# Lecture 2

# Lecture 2: roadmap

1.1 what *is* the Internet?

1.2 protocol layers, service models

1.3 network edge

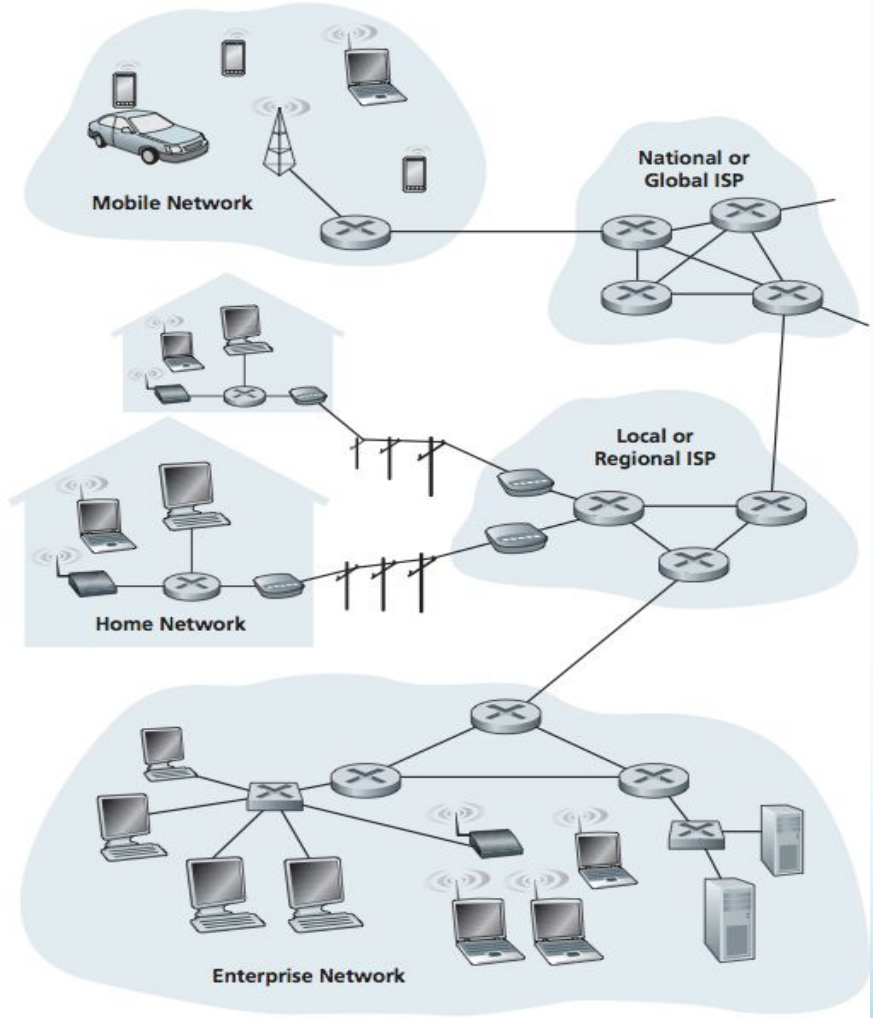
- end systems, access networks, links

1.4 network structure

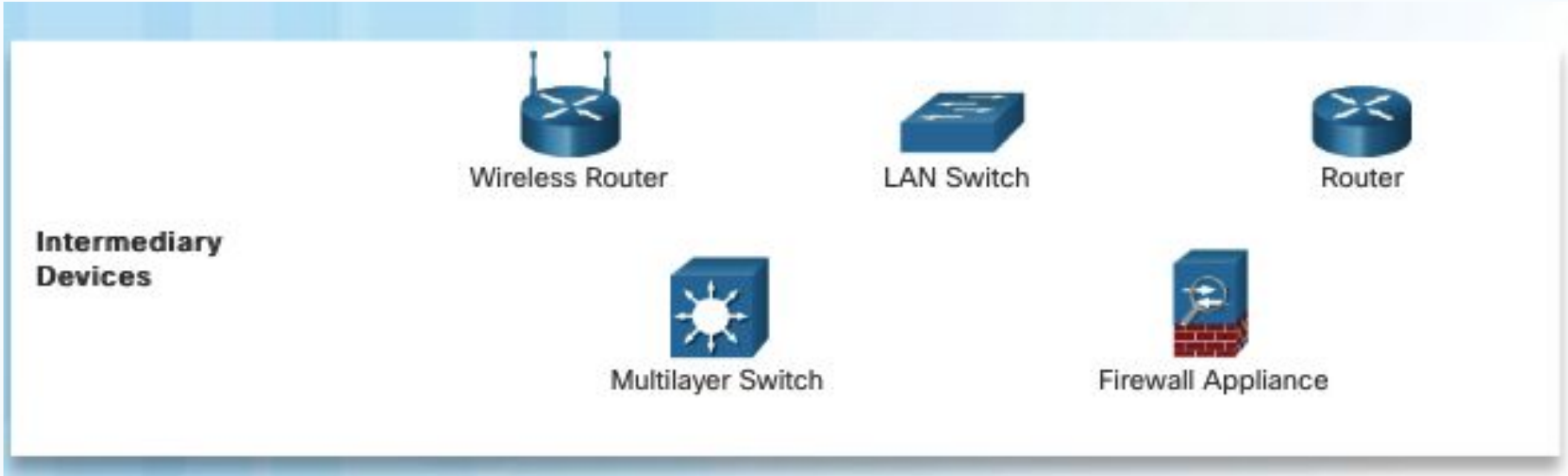
# What's the Internet: "nuts and bolts" view

