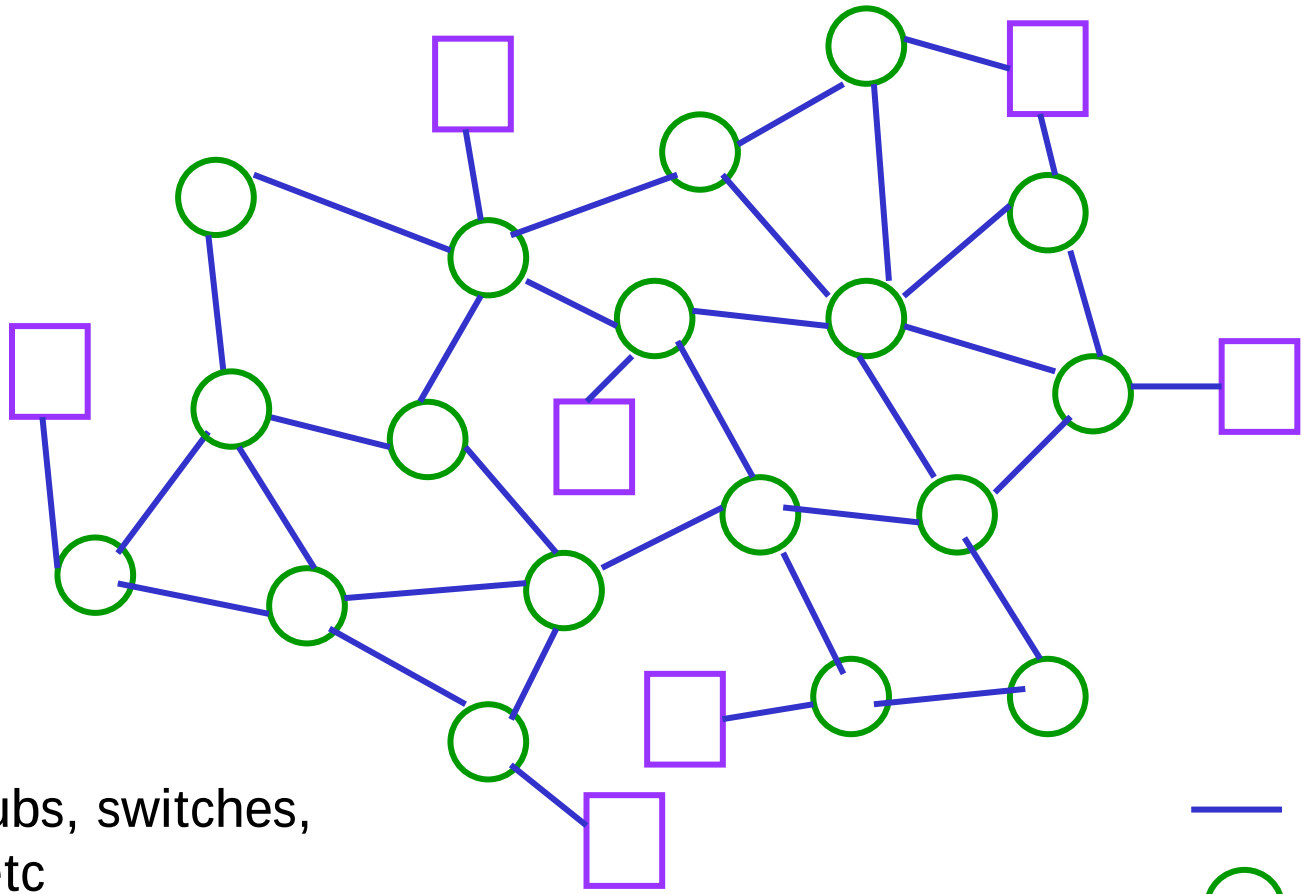
Computer Network Architecture and Components: A Review

Computer Network components

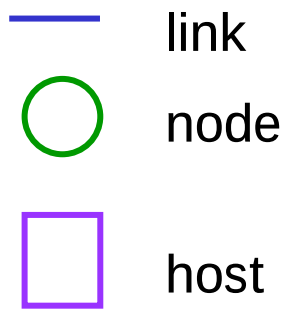
- Computer network

  → nodes, links, protocols, [hosts],

Computer network

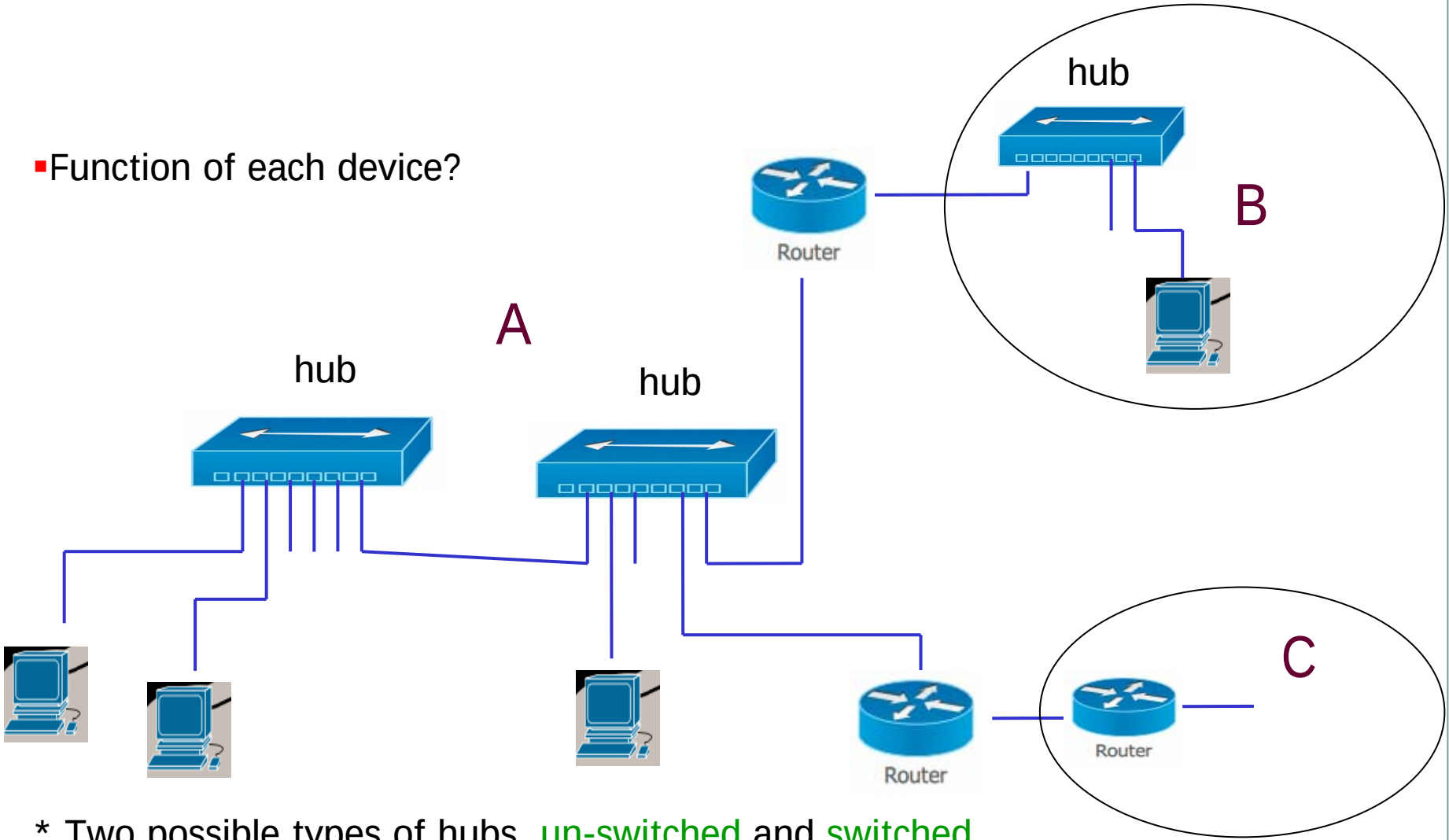


- Nodes: hubs, switches, bridges, etc
- Links: LANs or WANs
- Hosts: workstations, servers
- Protocol:



Computer network (physical)

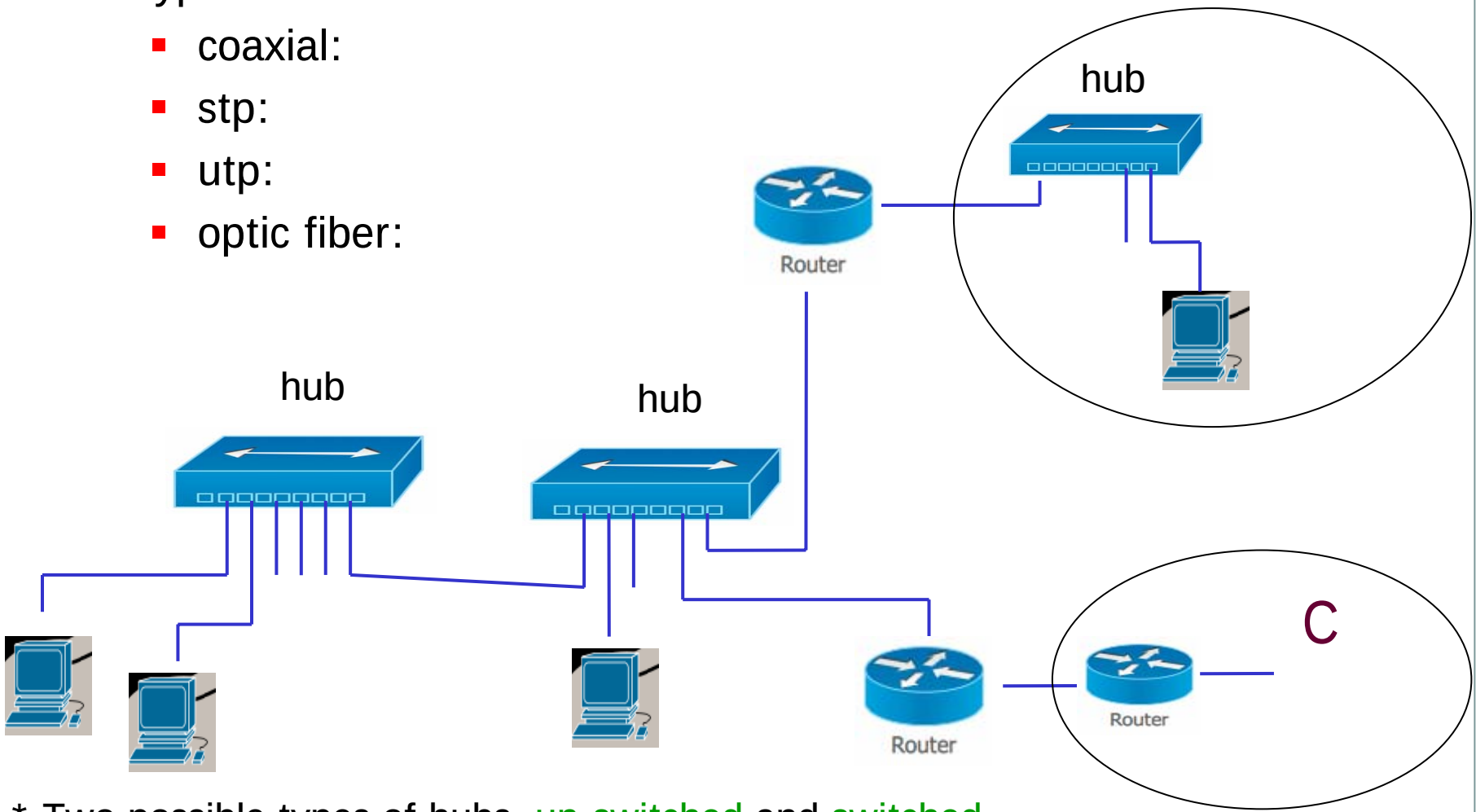
- Function of each device?



