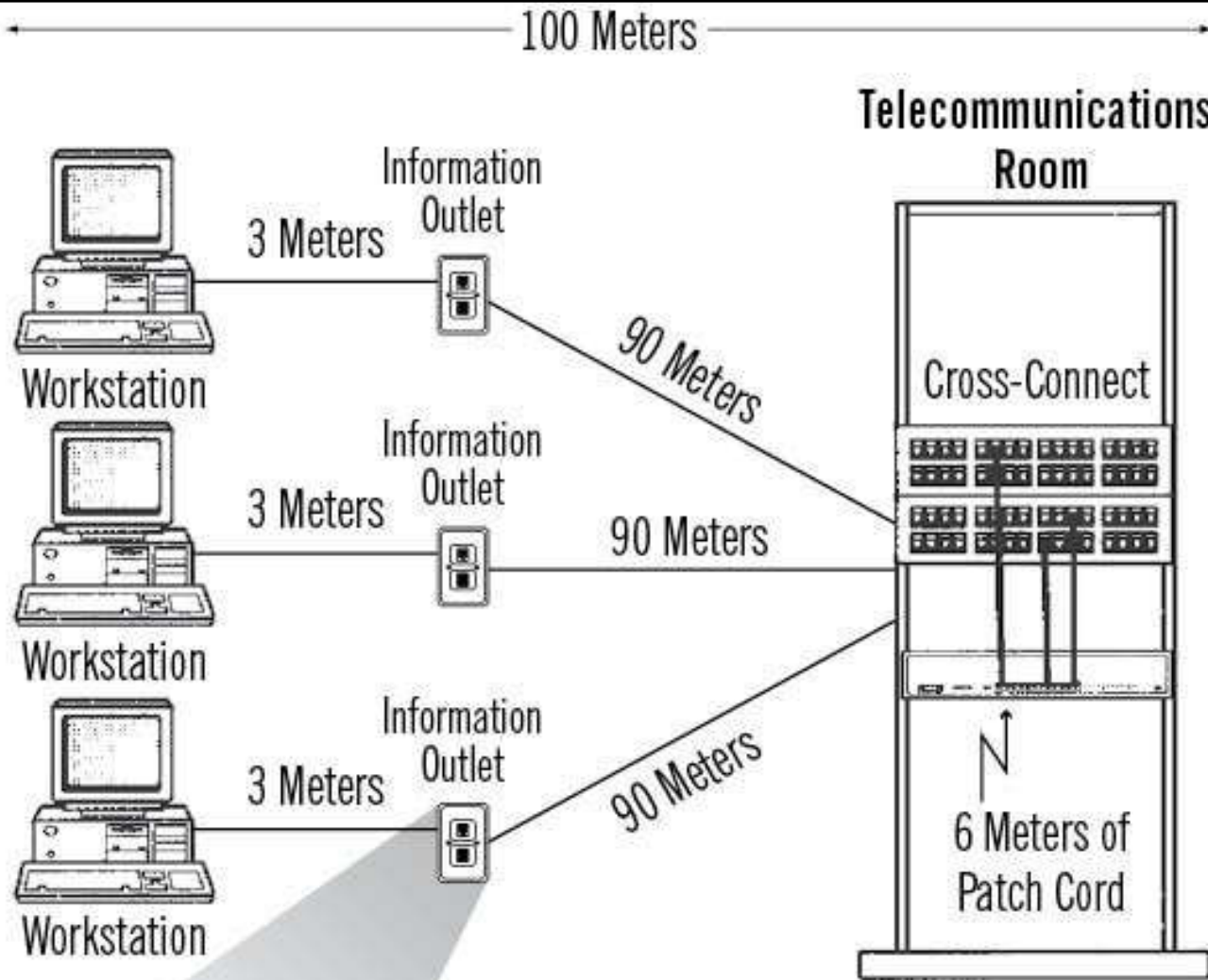
Horizontal cabling system & maximum cable length
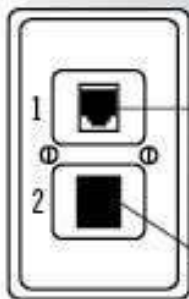
Cabling management

- Steps to design a structured cabling system
    - 1. Select the standards to follow (e.g. ISO 11801, EIA/TIA 568)
    - 2. Horizontal cabling
    - 3. Backbone cabling
    - 4. Positioning & design of telecomm closets
    - 5. Cable containment system
    - 6. Cable administration system
    - 7. Earthing scheme & testing

Cabling management

- Cable routing recommendations
  - Data & voice follow the same routes
  - Good labelling for identification
  - Duplicate routes (increase reliability for high priority equipment)
  - Secondary distribution: most demanding
    - Normally follows a rectangular grid (street & avenue)
  - Allow for future expansion/changes

Cabling management

- Distribution strategy
  - Cabling routes, capacity, distribution methods, outlet types, flexibility & allowance for future growth
  - Major requirements:
    - Primary plant locations & sub-distribution points
    - Load centres
    - Management and maintenance
    - Redundancy & extension allowance
    - Cable types & termination facilities
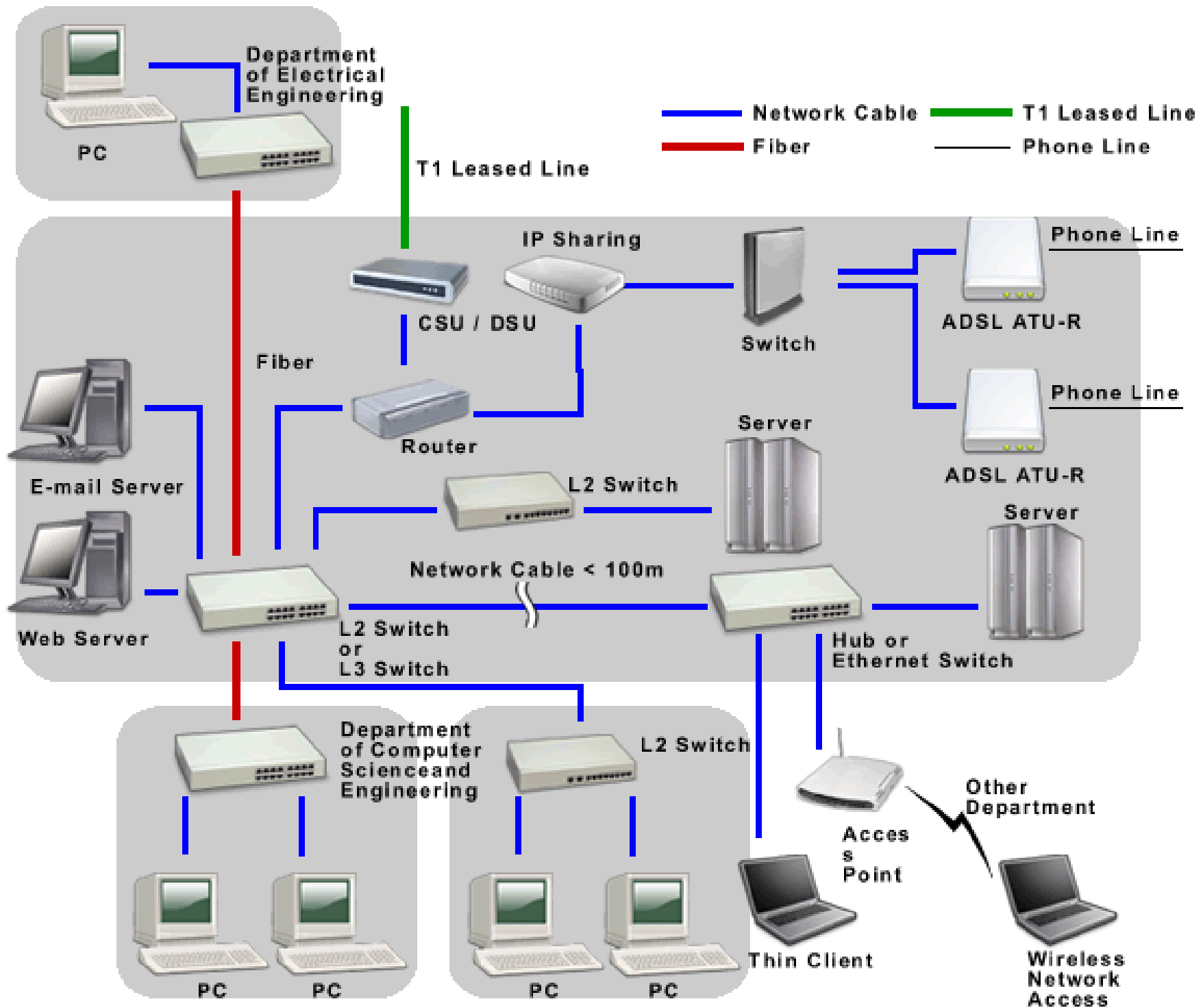   - Flexibility

Networking

- 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.

- Why Network?
  - Devices can be shared
  - Easier to manage
  - Easier to maintain
  - Less expensive for equipment & software