- millions of connected computing devices:
  - *hosts = end systems*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*
- *Packet switches:* forward packets (chunks of data)

*routers* and *link-layer switches*




# Intermediary Network Devices

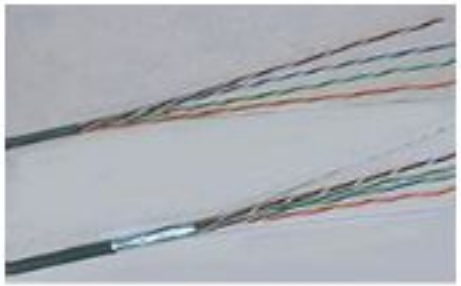



**Intermediary network devices perform some or all of these functions:**

- Regenerate and retransmit data signals
- Maintain information about what pathways exist through the network and internetwork
- Notify other devices of errors and communication failures
- Direct data along alternate pathways when there is a link failure
- Classify and direct messages according to priorities
- Permit or deny the flow of data, based on security settings

# Network Media

Copper



Fiber-optic

Wireless

# Physical media

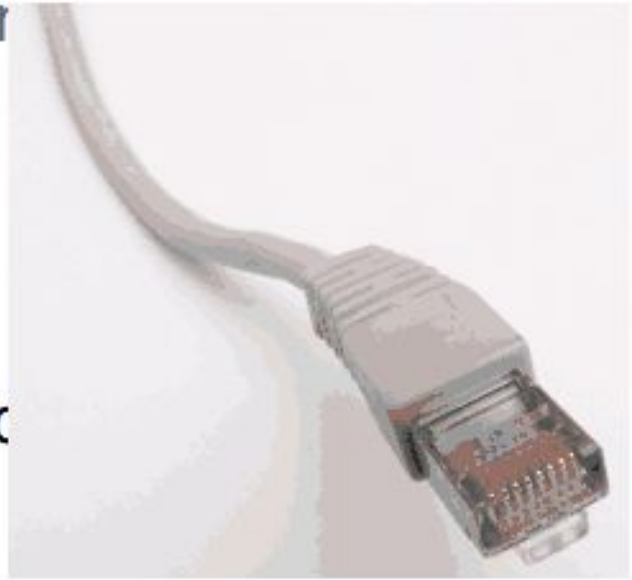
- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio

*twisted pair (TP)*

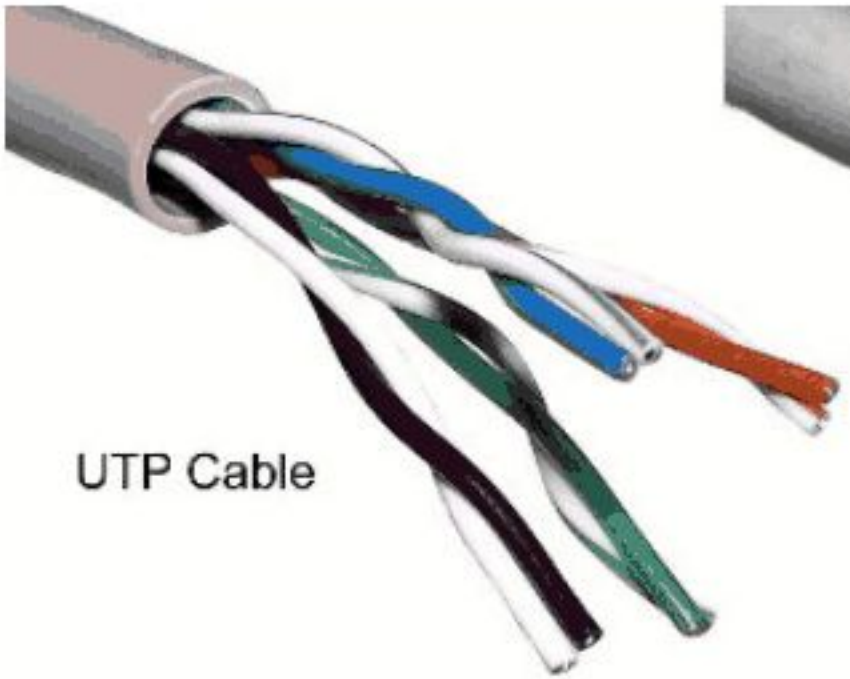
- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gpbs Ethernet
  - Category 6: 10Gbps