* Two possible types of hubs, un-switched and switched

Computer network

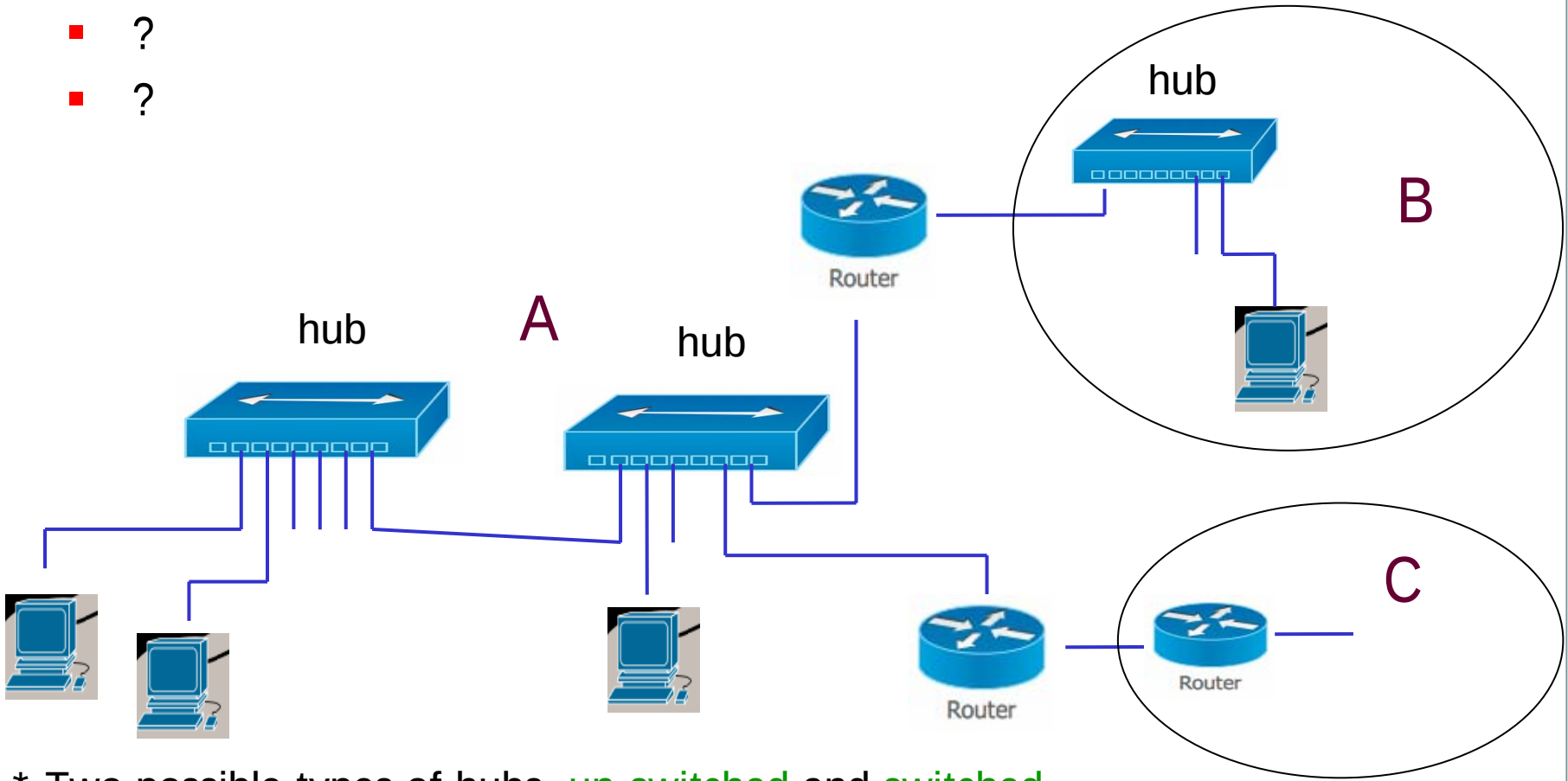
- Types of cables
  - coaxial:
  - stp:
  - utp:
  - optic fiber:



* Two possible types of hubs, un-switched and switched

Computer network

- Factors influencing choice of cable type for a given link
  - ?
  - ?
  - ?



* Two possible types of hubs, un-switched and switched

Network management

- $\Rightarrow$
  - Network topology
  - Components
  - architecture

- Network topology
  - Bus
  - Ring
  - Star
  - Hub
    - Ethernet hub
    - Token ring hub
  - Mesh
  - Tree

LANs

WANs

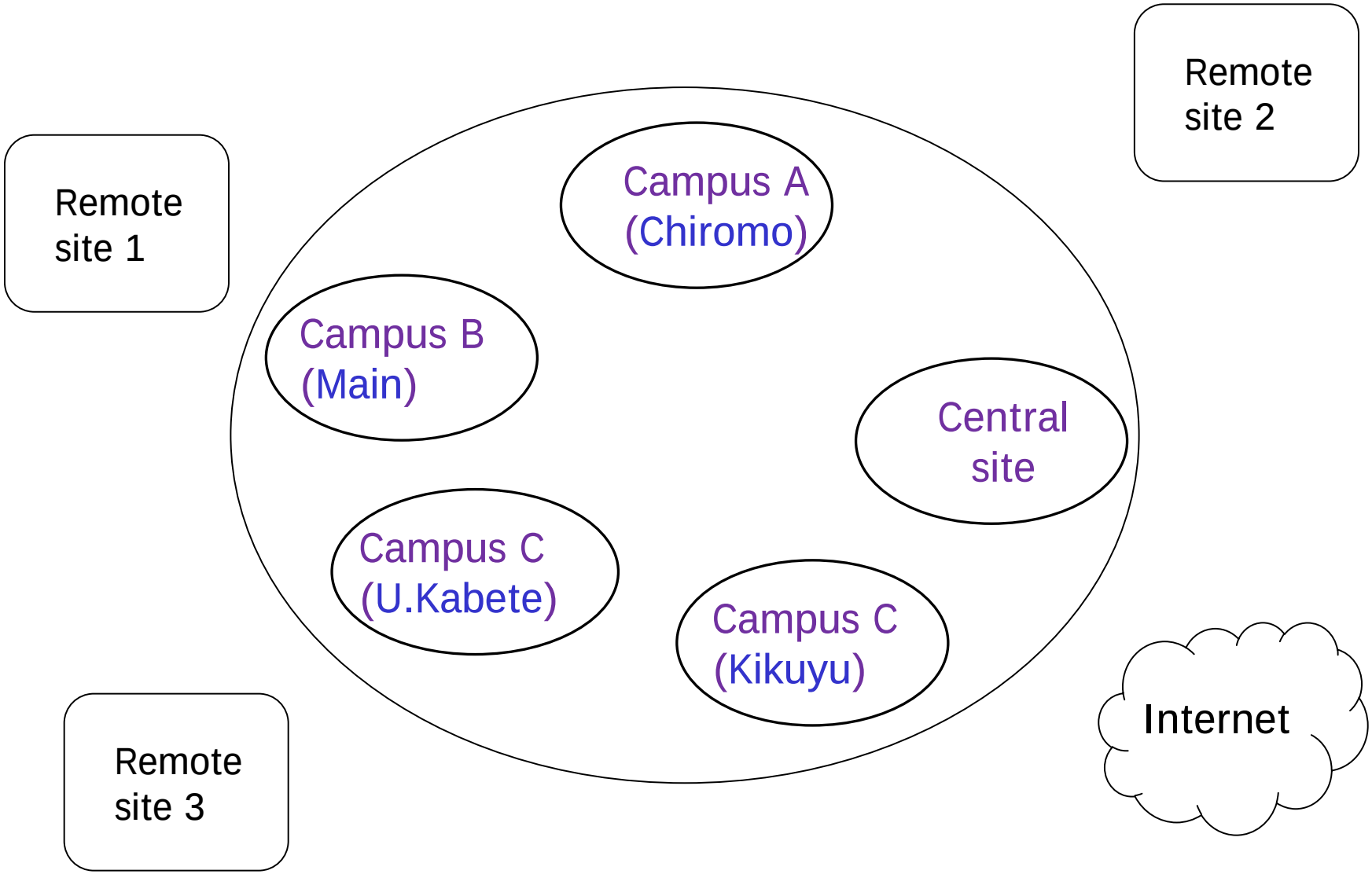
Architecture

- Enterprise internetwork
- Campus internetwork
- Classical hierarchical architectural model