Office/Enterprise computer network

Department of Electrical Engineering

PC

Network Cable — T1 Leased Line

Fiber — Phone Line

T1 Leased Line

IP Sharing

Phone Line

CSU / DSU

Switch

ADSL ATU-R

Fiber

Router

Phone Line

E-mail Server

L2 Switch

Server

ADSL ATU-R

Server

Web Server

Network Cable < 100m

L2 Switch or L3 Switch

Hub or Ethernet Switch

Department of Computer Scienceand Engineering

L2 Switch

Other Department

Access Point

PC   PC

PC   PC
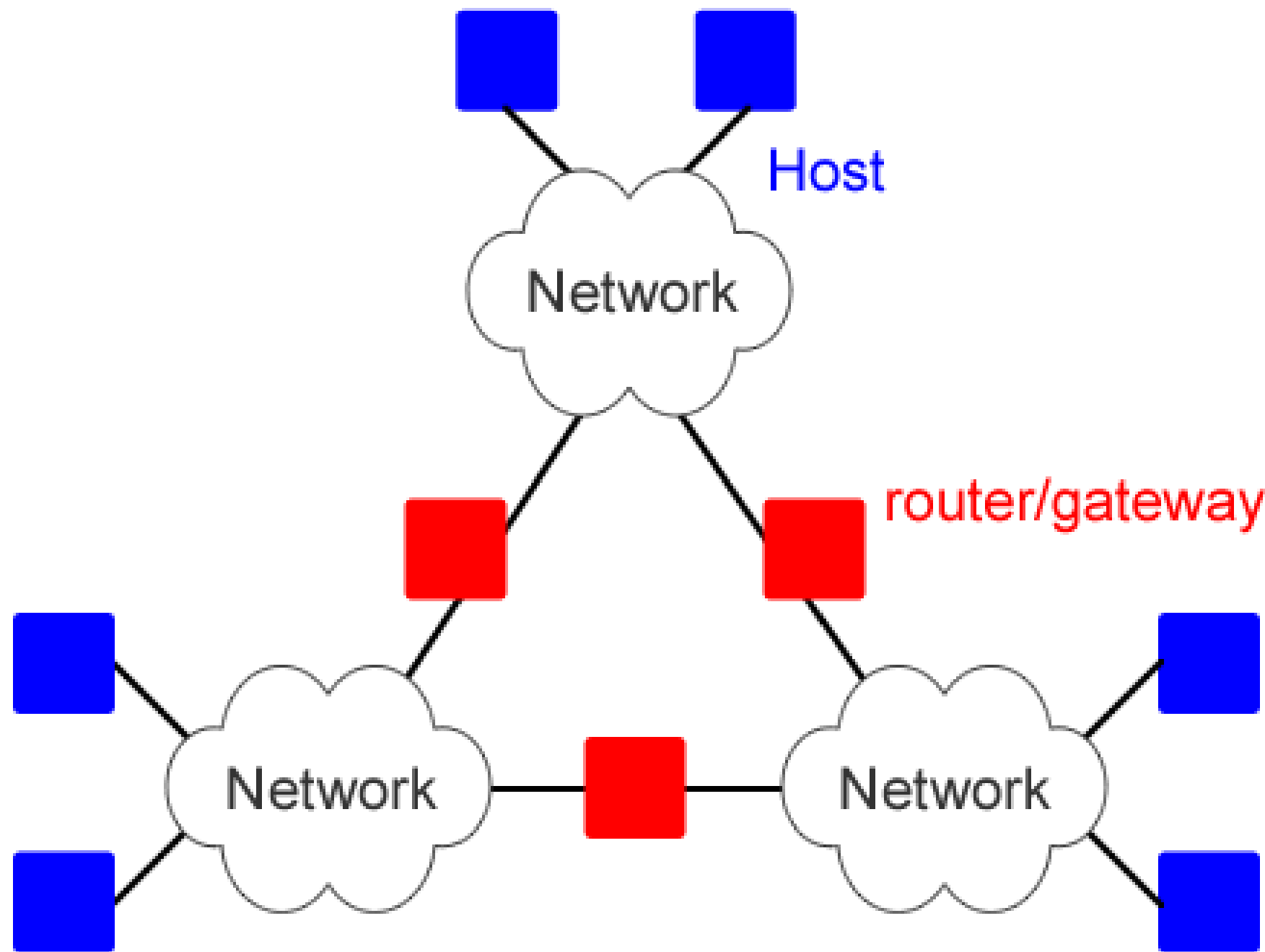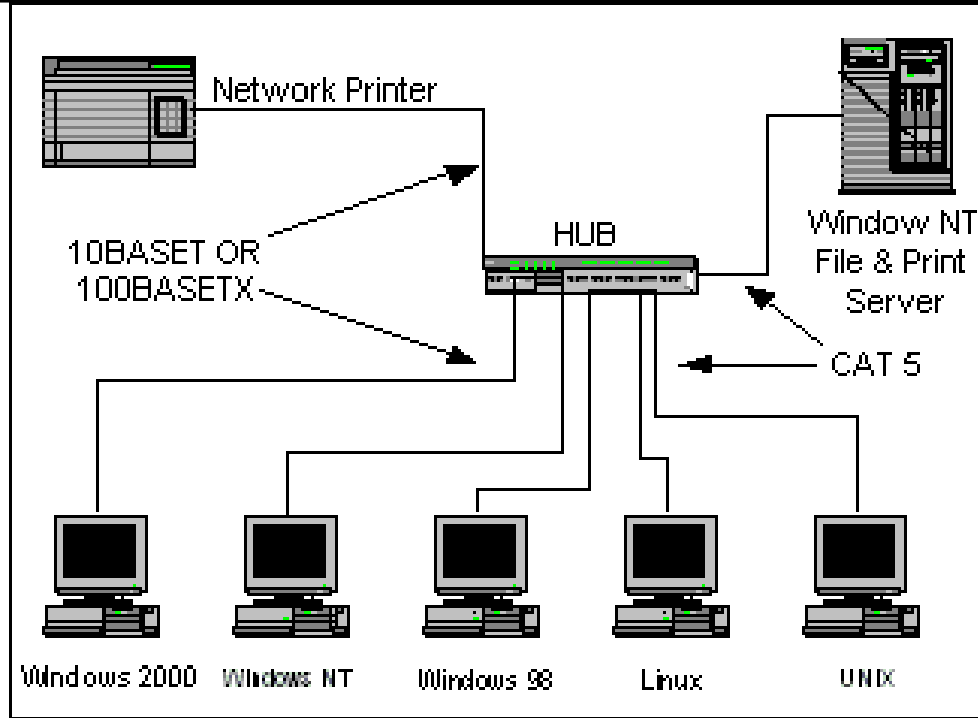
Thin Client

Wireless Network Access

Networking

- 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)
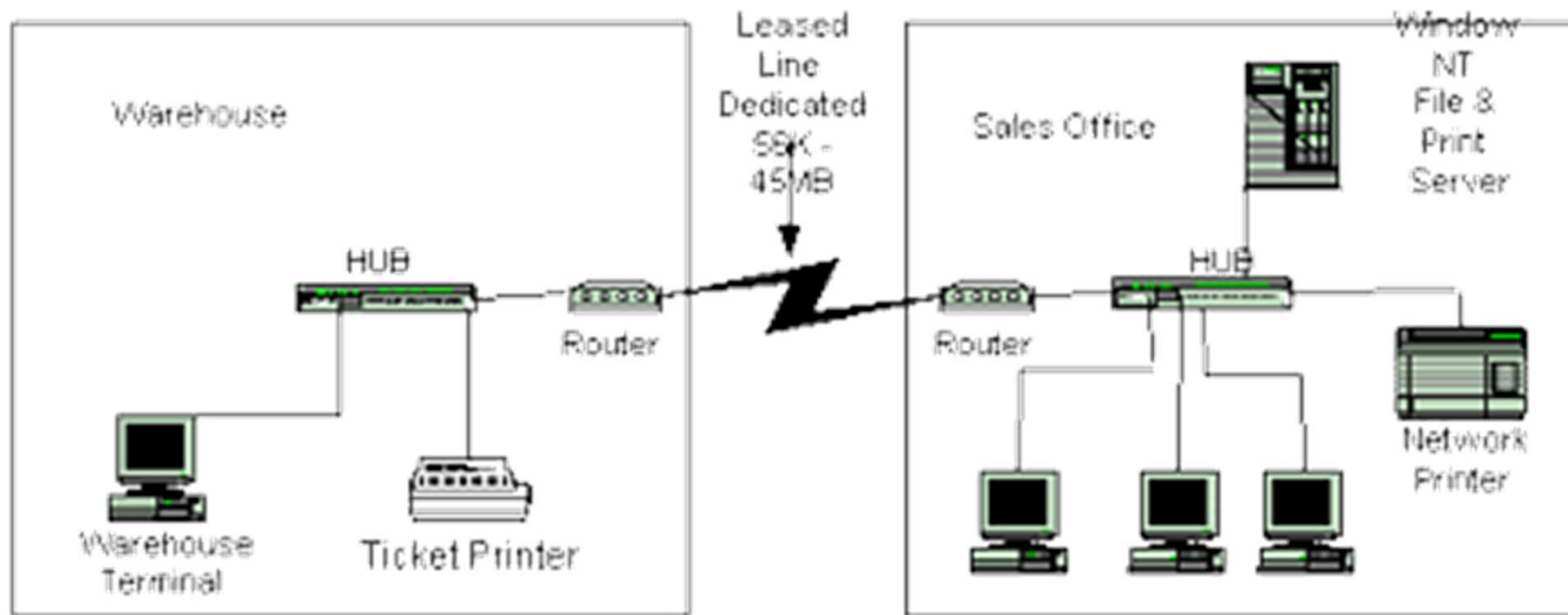 - Home area network (HAN)

Internetworking concept

Host

router/gateway

Local Area Network (LAN)

Network Printer

10BASET OR 100BASETX

HUB

Window NT File & Print Server

CAT 5

Windows 2000   Windows NT   Windows 98   Linux   UNIX

Local Area Network

Wide/Metropolitan Area Network (WAN/MAN)

Leased Line Dedicated 56K - 45MB

Warehouse

HUB

Router

Router

HUB

Sales Office

Window NT File & Print Server

Warehouse Terminal

Ticket Printer

Network Printer

Wide/Metropolitan Area Network

Example of network infrastructure -- HKU

Main Campus

Lady Ho Tung Hall, Starr Hall & Ricci Hall

St. John's College, Morrison Hall, Lee Shau Kee Hall, Suen Chi Sun Hall, Pokfield Road Residence

Gigabit Ethernet

Gigabit Ethernet

ITS Data Centre

Gigabit Ethernet

Gigabit Ethernet

Gigabit Ethernet

Gigabit Ethernet

Gigabit Ethernet

Robert Black College

Swire Hall

Simon Lee Hall

Graduate House

Other Campuses

Sassoon Road Premises, Faculty of Medicine Buildings & Residential Halls

Cyberport

Dual Gigabit Ethernet Connections

Dual Gigabit Ethernet Connections

54Mbps Fixed-access Wireless

Stanley Ho Sports Centre

CWDM Optical Network

CWDM Optical Network

Public Gigabit Ethernet WAN Connections

Optical Fibre

Duchess of Kent Children's Hospital

54Mbps Fixed-access Wireless

Kennedy Town Centre

Prince Philip Dental Hospital

University Hall

Queen Mary Hospital

100Mbps

Metro-Ethernet

100Mbps

100Mbps

100Mbps

100Mbps

Hing Wai Centre

Sch. Of Business

Tsang Yuk Hospital

Family Medicine Unit
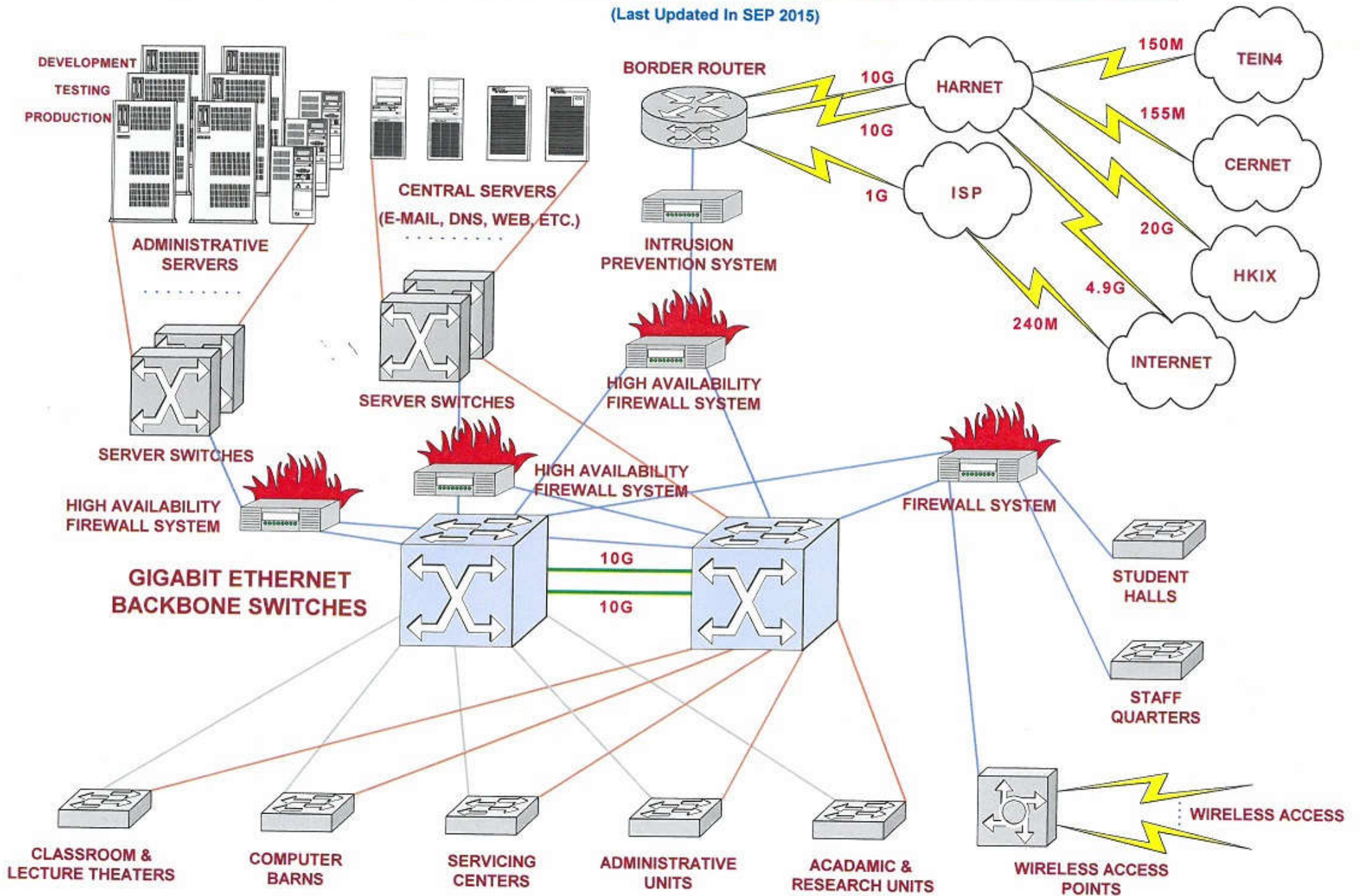
Computer Network of HKU Remote Campuses and Residential Halls