# Cable Media

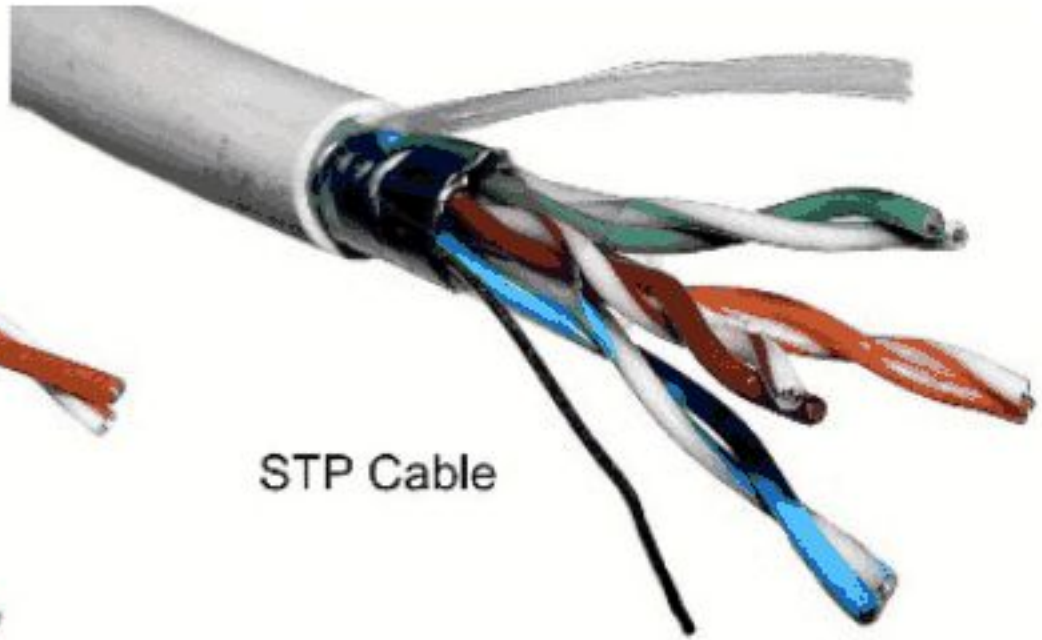
- ***Twisted Pair***
  - A type of cable that consists of two independently insulated wires twisted around one another. One wire carries the signal while the other wire is grounded and absorbs signal interferer
  - UTP (unshielded twisted pair)
  - STP (shielded twisted pair)
  - Looks similar to telephone cable
  - Uses square plastic ***RJ-45*** connecto