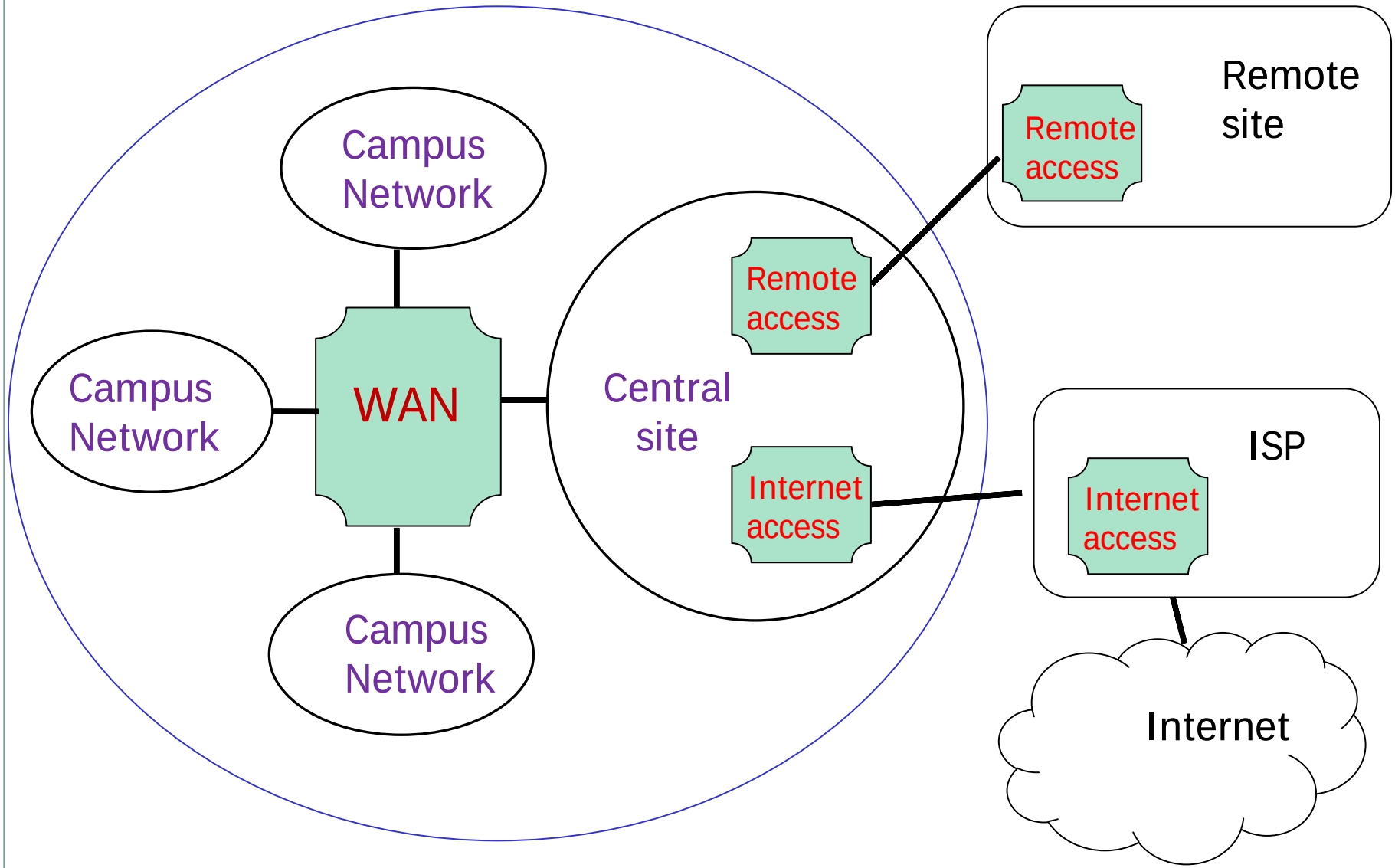
Enterprise internetwork

- The enterprise is considered in general as consisting of
  - central site (central campus):
  - several other branches (campuses) which may be a large distances from each other and from central site
- The enterprise may need allow
  - A user located anywhere within the campuses be able to access information and resources located anywhere within enterprise (subject to enterprise policies)
  - A user located anywhere within the campuses be able to have access to Internet (subject to enterprise policies)
  - Authorized users outside the campuses to access information and resources located anywhere within enterprise (subject to enterprise policies)

Enterprise internetwork



Enterprise internetwork broad architecture

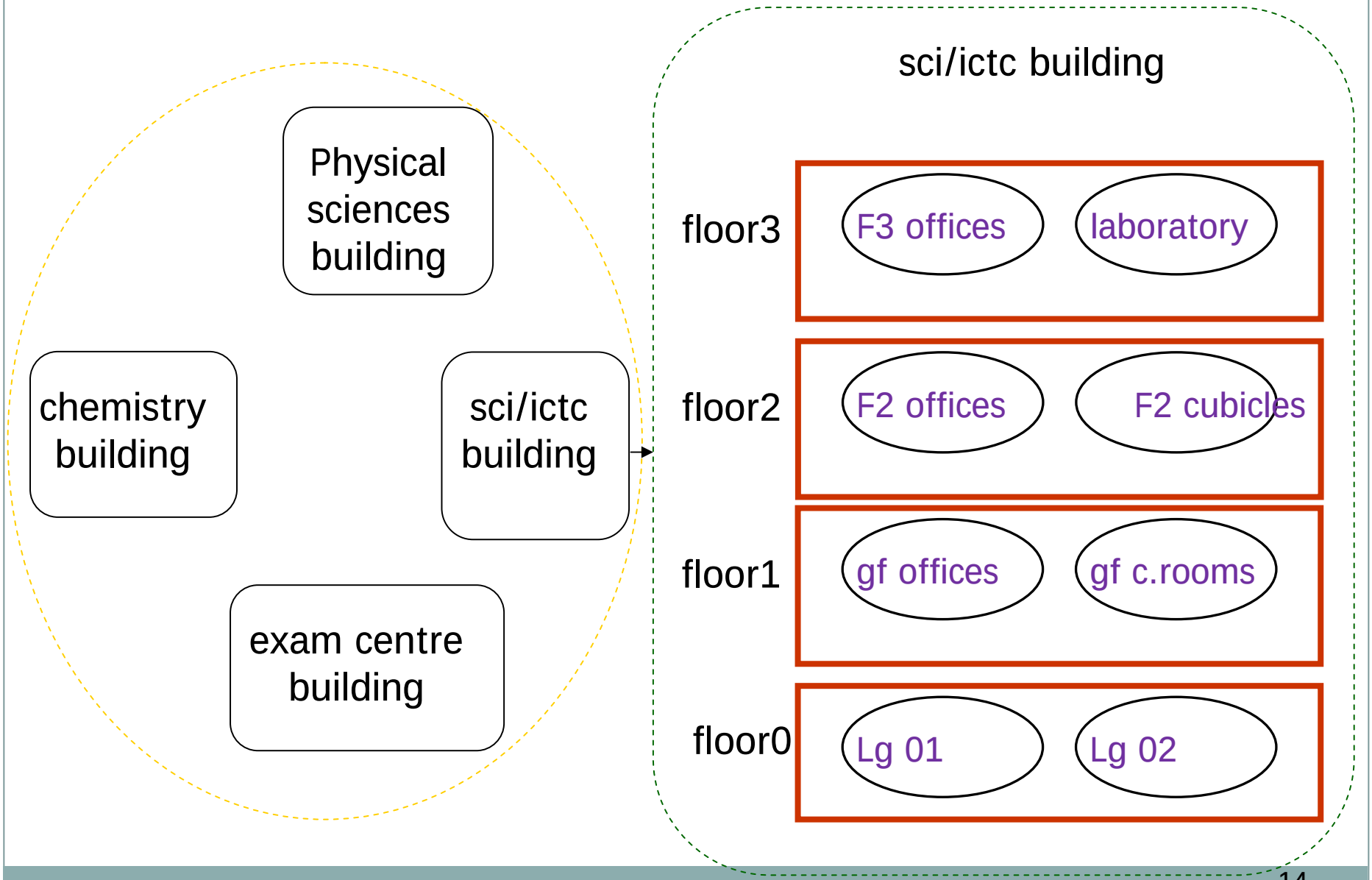


Campus internetwork

- The campus is considered in general as consisting of
  - A number of buildings
  - Each building may have several floors
  - Each floor has work areas
  - A work area accommodates workstations and other end-user devices
  - There may also be servers and small data centers

  - [note also the major bullet two on slide 10]