SIMPLIFIED HKUST CAMPUS NETWORK SCHEMATIC

(Last Updated In SEP 2015)

(Source: https://itsc.ust.hk/services/it-infrastructure/network-infrastructure/schematic)

Networking

- 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
    - 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 Ethernet system
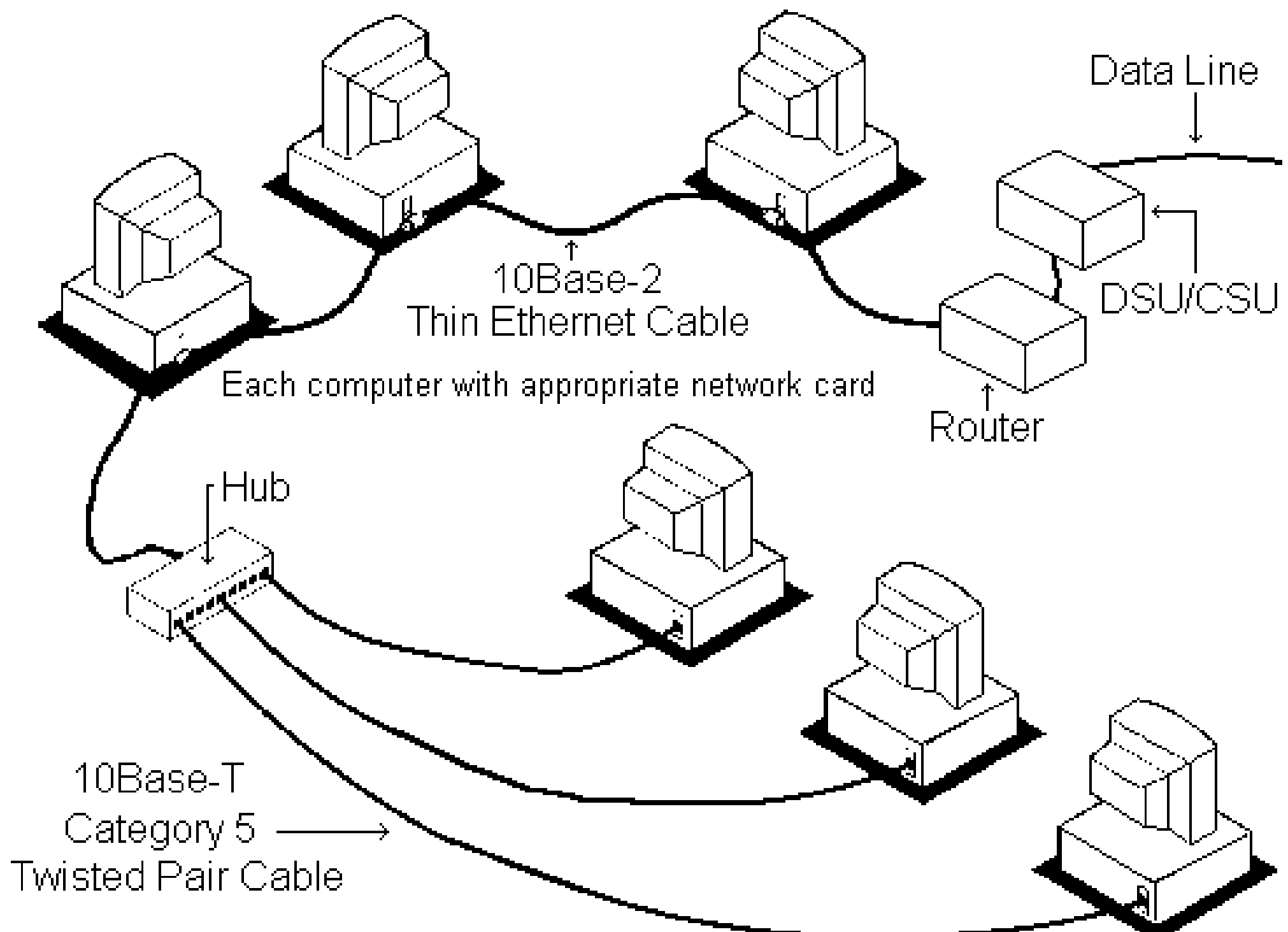
Data Line

DSU/CSU

Router

10Base-2
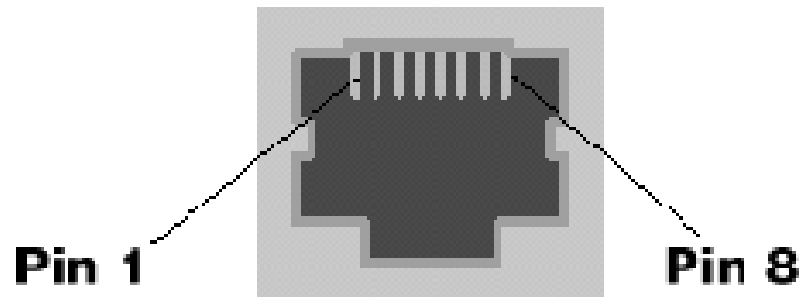Thin Ethernet Cable

Each computer with appropriate network card

Hub

10Base-T
Category 5 ———▶
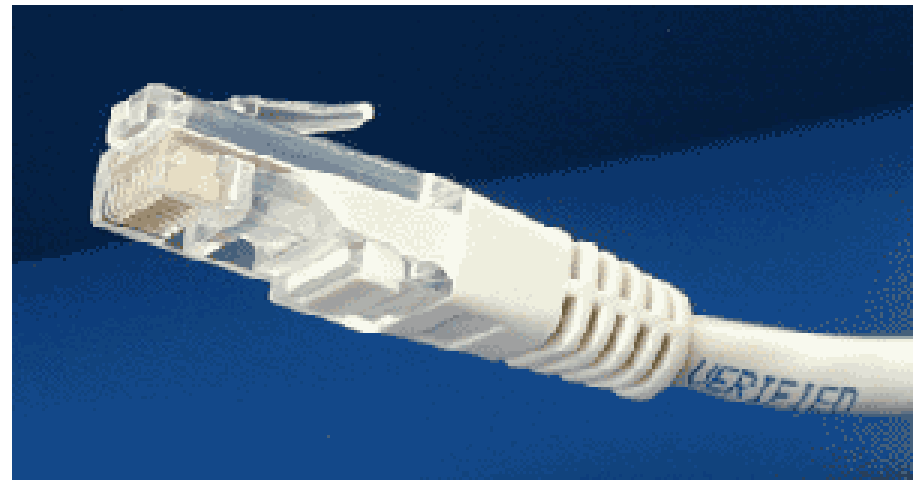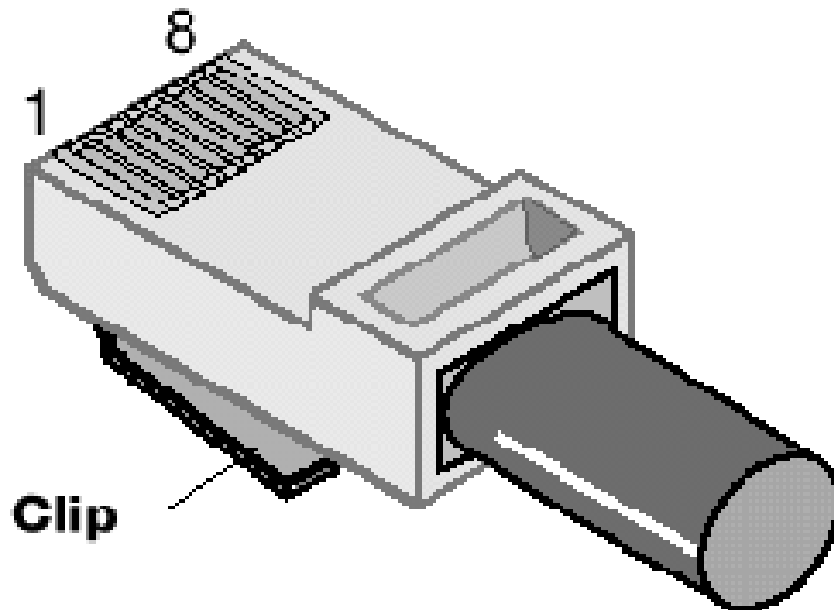Twisted Pair Cable

Ethernet port and connector

Ethernet Port

Pin 1   Pin 8

RJ-45 Connector

1   8

Clip

"100 Base T" means:
- 100 Mbps
- Baseband signal
- Twisted pair

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

Networking

- Network speed
  - How fast is fast? (time to transmit 10MB of data)
    - 28.8 kps modem: 5 minutes
    - 56 kps modem: 26 min. 20 sec.
    - 128 kps (ISDN):   10 minutes
    - 1.544 Mbps (T-1):   50 seconds
    - 10 Mbps (10BaseT):   8 seconds
    - 100 Mbps (100BaseT):   0.8 seconds
    - 1000 Mbps (1000BaseT):   0.08 seconds
    - 10 Gbps (10GBaseT):   0.008 seconds

The world is going Gigabit!