# UTP vs STP



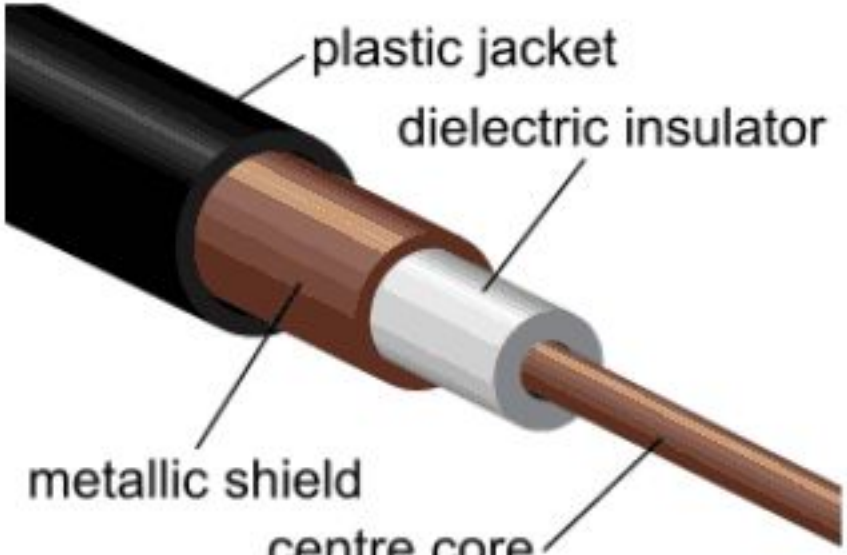
UTP Cable



STP Cable

# Cable Media (continued)

- ***Coaxial cable***
  - A type of wire that consists of a center wire surrounded by insulation and then a grounded shield of braided wire. The shield minimizes electrical and radio frequency interference.
  - Resembles cable-TV cable
  - Uses round, silver BNC connector




# Physical media: coax, fiber

*coaxial cable:*

- two concentric copper conductors
- bidirectional
- broadband:
  - multiple channels on cable