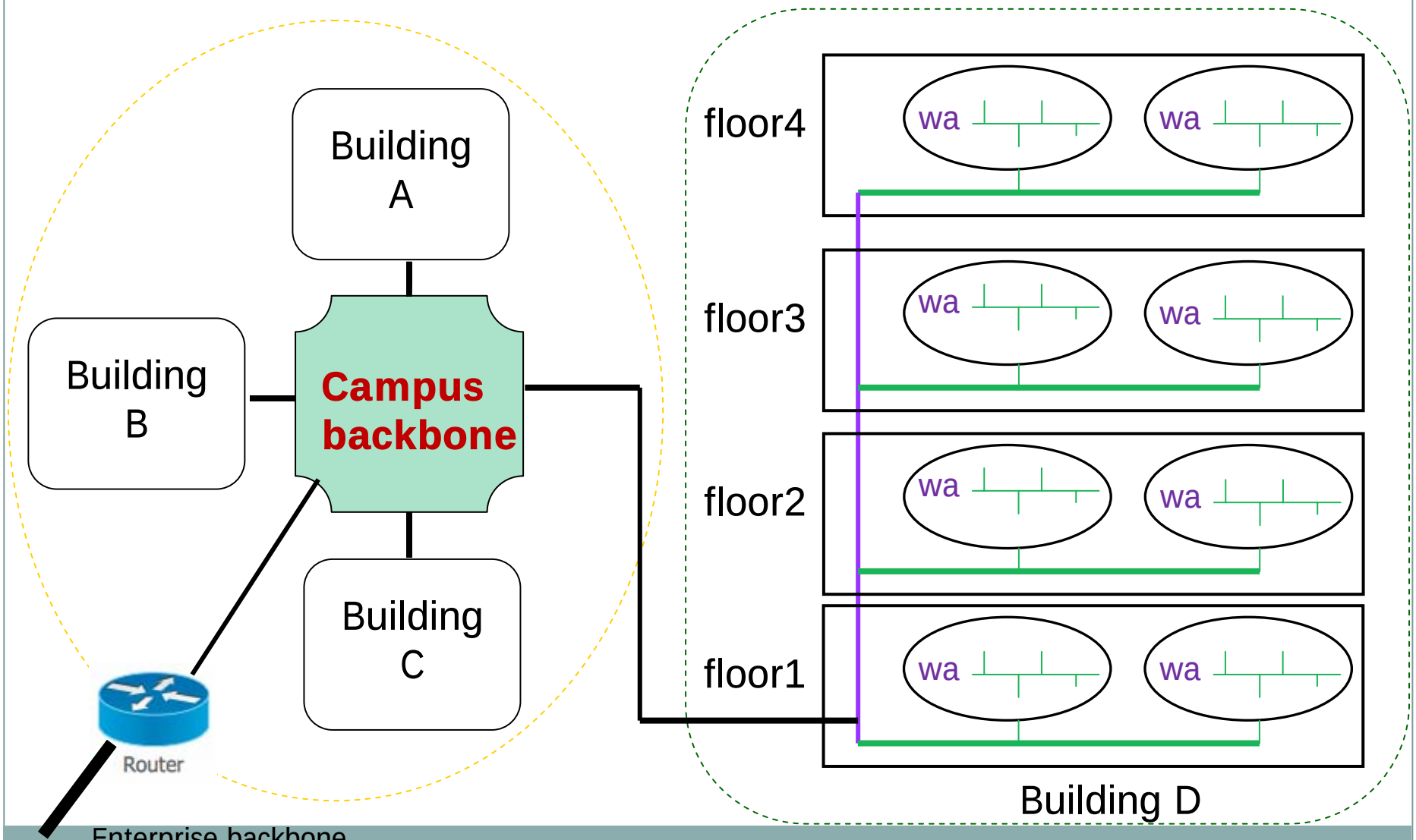
Campus internetwork



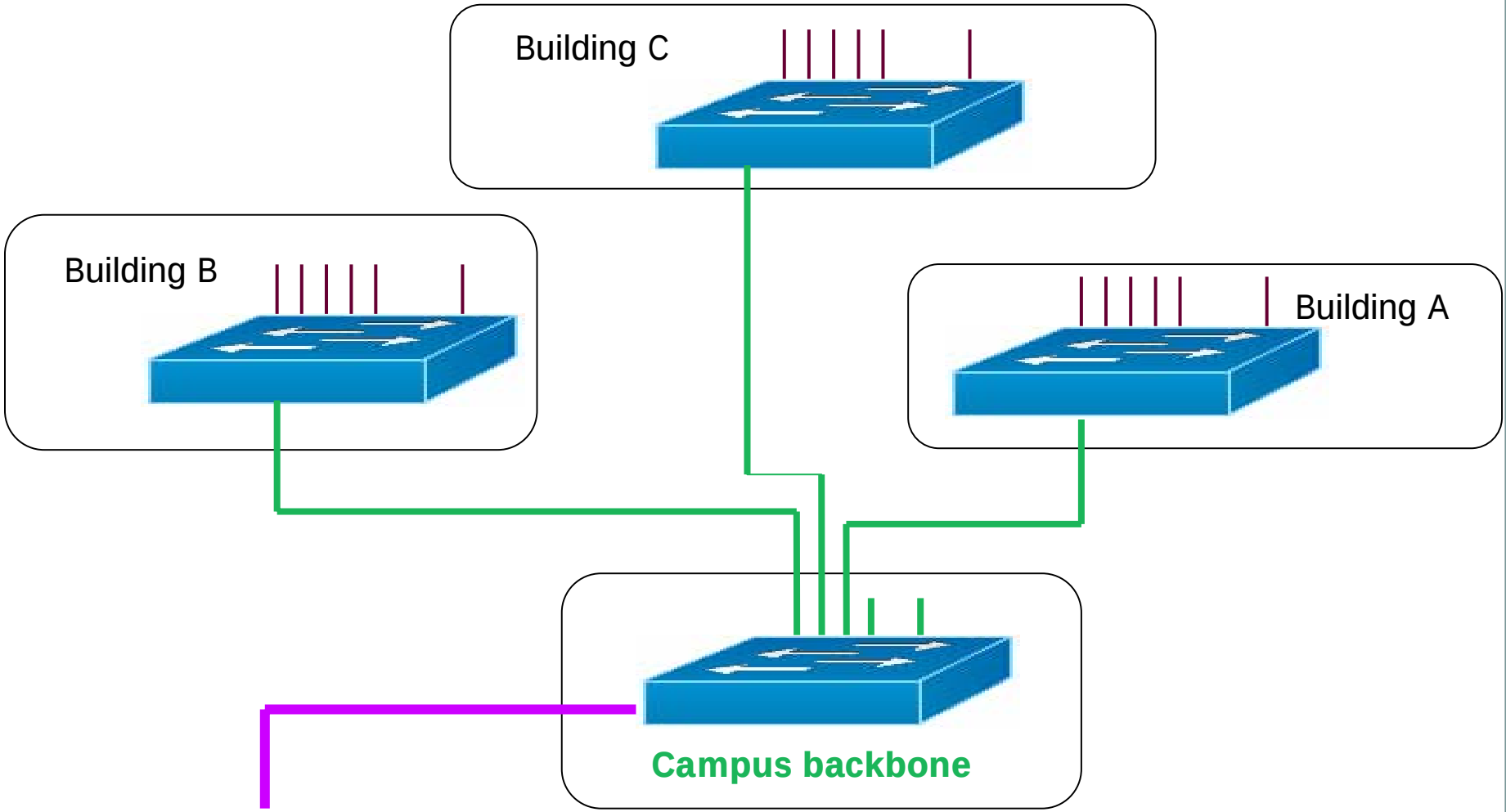
Campus internetwork

- Connectivity:
  - Potentially require all-to-all at host level, but need to consider:
    - Traffic flow patterns
    - Structured design
    - Management
    - Maintainability
    - Scalability
  - Leads to hierarchical structure...
    - Campus backbone
    - Vertical wiring
    - Horizontal wiring

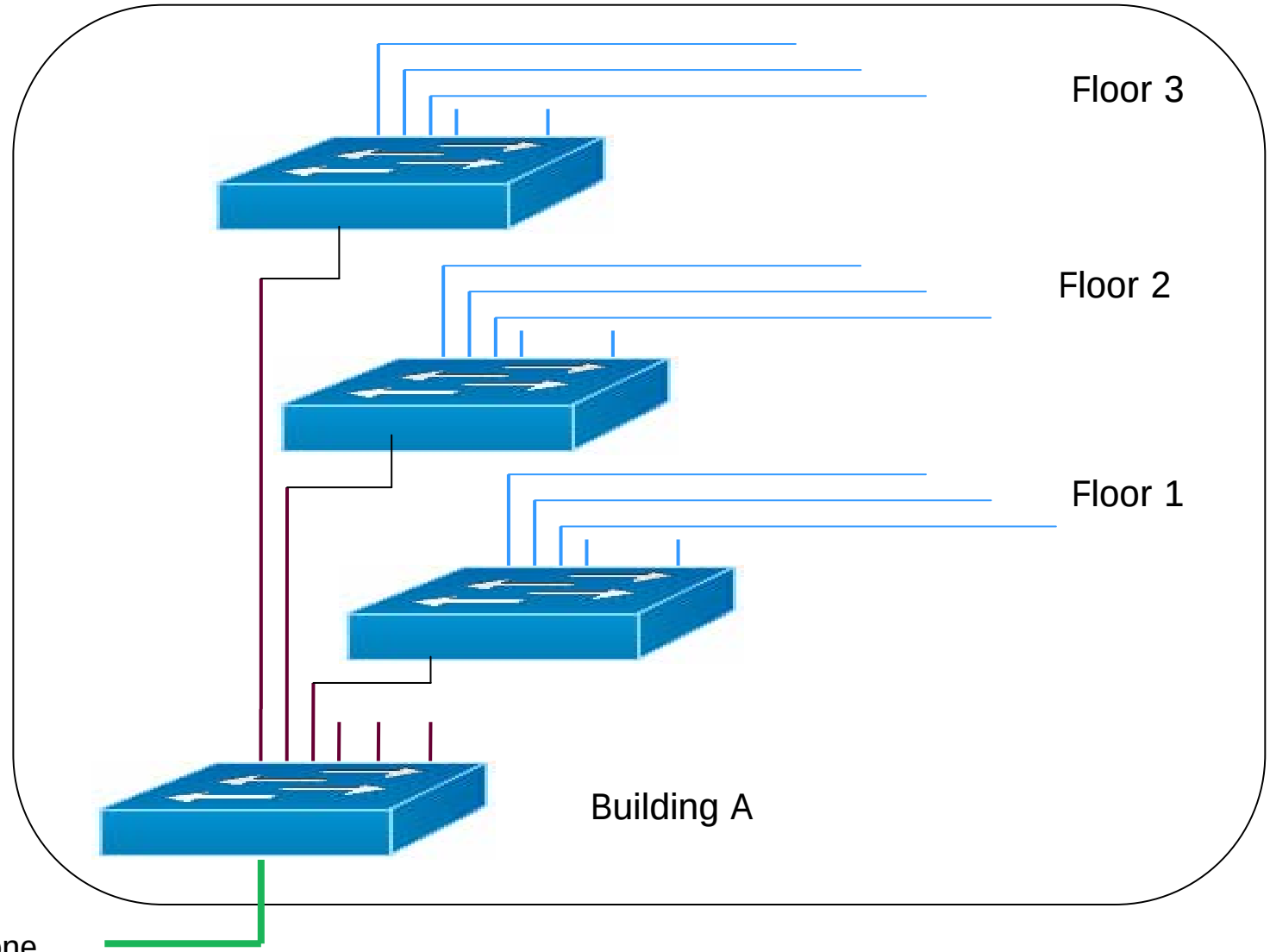
Campus internetworkn (logical)



Campus internetwork (physical)