Networking

- Leading official standards organisation
  - IEEE 802 LAN/MAN Standards Committee (www.ieee802.org) and its working groups
    - 802.1: interface between OSI levels 1 & 2 with five higher level layers (OSI = Open Systems Interconnection)
    - 802.2: logical data link
    - 802.3: CSMA/CS (carrier sense multiple access with collision avoidance)
    - 802.4: Token bus
    - 802.5: Token ring

Communication of building sub-systems using open system framework
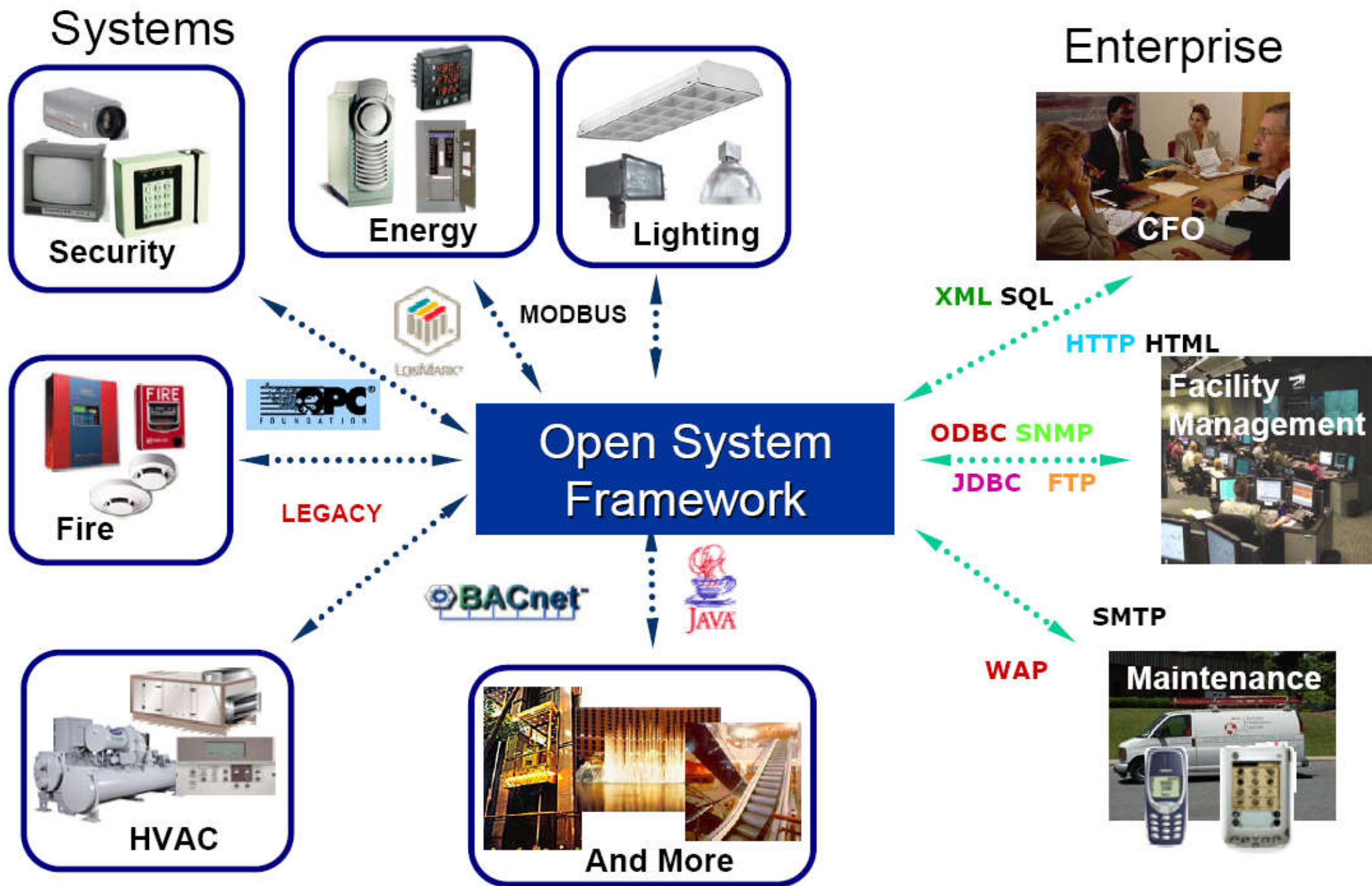
Transmission methods

- Media/transmission methods
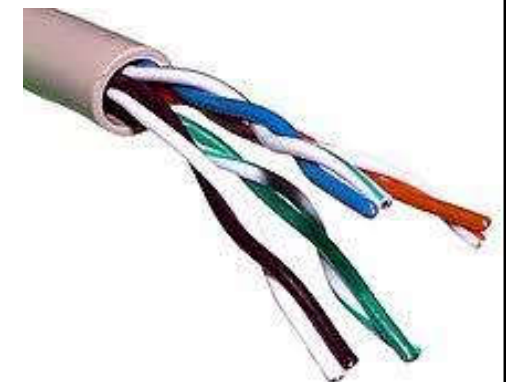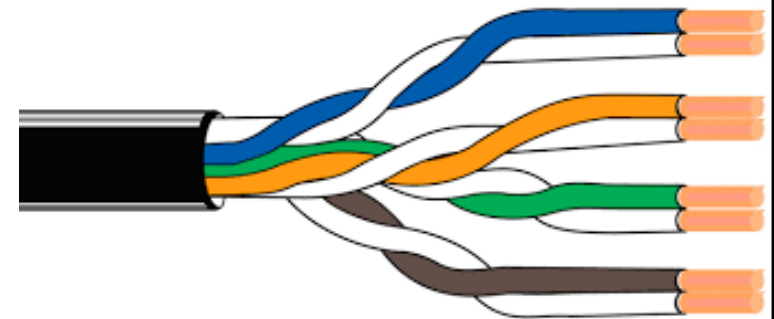 - Twisted pairs (TP)
    - Two insulated conductors twisted together to minimise interference by unwanted signals
      - Line bandwidth (300-3000 Hz)
      - Signal-to-noise ratio
      - Conditioning (of the line)
    - Conditioned line has speed up to 9600 bps
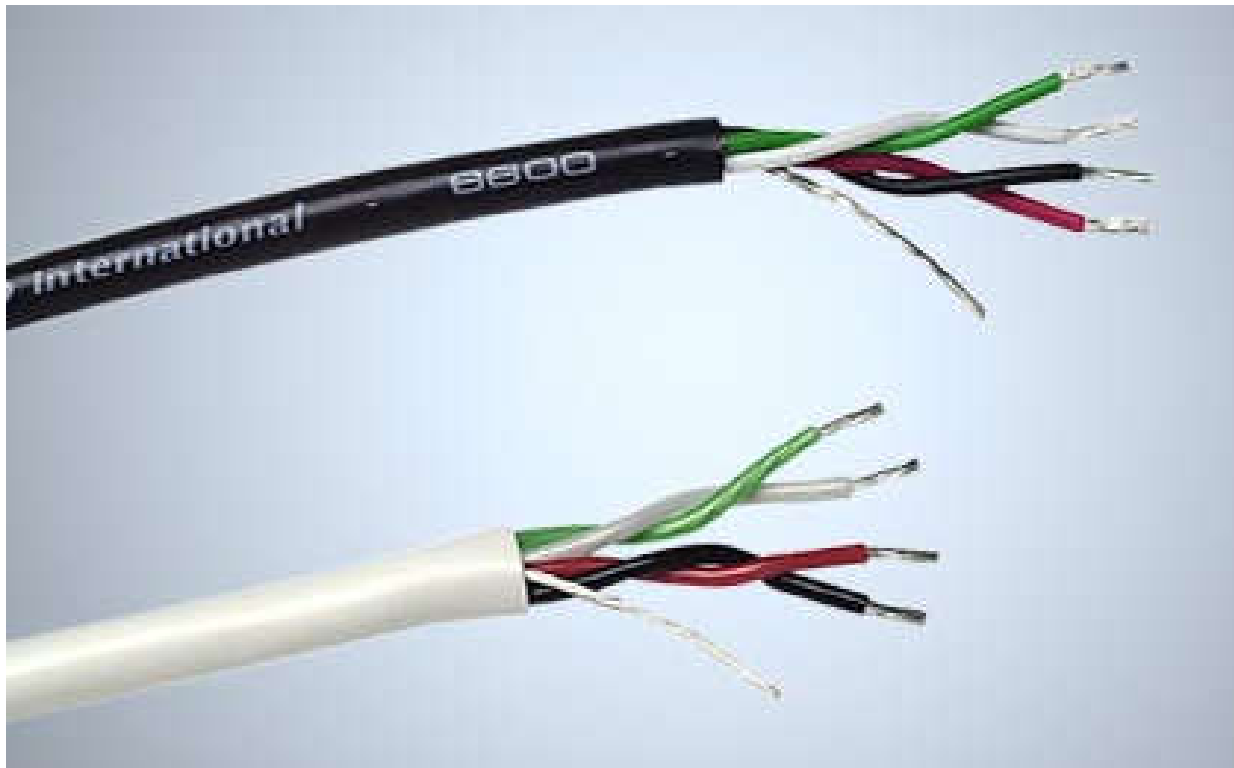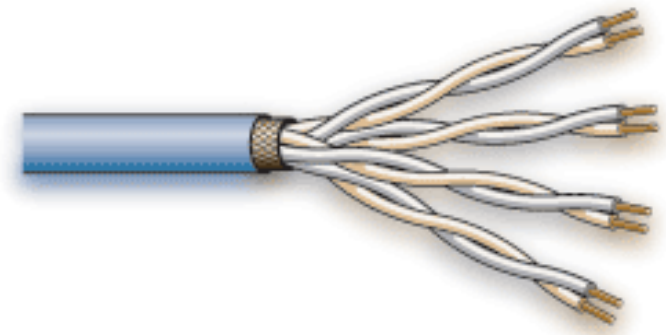   - In most cases, 1200 bps is maximum
    - Unshielded twisted pairs (UTP)

Twisted pairs (TP)

Unshielded twisted-pair

Foiled twisted-pair

Transmission methods

- Media/transmission methods (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
    - Using carrier current transmission that superimposes a low RF signal (100 kHz) onto the 50/60 Hz power distribution system