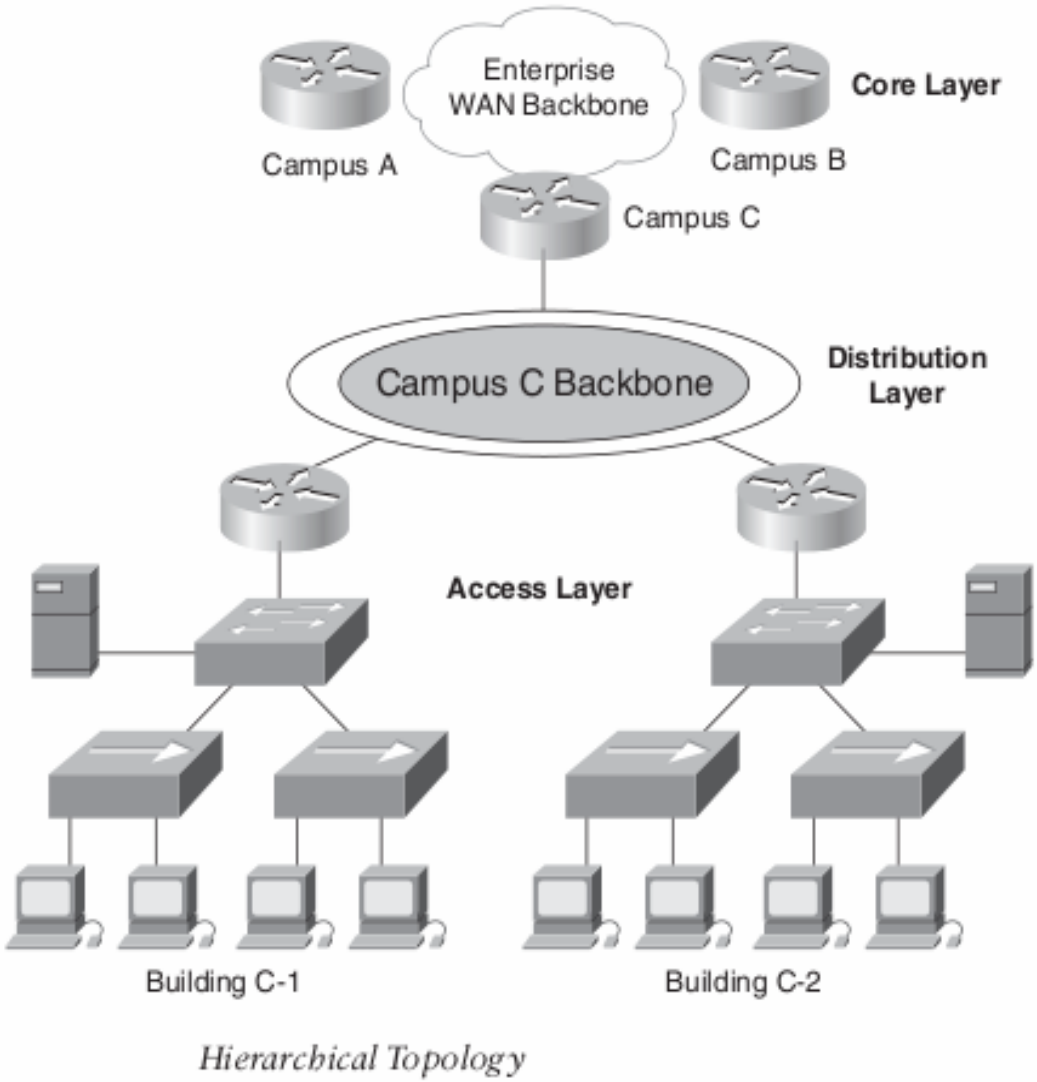


Campus internetwork (physical)



Classic Three-Layer Hierarchical Model

Classic Three-Layer Hierarchical Model



Hierarchical Topology

- A core layer of high-end routers and switches that are optimized for availability and performance
- A distribution layer of routers and switches that connects network services to the access layers and implements policies regarding security, traffic loading, and routing
- An access layer that connects users via lower-end switches and wireless access points
- In WAN design, the access layer consists of routers at the edge of the campus network.

Technology and Devices for campus Network

Cables

Types of Cables

- Ethernet technology is now dominant for campus internetwork
- Ethernet generally uses
  - UTP cables
  - fiber-optic cables
- Coax and other types of shielded copper cabling are generally not recommended for new installations.

categories of UTP cabling

- Category 1 and 2: not recommended for data transmissions due to lack of support for high bandwidth requirements
- Category 3: tested to 16 MHz. Voice-grade cabling, but it is used for data transmission also in older 10BASE-T Ethernet
- Category 4: tested at 20 MHz, allowing it to run 16-Mbps with a better safety margin than Category 3. Has been made obsolete by Category 5.

categories of UTP cabling

- Category 5: tested at 100 MHz, allowing it to run high-speed protocols such as 100-Mbps Ethernet.. When four pairs are used, Category 5 supports Gigabit Ethernet.
- Category 5 Enhanced (Category 5e): is suitable for 100-Mbps Ethernet, Gigabit Ethernet, and ATM.
- Category 6: suitable for 100-Mbps Ethernet, Gigabit Ethernet, and ATM.

Fiber-optic cabling

Optic fiber

- Optic fiber cabling appropriate for
  - vertical and horizontal wiring between telecommunications closets
  - between buildings.

- may also be used for work-area wiring, but the cost of network interface cards (NIC) with fiber-optic support is still high.

Ethernet

Ethernet

- Has gained wide-spread popularity and adapted to new demands for capacity, reliability, and low prices.

- Many troubleshooting tools, including
  - cable testers,
  - protocol analyzers, and
  - network management applications,

  are available for isolating the occasional problems

- Occasional problems
  - cable breaks,
  - electromagnetic interference,
  - failed ports, or
  - malfunctioning NICs.

Ethernet Technology Choices

- Ethernet is a scalable technology
- has adapted to increasing capacity requirements
- Available options:
  - Half- and full-duplex Ethernet
  - 100-Mbps Ethernet
  - 1000-Mbps (1-Gbps or Gigabit) Ethernet
  - 10-Gbps Ethernet
  - Cisco EtherChannel

Gigabit Ethernet Specifications

spec	1000BASE-SX	1000BASE-LX (multimode)	1000BASE-LX (single-mode)	1000BASE-CX	1000BASE-T
Type of cabling	850-nm wavelength multimode fiber	1300-nm wavelength multimode fiber	1300-nm wavelength multimode and single-mode fiber	Twinax	UTP
Distance limitations (meters)	220–550	550	5000	25	100

10-Gbps Ethernet implementations

Implementation	Wavelength	Medium	Minimum Modal Bandwidth	Operating Distance
10GBASE-LX4	1310 nm	62.5-micron multimode fiber	500 MHz/km	2–300 m
10GBASE-LX4	1310 nm	50-micron multimode fiber	400 MHz/km	2–240 m
10GBASE-LX4	1310 nm	50-micron multimode fiber	500 MHz/km	2–300 m
10GBASE-LX4	1310 nm	10-micron single-mode fiber	Not applicable	2–10 km

10-Gbps Ethernet implementations

Implementation	Wavelength	Medium	Minimum Modal Bandwidth	Operating Distance
10GBASE-S	850 nm	62.5-micron multimode fiber	160 MHz/km	2–26 m
10GBASE-S	850 nm	62.5-micron multimode fiber	200 MHz/km	2–33 m
10GBASE-S	850 nm	50-micron multimode fiber	400 MHz/km	2–66 m
10GBASE-S	850 nm	50-micron multimode fiber	500 MHz/km	2–82 m
10GBASE-S	850 nm	50-micron multimode fiber	2000 MHz/km	2–300 m

10-Gbps Ethernet implementations

Implementation	Wavelength	Medium	Minimum Modal Bandwidth	Operating Distance
10GBASE-L	1310 nm	10-micron single-mode fiber	Not applicable	2–10 km
10GBASE-E	1550 nm	10-micron single-mode fiber	Not applicable	2–30 km*
10GBASE-CS4	Not applicable	Twinax	Not applicable	15 m
SFP+ Direct Attach	Not applicable	Twinax	Not applicable	10 m
10GBASE-T	Not applicable	UTP or STP	Not applicable	100 m

* The standard permits 40-km lengths if link attenuation is low enough.

Cisco EtherChannel

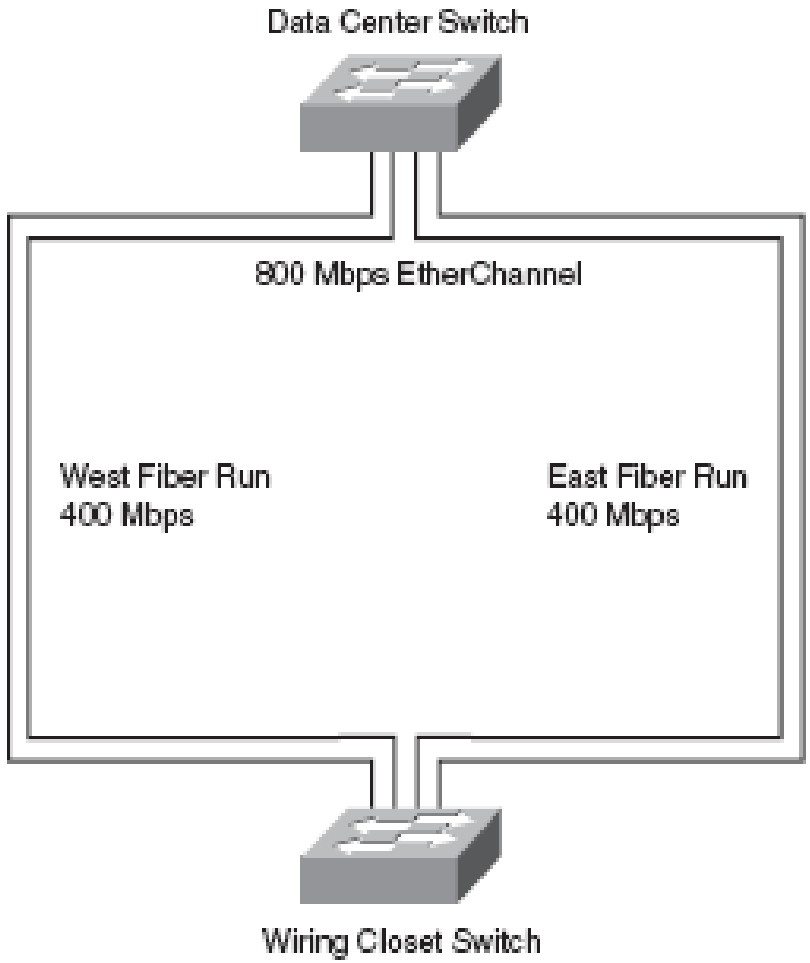
- EtherChannel can be used between routers, switches, and servers on point-to-point links that require more bandwidth than a single Ethernet link can provide.
- Cisco provides EtherChannel ports for many of its high-end switches and routers.
- Intel and other vendors make EtherChannel NICs for servers.

Cisco EtherChannel

- Fast EtherChannel: up to four Fast Ethernet links can be grouped to provide a maximum aggregate bandwidth of 800 Mbps (full duplex).
- Gigabit EtherChannel: up to four Gigabit Ethernet links can be grouped to provide a maximum aggregate bandwidth of 8 Gbps.
- 10-Gbps EtherChannel: up to four 10-Gbps Ethernet links grouped to provide a maximum aggregate bandwidth of 80 Gbps.

Cisco EtherChannel

- EtherChannel trunks effectiveness as a redundancy feature can be increased by grouping links that run on cables in different parts of a campus network.



Internetworking Devices for a Campus Network

Internetworking Devices for a Campus Network

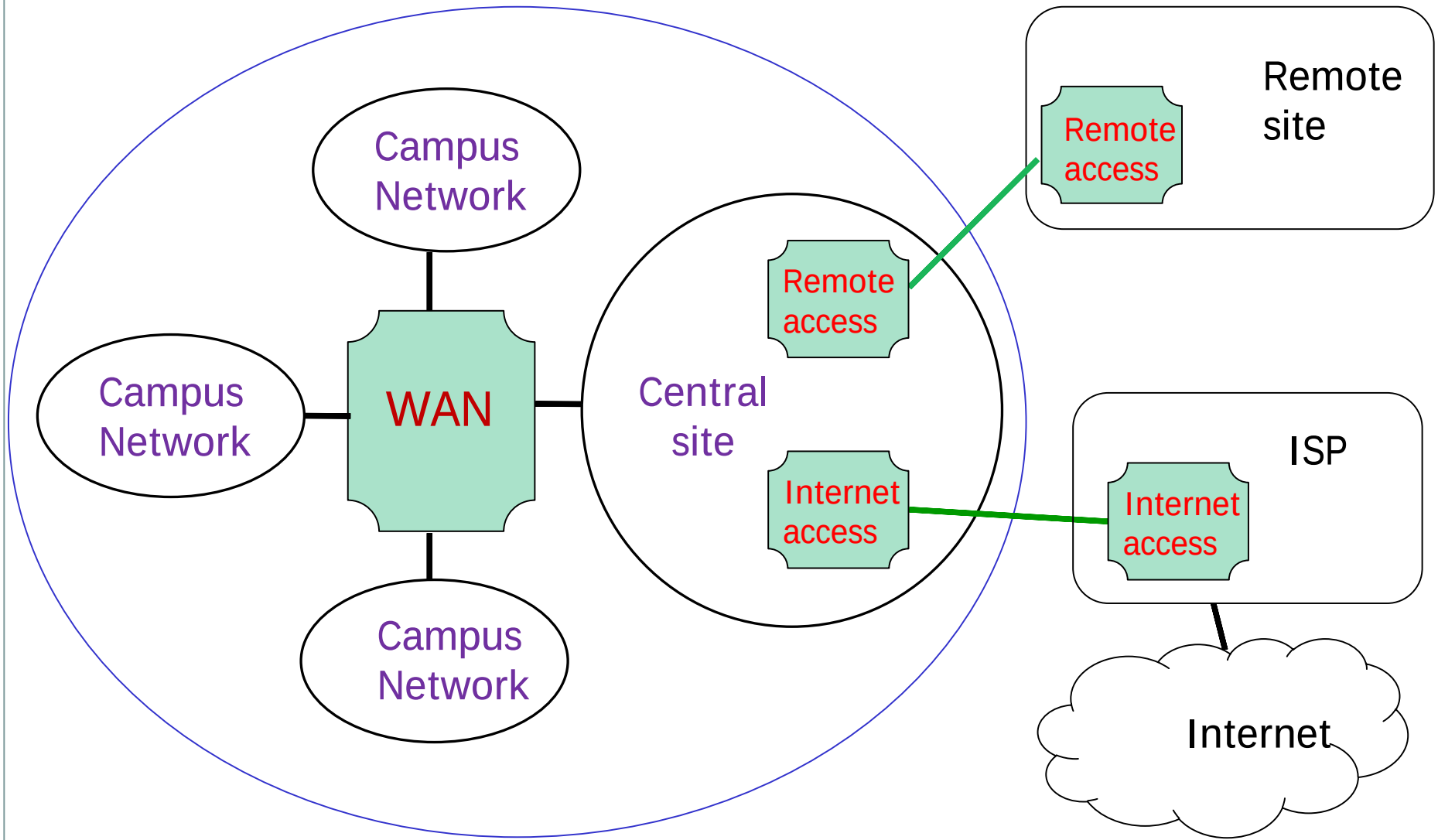
- The table on next slide provides a review of the major differences between internetworking devices that can be used to connect network segments.
- In most cases, the choice will be between a **switch** and a **router**.
- Hubs and bridges are generally obsolete

Review internetworking devices

Device / OSI Layers Implemented	How Bandwidth (Collision) Domains Are Segmented	How Broadcast Domains Are Segmented	Typical Deployment	Typical additional Features
Hub 1	All ports are in the same bandwidth domain.	All ports are in the same broadcast domain.	Connects individual devices in small LANs	Auto-partitioning to isolate misbehaving nodes
Bridge 1–2	Each port delineates a band-width domain.	All ports are in the same broadcast domain.	Connects networks	User-configured packet filtering
Switch 1–2	Each port delineates a bandwidth domain.	All ports are in the same broadcast domain unless VLANs are used.	Connects individual devices or networks	Filtering, cell-relay capabilities, cut-through processing, Multimedia (multicast) features
Router 1–3	Each port delineates a bandwidth domain.	Each port delineates a broadcast domain.	Connects networks	Filtering, fire-walling, high-speed WAN links, compression, advanced queuing and forwarding processes, multi-media (multicast) features

Technology and devices for Enterprise Network

Enterprise internetwork



Remote Access

- Remote Access Technologies
- Remote access devices
  - Devices for Remote Users
  - Devices for Central Site

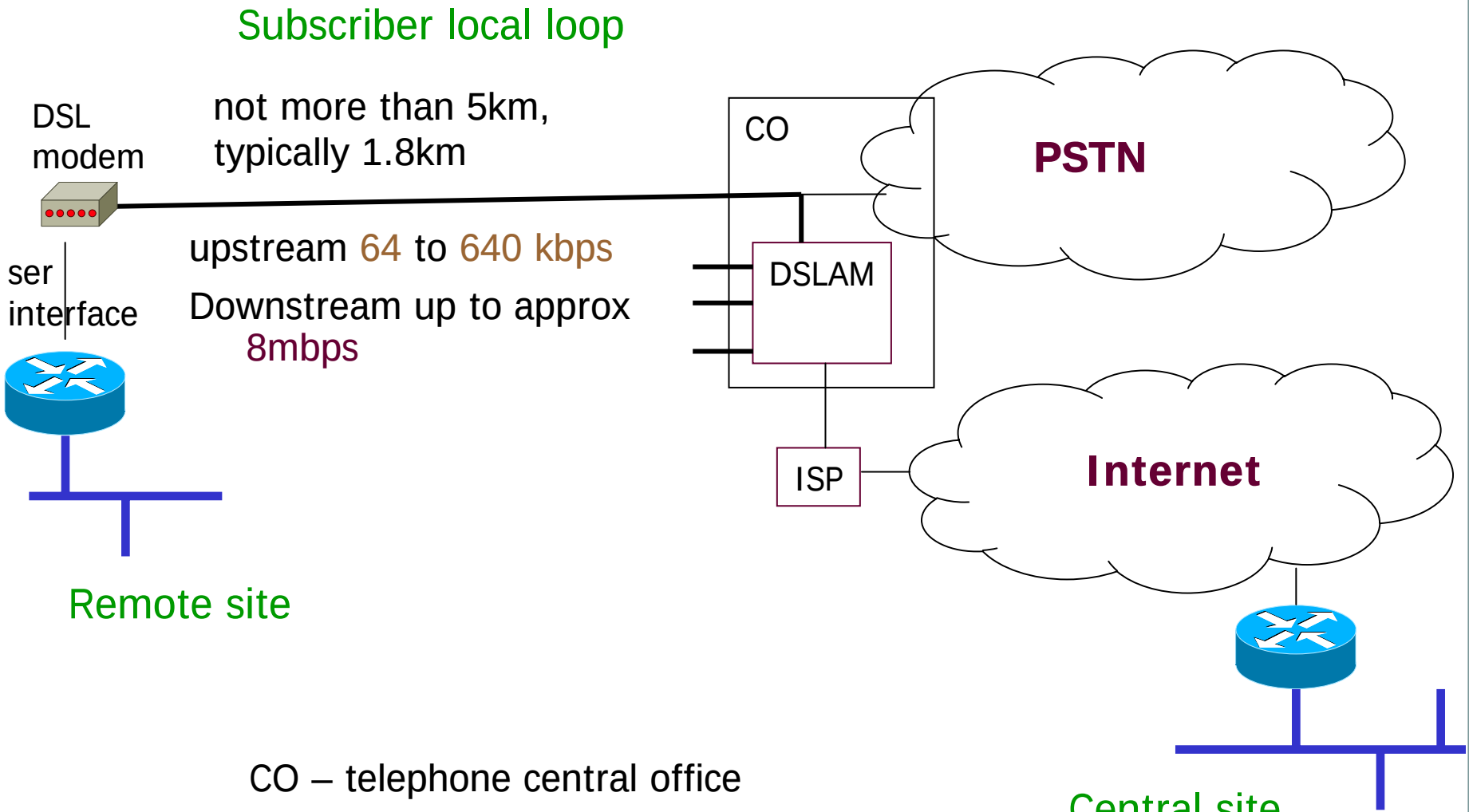
Remote Access

- Remote Access Technologies
  - DSL
  - PPP
  - VPN
  - Multilink PPP (channel aggregation)

Remote Access Technologies

- DSL
  - Digital subscriber line (DSL) (originally digital subscriber loop) is a family of technologies that are used to provide internet access by transmitting digital data over telephone lines

Remote Access Technologies: DSL



Remote Access Technologies: DSL with PPP and VPN

- PPP: point-to-point protocol
- VPN: virtual private network
- Multilink PPP (channel aggregation)

PPP: point-to-point protocol

- PPP has four functional layers:
  - The physical layer is based on various international standards for serial communication, including EIA/TIA-232-C, EIA/TIA-422, V.24, and V.35.
  - The encapsulation of network layer datagrams is based on the standard HDLC protocol.
  - The Link Control Protocol (LCP) is used for establishing, configuring, authenticating, testing, and terminating a data-link connection.
  - A family of Network Control Protocols (NCP) is used for establishing and configuring various network layer protocols, such as IP, IPX, AppleTalk, …