Coaxial cable

Dielectric insulator

Plastic jacket

Copper central core

Copper mesh sheild

COPPER WIRE

INSULATION

COPPER MESH

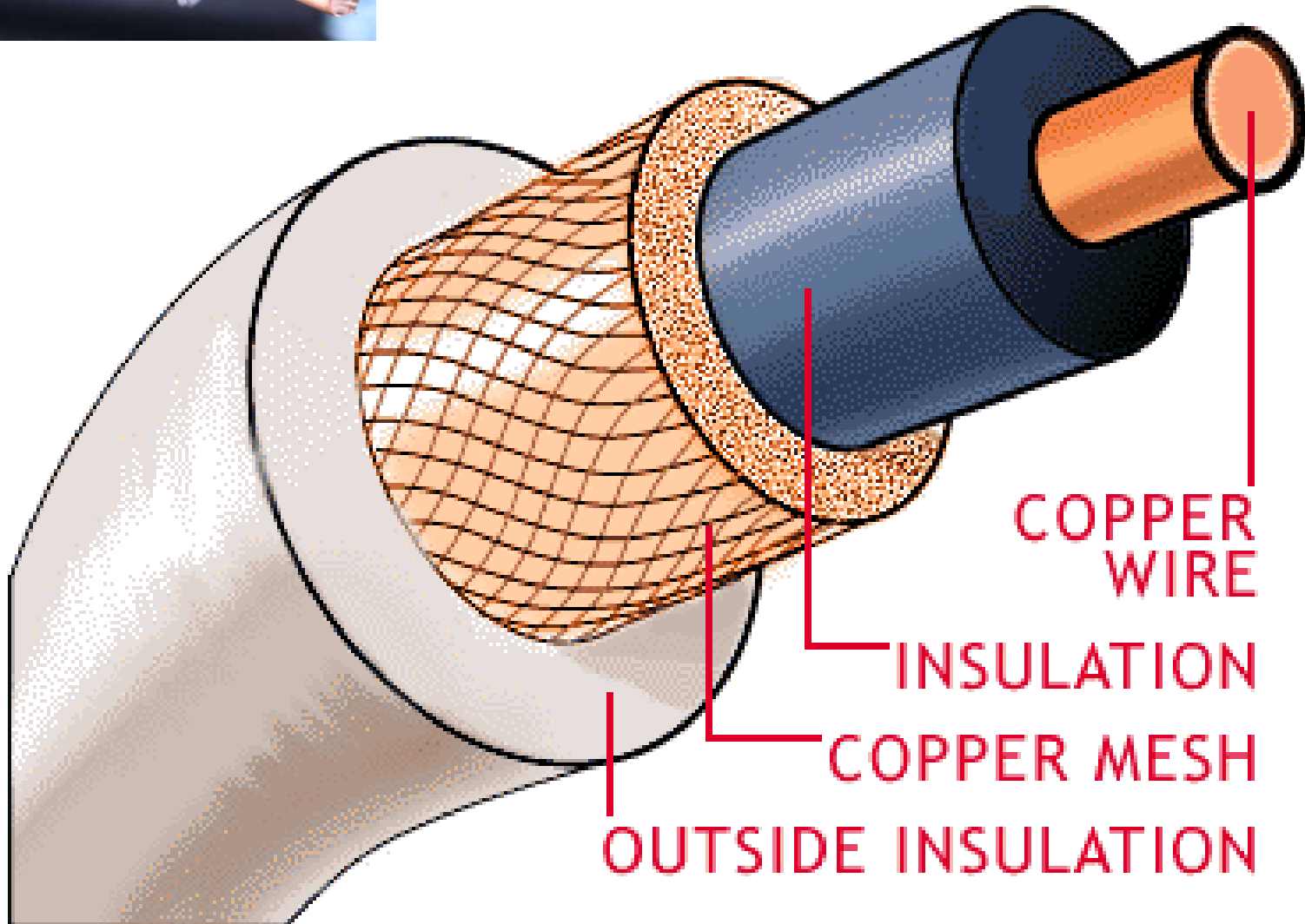OUTSIDE INSULATION
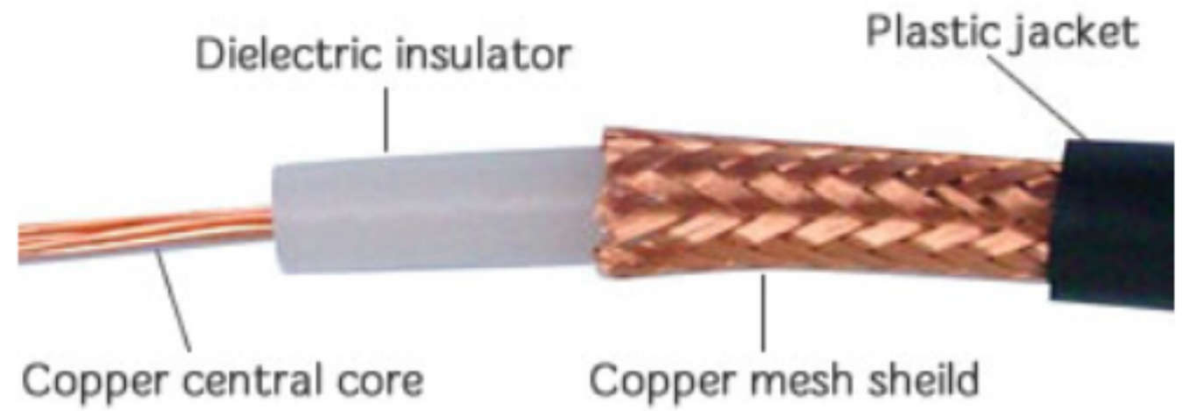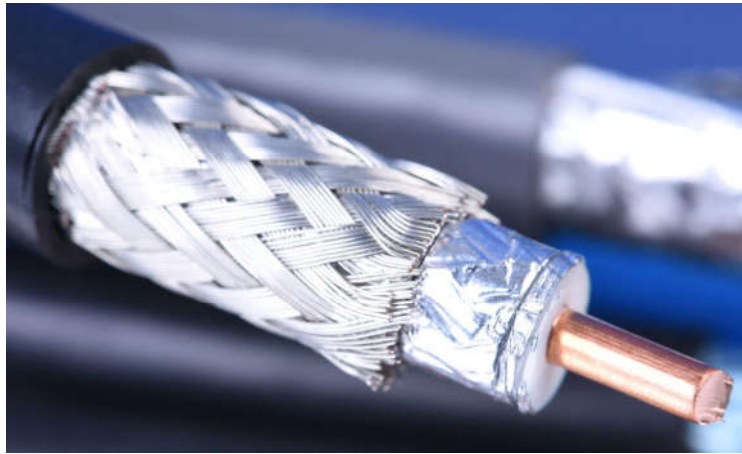
Power line transmission and communication
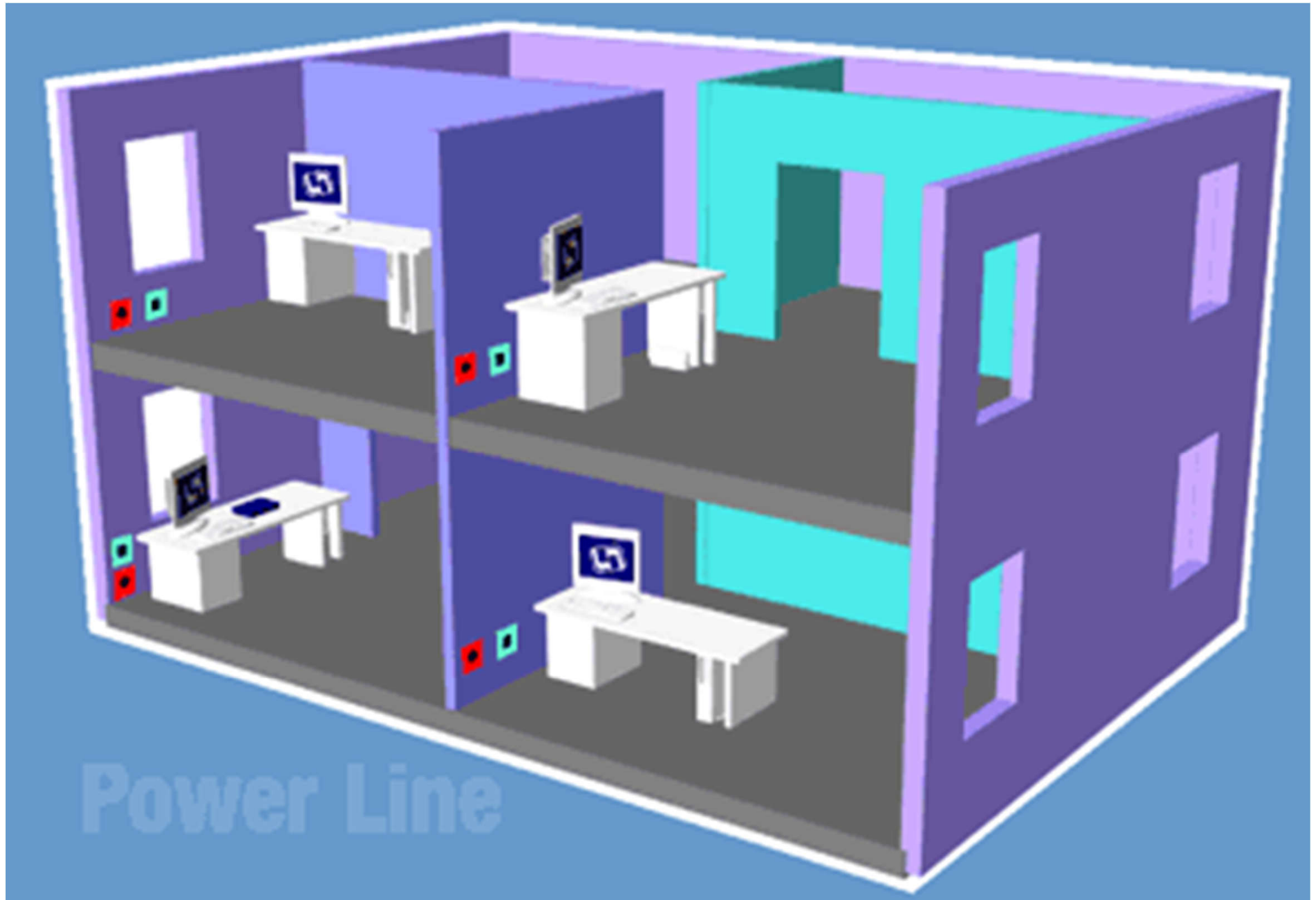
Transmission methods

- Media/transmission methods (cont'd)
  - Radio frequency (RF)
    - Modulated RF, with radio receivers and transmitters
  - 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
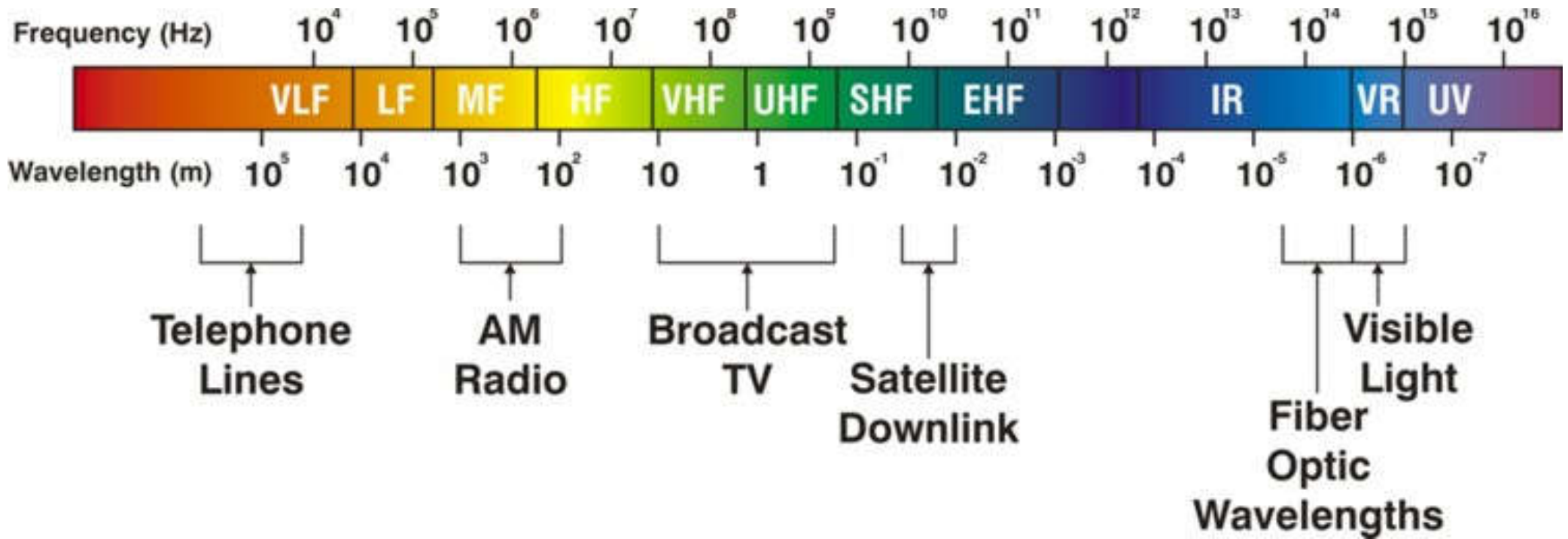   - Bandwidth virtually unlimited

Fibre optics transmission

Core
Cladding
Coating
or Buffer

Frequency (Hz) 10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16}

VLF **LF** **MF** **HF** **VHF** **UHF** **SHF** **EHF** **IR** **VR** **UV**

Wavelength (m) 10^5 10^4 10^3 10^2 10 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7}