VPN: virtual private network

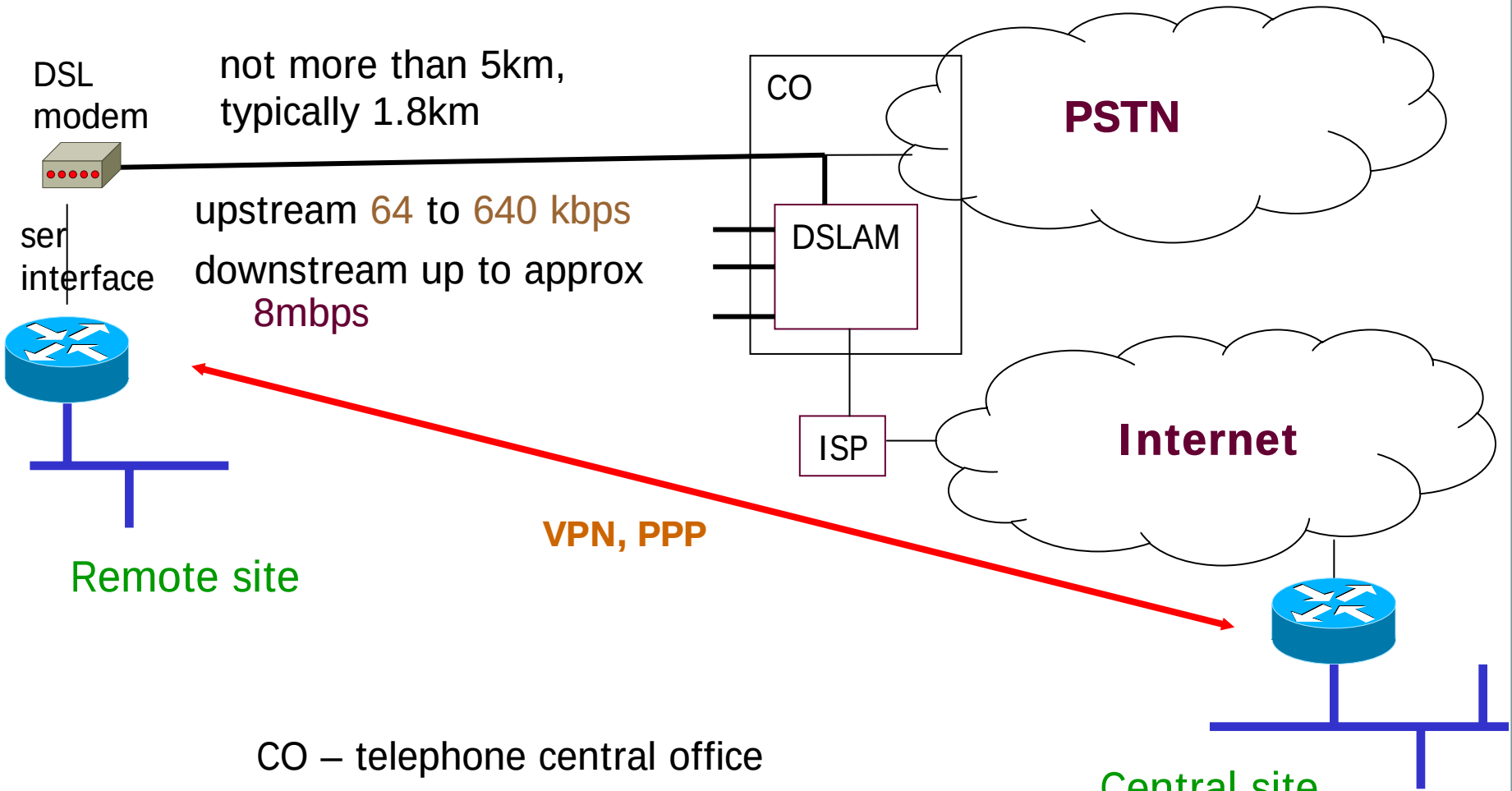
- VPN secures enterprise information and connections traversing un-trusted network
- Uses cryptography

Components:

- Remote: VPN functionality may be provided by router or the client workstation

- Central site: a VPN firewall or concentrator at the central site
  - (A VPN concentrator is a standalone hardware platform that aggregates a large volume of simultaneous VPN connections.)

Remote Access Technologies: DSL with PPP and VPN



CO – telephone central office

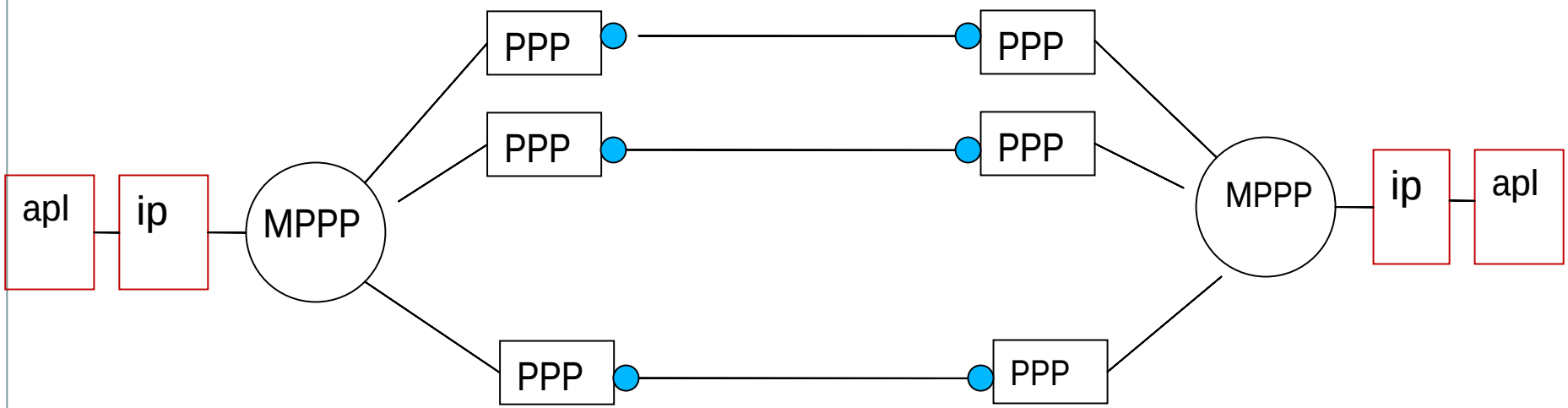
DSLAM - DSL Access Multiplexer

Multilink PPP (channel aggregation)

- MultilinkPPP(MPPP) adds support for channel aggregation to PPP.
- Channel aggregation can be used for load sharing and providing extra bandwidth.
  - With channel aggregation, a device can automatically bring up additional channels as bandwidth requirements increase.
  - MPPP ensures that packets arrive in order at the receiving device.
  - Multiple channels appear as one logical link to upper-layer protocols.

Remote Access Technologies: Multilink PPP

- Link aggregation with Multilink PPP



Technologies for WAN

Technologies for WAN

- WAN Capacity Provisioning
- WAN Technologies

WAN

- WAN capacity is usually obtained from a provider
- WAN bandwidth provisioning is standardized by
  - The *North American Digital Hierarchy* (NADH)
  - Committee of European Postal and Telephone (CEPT) *E system Hierarchy*
  - *Synchronous Digital Hierarchy (SDH) (international)*

The North American Digital Hierarchy

Signal	Capacity	Number of DS0s	Colloquial Name
DS0	64 Kbps	1	Channel
DS1	1.544 Mbps	24	T-1
DS1C	3.152 Mbps	48	T-1C
DS2	6.312 Mbps	96	T-2
DS3	44.736 Mbps	672	T-3
DS4	274.176 Mbps	4032	T-4

Synchronous Digital Hierarchy (SDH)

STS Rate	OC Level	Speed
STS-1	OC-1	51.84 Mbps
STS-3	OC-3	155.52 Mbps
STS-12	OC-12	622.08 Mbps
STS-24	OC-24	1.244 Gbps
STS-48	OC-48	2.488 Gbps
STS-96	OC-96	4.976 Gbps
STS-192	OC-192	9.952 Gbps

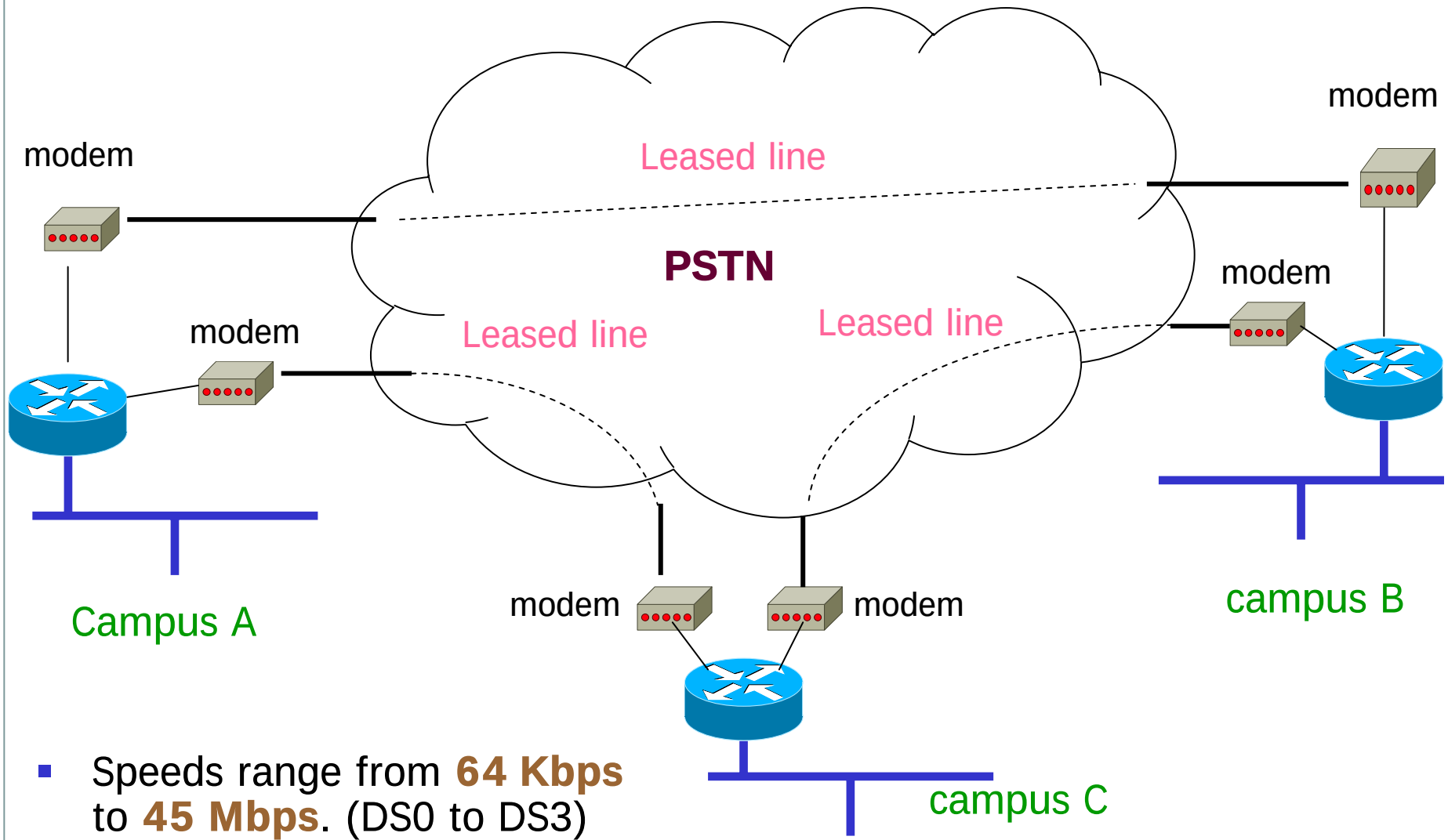
WAN Technologies

- Leased lines
- Synchronous Optical Network (SONET)
- Asynchronous Transfer Mode (ATM)
- Multi Protocol Label Switching (MPLS)

Leased Lines

- Dedicated digital, copper circuits that a customer leases from a carrier for a predetermined amount of time, usually for months or years.
- Speeds range from 64 Kbps to 45 Mbps. (DS0 to DS3)
- Enterprises use leased lines for both voice and data traffic.
- Data Traffic is typically encapsulated in PPP or HDLC
- Dedicated to each customer

Leased Lines

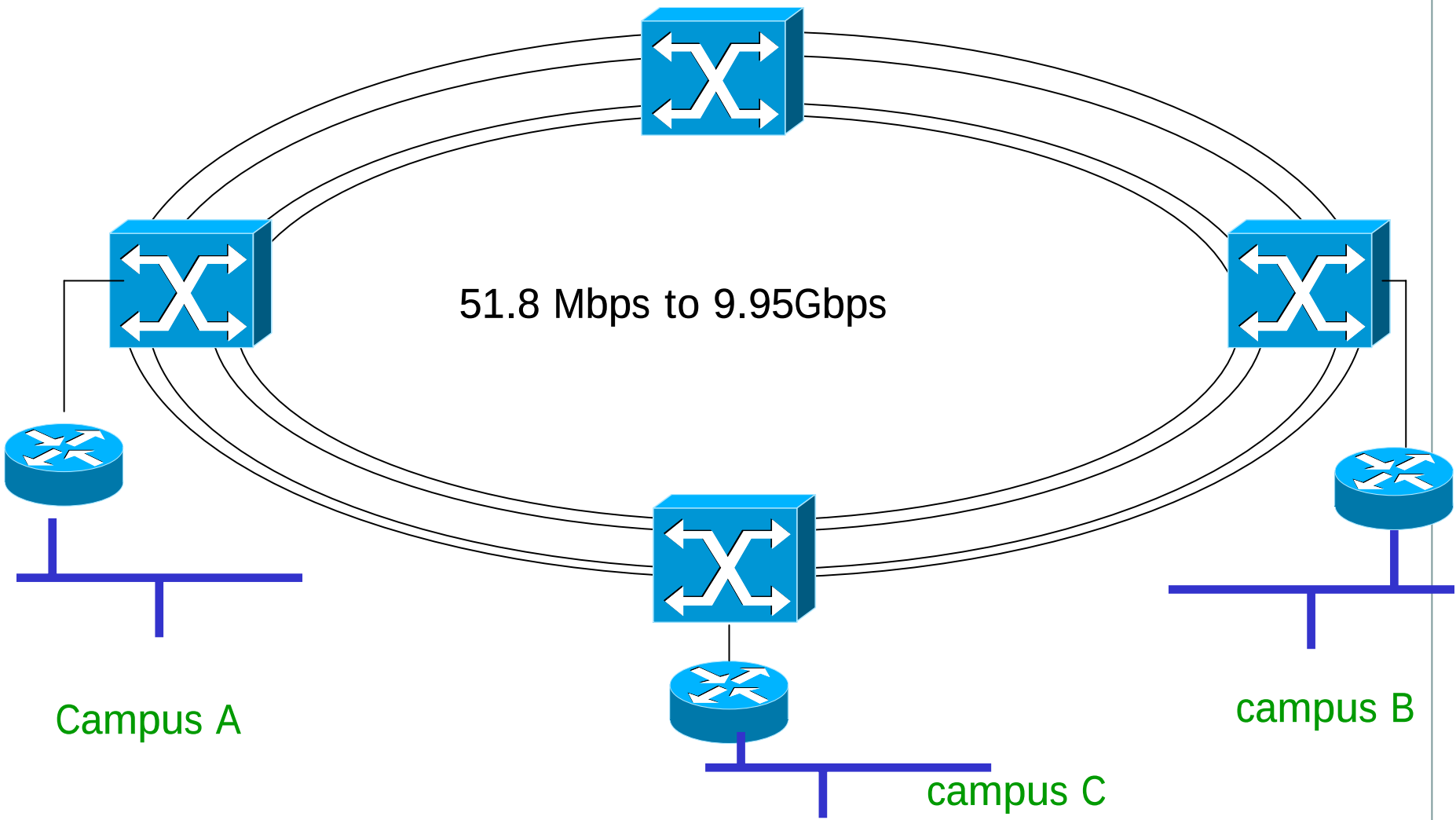


- Speeds range from **64 Kbps** to **45 Mbps**. (DS0 to DS3)

Synchronous Optical Network (SONET)

- Physical-layer specification for high-speed synchronous transmission of packets or cells over fiber-optic cabling.
- Service providers and carriers make wide use of SONET in their internal networks.
- Gaining popularity within private networks.
- Transports both ATM and POS Packet Over Sonet traffic

Typical SONET Topology

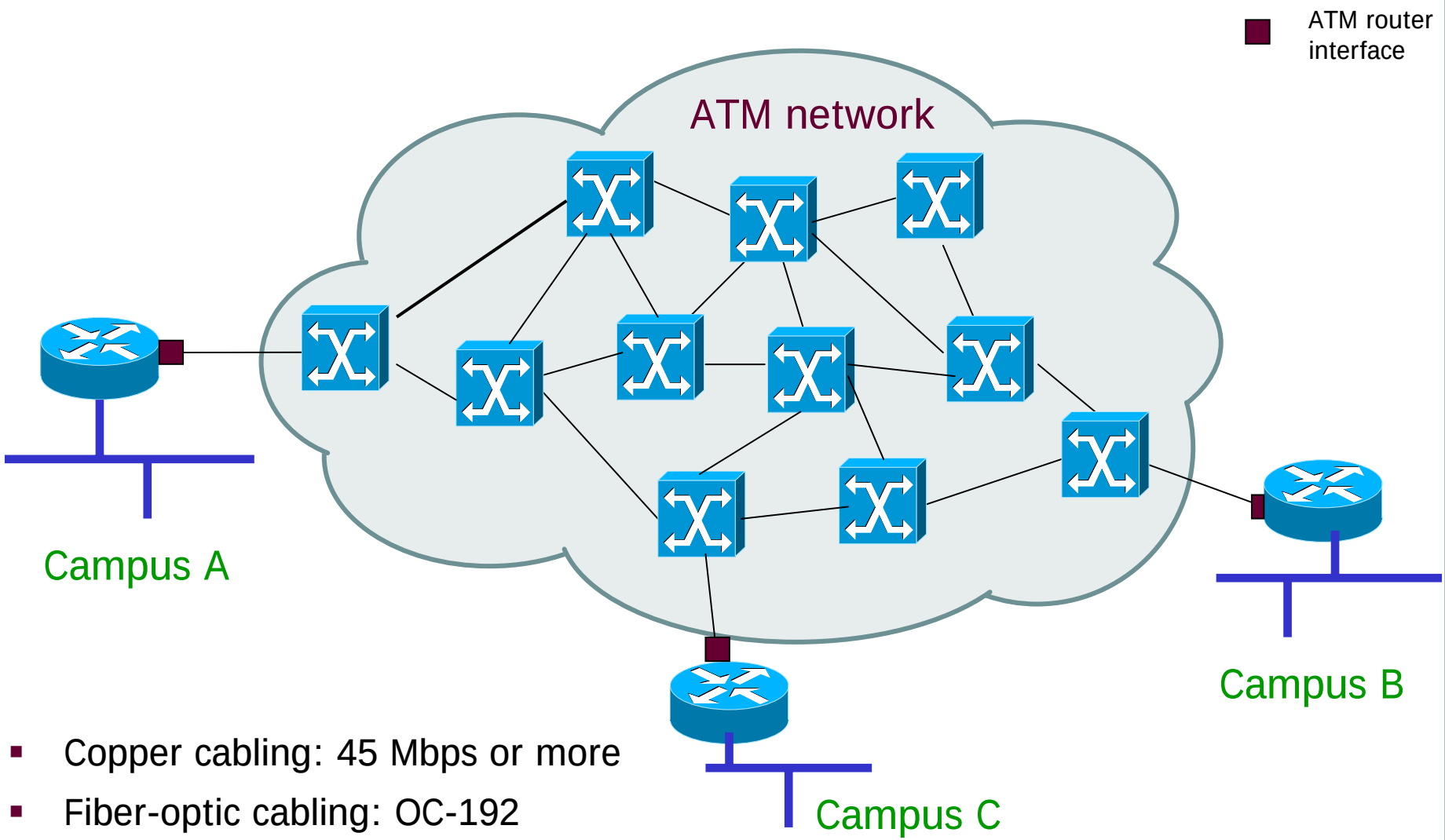


Asynchronous Transfer Mode (ATM)

- Used in service provider internal networks.
- Ethernet over ATM is gaining popularity with Service providers.

- Supports very high bandwidth requirements:
  - Copper cabling: 45 Mbps or more
  - Fiber-optic cabling: OC-192 (9.952 Gbps) and beyond, especially if technologies such as wave-division multiplexing (WDM) are used

Asynchronous Transfer Mode (ATM)



- Copper cabling: 45 Mbps or more
- Fiber-optic cabling: OC-192 (9.952 Gbps) and beyond

ATM...

- Provides efficient sharing of bandwidth among applications with various Quality of Service (QoS) requirements:
  - Cell-based system inherently better for QoS than frames.
- Application can specify upon connection establishment the QoS it requires.
- Peak and minimum cell rates, cell-loss ratio, and cell-transfer delay.

Ethernet over ATM

- ATM router interfaces are expensive.
- Some providers allow a customer to use an Ethernet interface to access the provider's ATM WAN.
- May require a converter.
- Expected to gain popularity because it has the advantages of both worlds:
  - Easy-to-use LAN
  - QoS-aware WAN

Metro Ethernet

- Most Carriers now offer native Ethernet port access
- This can be layer 2 or 3
- Can use many transport mechanisms
  - SONET, ATM, Frame Relay and MPLS
- Complexities of transport network is hidden from customer
- Termination is Ethernet
- These services are commonly referred as
  - Transparent LAN Service (TLS)
  - LAN Extension Service (LANe)
  - Metro Ethernet
- Most of the current offering use MPLS at the transport level

MPLS – Multi Protocol Label Switching

- New Emerging Technology
- Switching of IP packets using labels across a layer 3 network core
- Supports Multiple Closed User Groups similar to Frame Relay
- Supports QOS similar to ATM
- Provides support for RSVP and traffic engineering.
- Uses Frame and ATM as Transport Networks.
- Next Generation Networking, Most carrier networks are evolving to MPLS

next

Introduction to network management