Telephone
Lines

AM
Radio

Broadcast
TV

Satellite
Downlink

Fiber
Optic
Wavelengths

Visible
Light
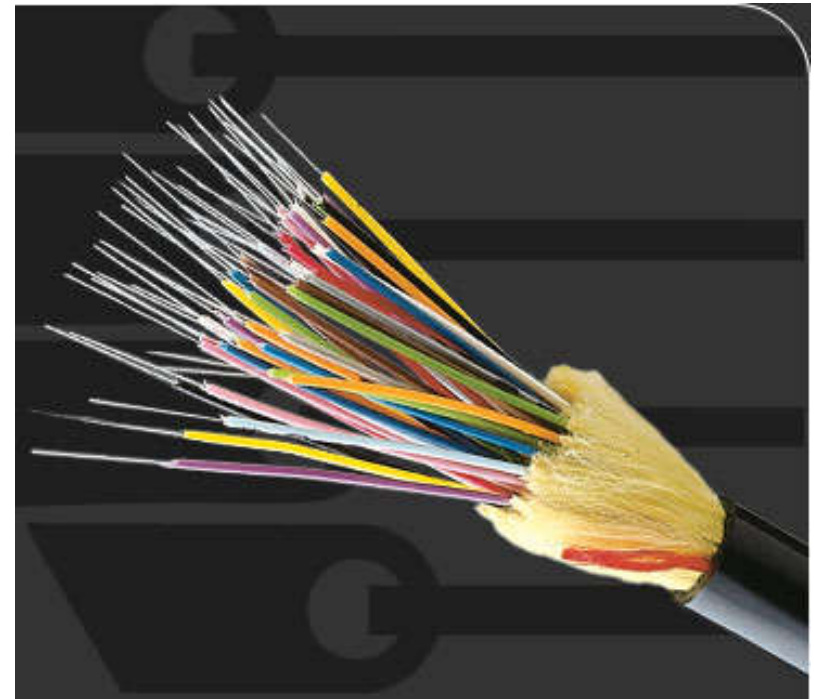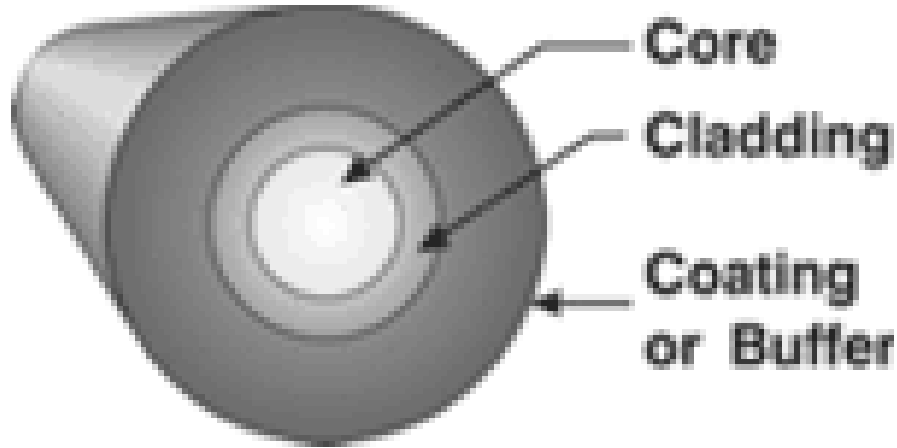
Comparison of transmission methods

Method	First cost	Scan rates	Reliability	Maint. Effort	Expand-ability	Compati-bility
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 methods
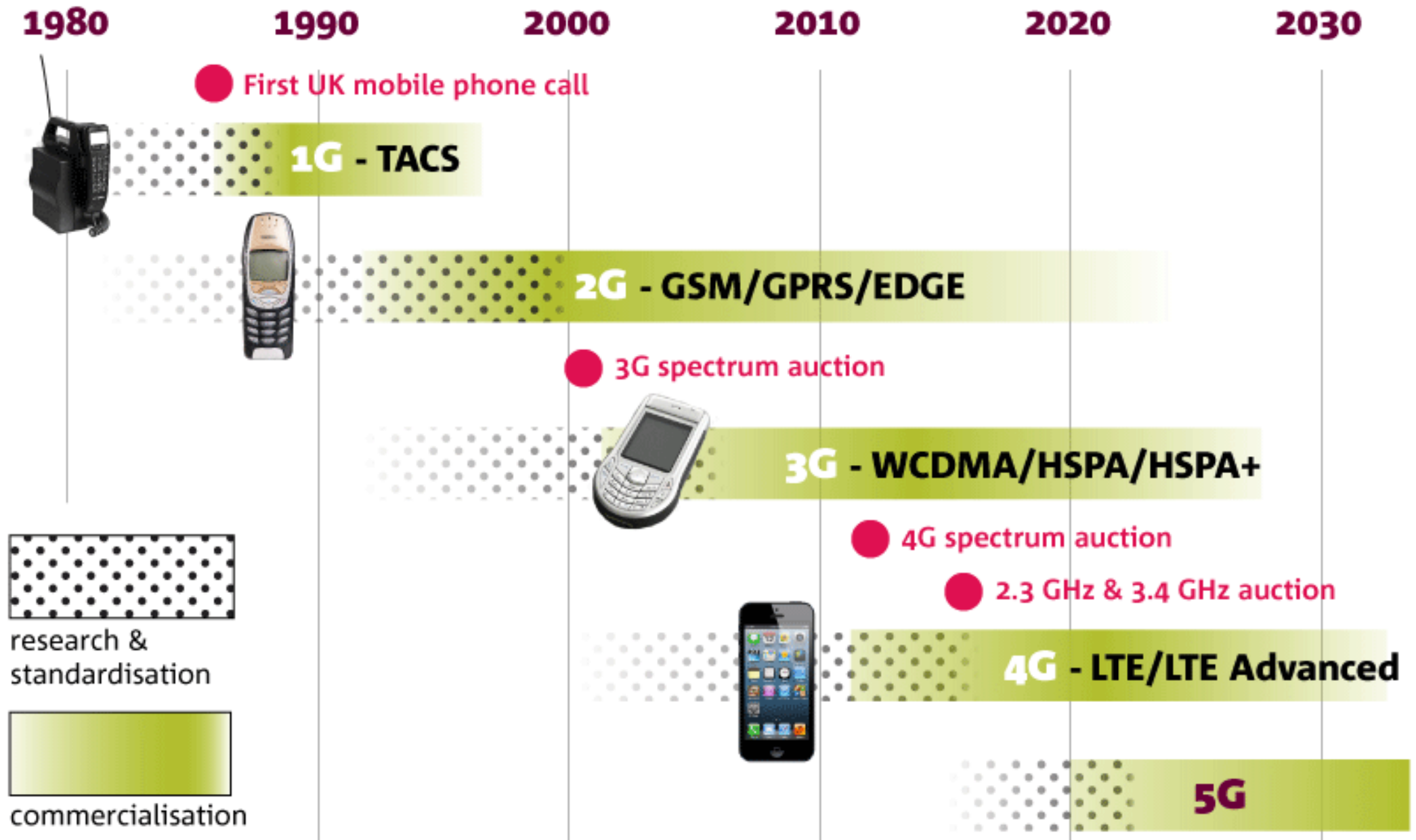
- Wireless communication
  - Transfer of information between two or more points that are not connected by an electrical conductor, such as radio & infrared controller

- 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 (wireless LAN), Bluetooth

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

802.11 b	802.11 g	802.11 n	802.11 ac	802.11 ad
1999	2003	2009	2013	~2018
Web browsing, FTP	Web browsing, FTP	Video, Web browsing	HD Video, Wireless link to display	HD Video streaming, Extended display
11 Mbps	54Mbps	600Mbps	6.93Gbps	6.93Gbps
Frequency: 2.4GHz Radio: DSSS Range: Indoor: 35m Outdoor: 140m	Frequency: 2.4GHz Radio: OFDM Range: Indoor: 35m Outdoor: 140m	Frequency: 2.4/5GHz Radio: OFDM, MIMO Range: Indoor: 35m/70m Outdoor: 250m	Frequency: 5GHz Radio: OFDM, MIMO Range: Indoor: 35m/70m	Frequency: 60GHz Radio: SC, OFDM, Beamforming Range: Indoor: 3.5m

Wireless technology evolution

MOBILE WIRELESS EVOLUTION

- No standard yet
- > 1 Gbps

5G

- LTE advanced
- ~ 100 Mbps

4G

- UMTS, WCDMA
- ~14.4 Mbps

3G

- GSM、TDMA
- ~ 270 kbps

2G

- AMPS, TACS, NMT
- 2.4 – 9.6 kbps

1G

5G

4G

- IEEE 802.11 ac (6.9 Gbps)

3G

- IEEE 802.11n (600 Mbps)

2G

- IEEE 802.11 g/a (54 Mbps)

1G

- IEEE 802.11b (11 Mbps)

WIRELESS LAN EVOLUTION

- IEEE 802.11 (2 Mbps)

| 1980 | 1990 | 2000 | 2010 | 2020 |
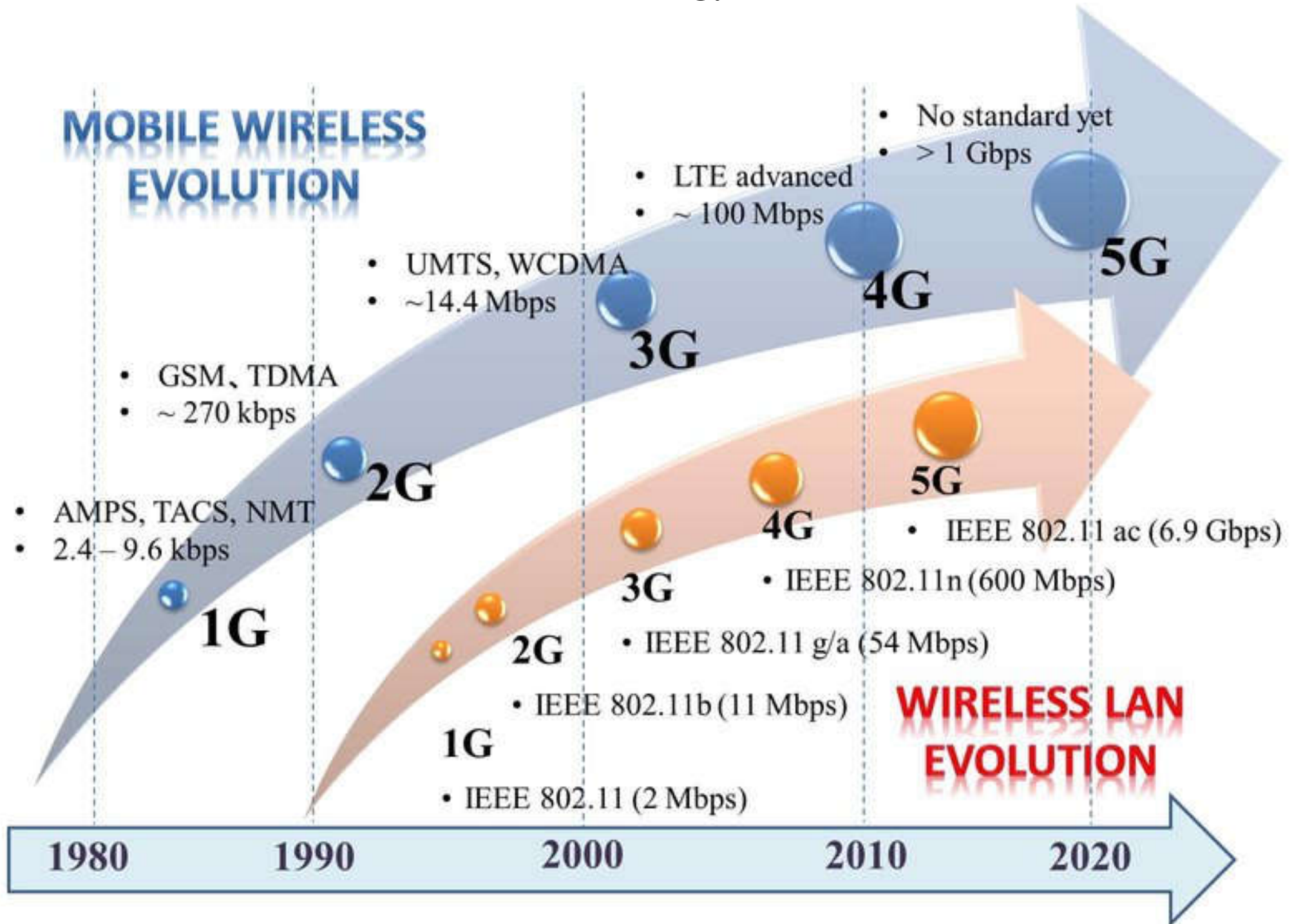
In-building wireless systems

- Mobility of people and business
  - Mobile devices become a must
    - "One person one number" + Voice to data
  - 70%+ of mobile traffic occurs inside buildings
  - Full in-building coverage is essential (e.g. lift cars)
- Indoor systems should be pre-installed, like other utilities in the building
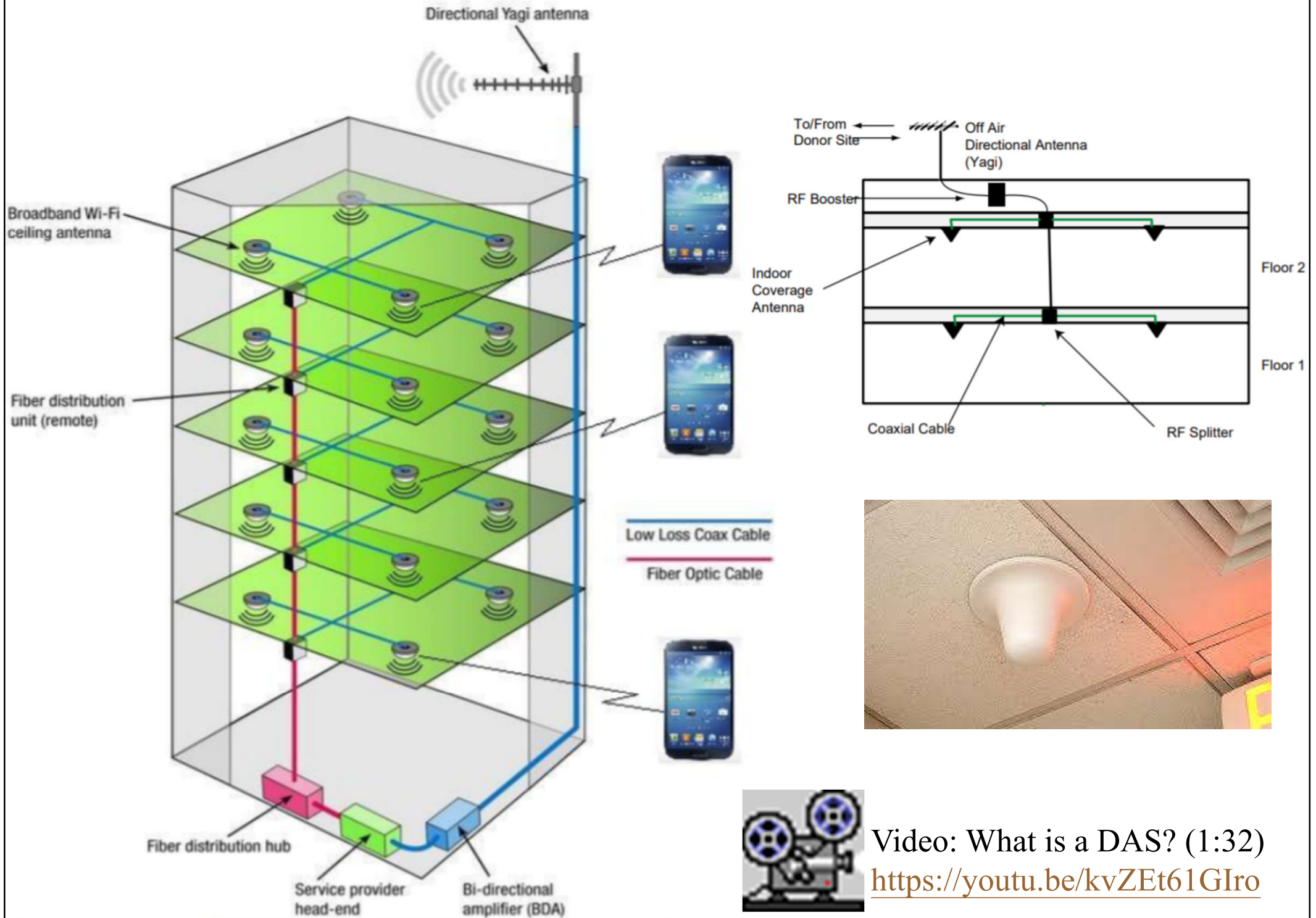 - Covering areas of high user density
  - Keep the building users "Happy"
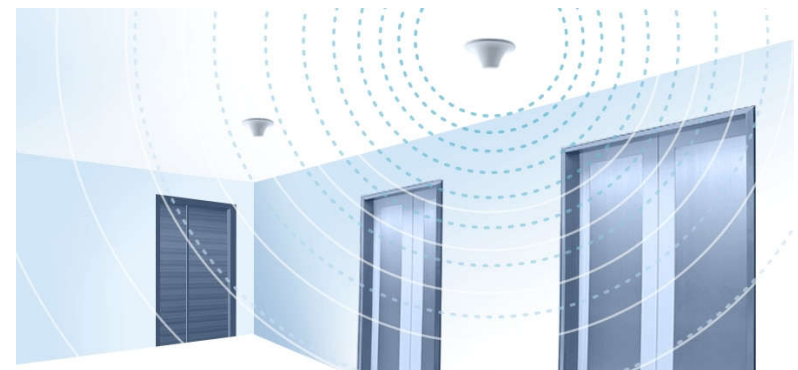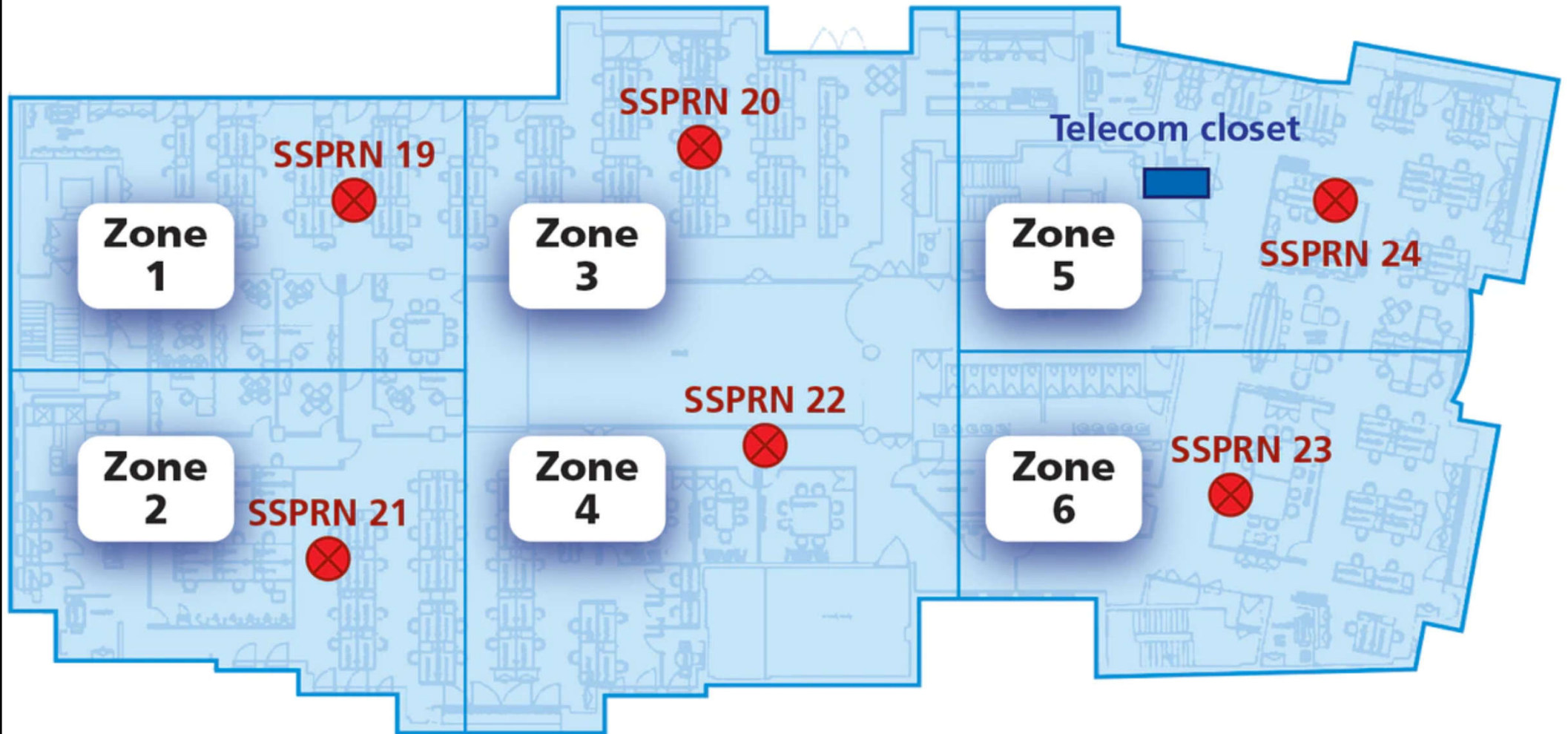
In-building wireless systems

- Telecommunications infrastructure or Internet broadband as the "*Fourth Utility*", after electricity, water & gas

    - Reliable connectivity without restriction – all the time, at full speed, on any device, from anywhere – has become the expectation in our connected world

    - Indoor access to Wi-Fi, cellular & VoIP networks

    - In-building network for building automation, BMS, fire, security & other operations

In-building distributed antenna systems (DAS) – a repeater system

Directional Yagi antenna

Broadband Wi-Fi ceiling antenna

Fiber distribution unit (remote)

Fiber distribution hub

Service provider head-end

Bi-directional amplifier (BDA)

Low Loss Coax Cable

Fiber Optic Cable

To/From Donor Site

Off Air Directional Antenna (Yagi)

RF Booster

Indoor Coverage Antenna

Coaxial Cable

RF Splitter

Floor 2

Floor 1

Video: What is a DAS? (1:32)
https://youtu.be/kvZEt61GIro

A single telecom closet serves 6 radios on this floor with 6 wiring zones

SSPRN 19

SSPRN 20

Telecom closet

SSPRN 24

Zone 1

Zone 3

Zone 5

SSPRN 22

SSPRN 23

Zone 2

SSPRN 21

Zone 4

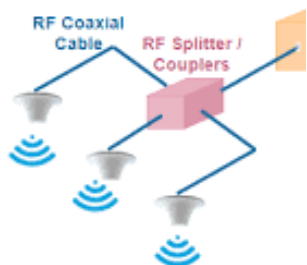Zone 6

In-building wireless systems

- System design options:
  - RF (radio frequency) source
    - Antenna/Repeater – brings in RF from the outdoor cellular network
    - Carrier installed base transceiver station provides dedicated RF
  - Passive distributed antenna systems
    - RF is distributed over coax cables to each antenna from an RF source (repeater or base station)
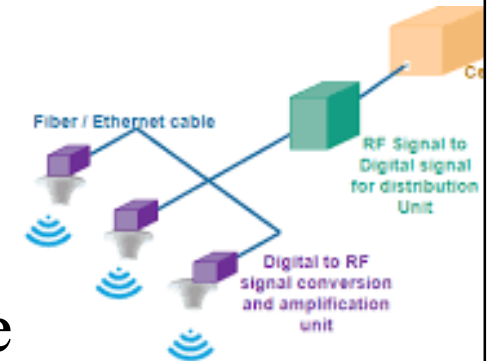   - Coax cable losses limit their effectiveness in large buildings for higher frequency transmissions

In-building wireless systems

- System design options: (cont'd)
  - Active distributed antenna systems
    - Fiber-optic cabling backbone overcomes the transmission losses that occur w/ coax-based system
    - Electric components convert and amplify signals to RF by the antenna (preferred for medium to large buildings)
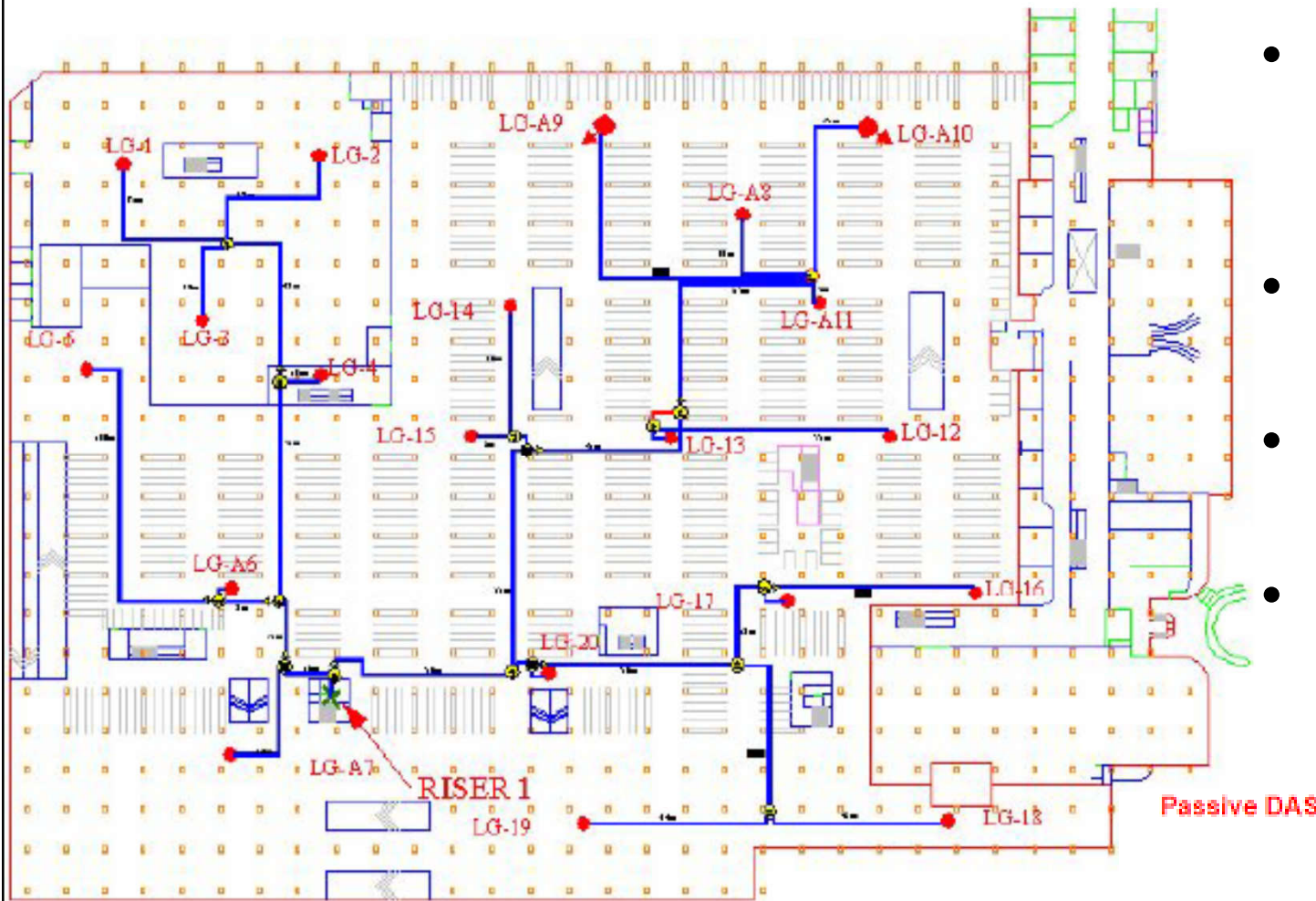 - Distributed radios (small cells)
    - Consist of small cellular radios, called picocells & femtocells to create an internal cellular network
    - Do not rely on the macro network for switching & hand-offs; only wireless carriers can provide this

Fiber / Ethernet cable

RF Signal to Digital signal for distribution Unit

Digital to RF signal conversion and amplification unit

# Example of passive distributed antenna system

- Essentially a "sprinkler system" for cell phone signals
- Distribution via large coaxial cables
- Losses through the cable limit the size
- New, higher frequency bands have high loss
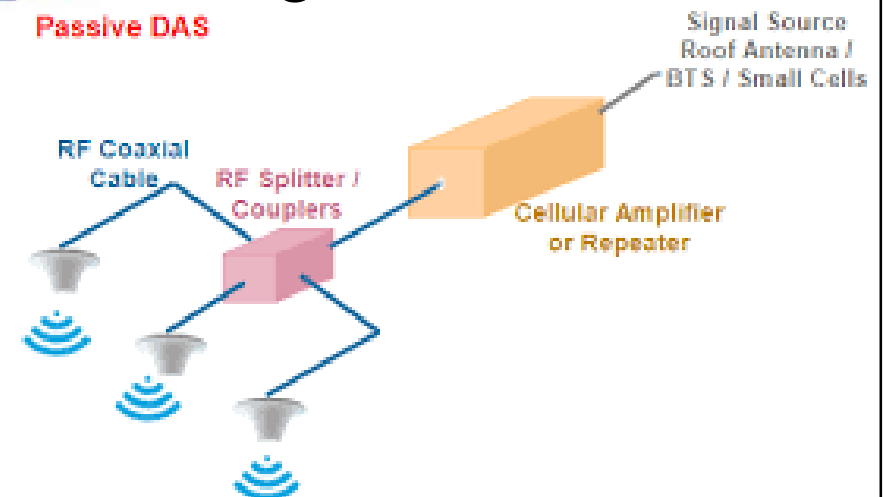
Example of active distributed antenna system

- LAN/WLAN-like topology
- Standard structured cabling – fibre optic and CAT5 or CATV cabling
- Less disruptive install
- Amplifiers at the antenna point means zero "loss"
- Significant cost and performance advantages in medium and large buildings
- Excellent performance regardless of frequency
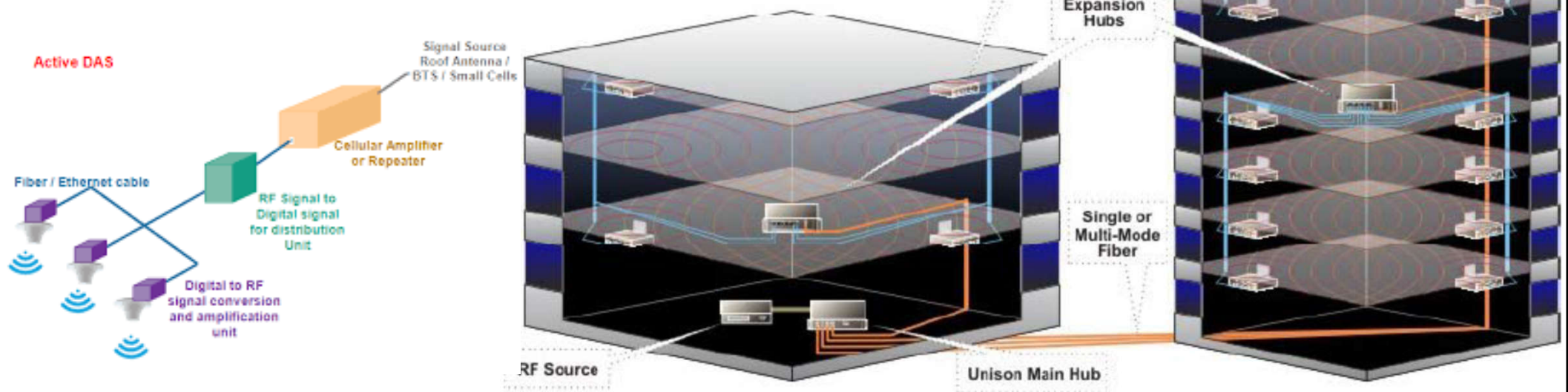
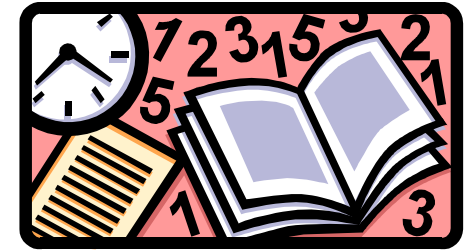# In-building wireless systems

- In-building wireless (IBW) implementation
  - Budgetary design – usually based on floor plans
    - Determine which areas of the building require coverage (entire building, public areas, parking levels, etc.)
    - Determine the building's construction materials
    - Determine capacity requirements
  - Site survey
    - Confirm RF propagation, determine locations for equipment, confirm antenna locations, measure interference thresholds, confirm cable routes and lengths, power, security
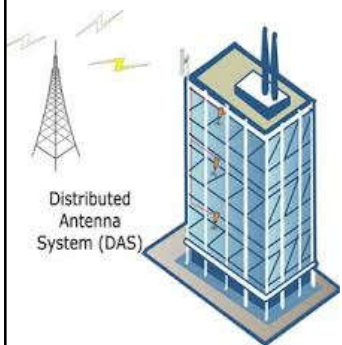
Further Reading

- Placing Electrical Systems and Communications Systems in Buildings [US GSA]
  - https://www.gsa.gov/node/82713
- Structured cabling - Wikipedia http://en.wikipedia.org/wiki/Structured_cabling
- Structured Cabling Solutions https://datalinetechnologies.com/structured-cabling-solutions/
- In-Building Cellular Enhancement System - Wikipedia https://en.wikipedia.org/wiki/In-Building_Cellular_Enhancement_System

References

- APP-84 Access Facilities for Telecommunications and Broadcasting Services https://www.bd.gov.hk/doc/en/resources/codes-and-references/practice-notes-and-circular-letters/pnap/APP/APP084.pdf

- CA, 2012. Code of Practice for the Installation and Maintenance of In-Building Telecommunications Systems and In-building Access by Telecommunications Network Operators, Communications Authority (CA), Hong Kong. https://www.coms-auth.hk/filemanager/statement/en/upload/105/cop201202e.pdf

- CA, 2012. Code of Practice for the Provision of Access Facilities in Buildings for the Supply of Telecommunications and Broadcasting Services, Communications Authority (CA), Hong Kong. https://www.coms-auth.hk/filemanager/statement/en/upload/104/cop201201e.pdf

- CIBSE, 1992. *Information Technology and Buildings*, Applications Manual 7, Chartered Institution of Building Services Engineers, London.