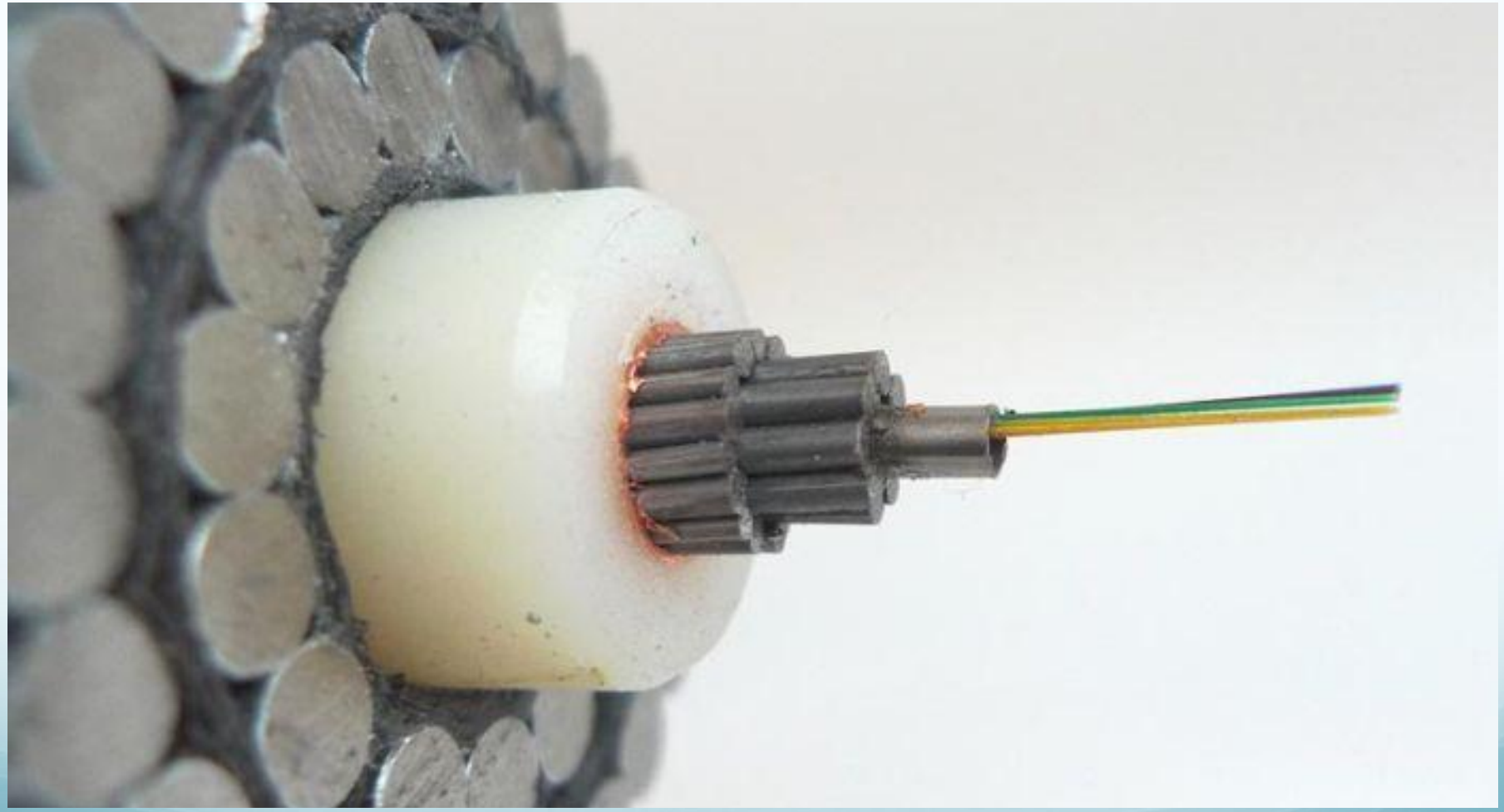
*fiber optic cable:*

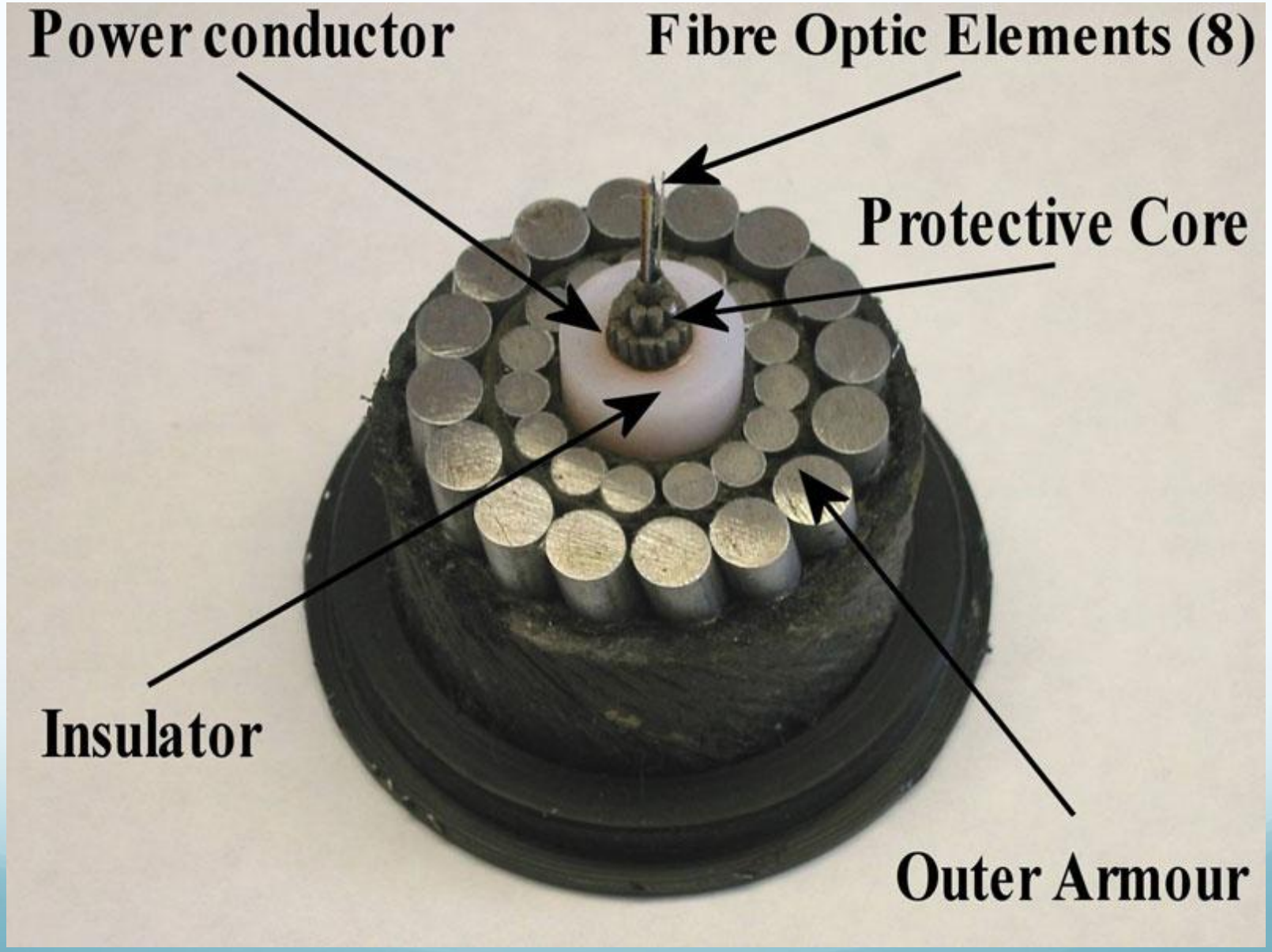
- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10's-100's Gpbs transmission rate)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise

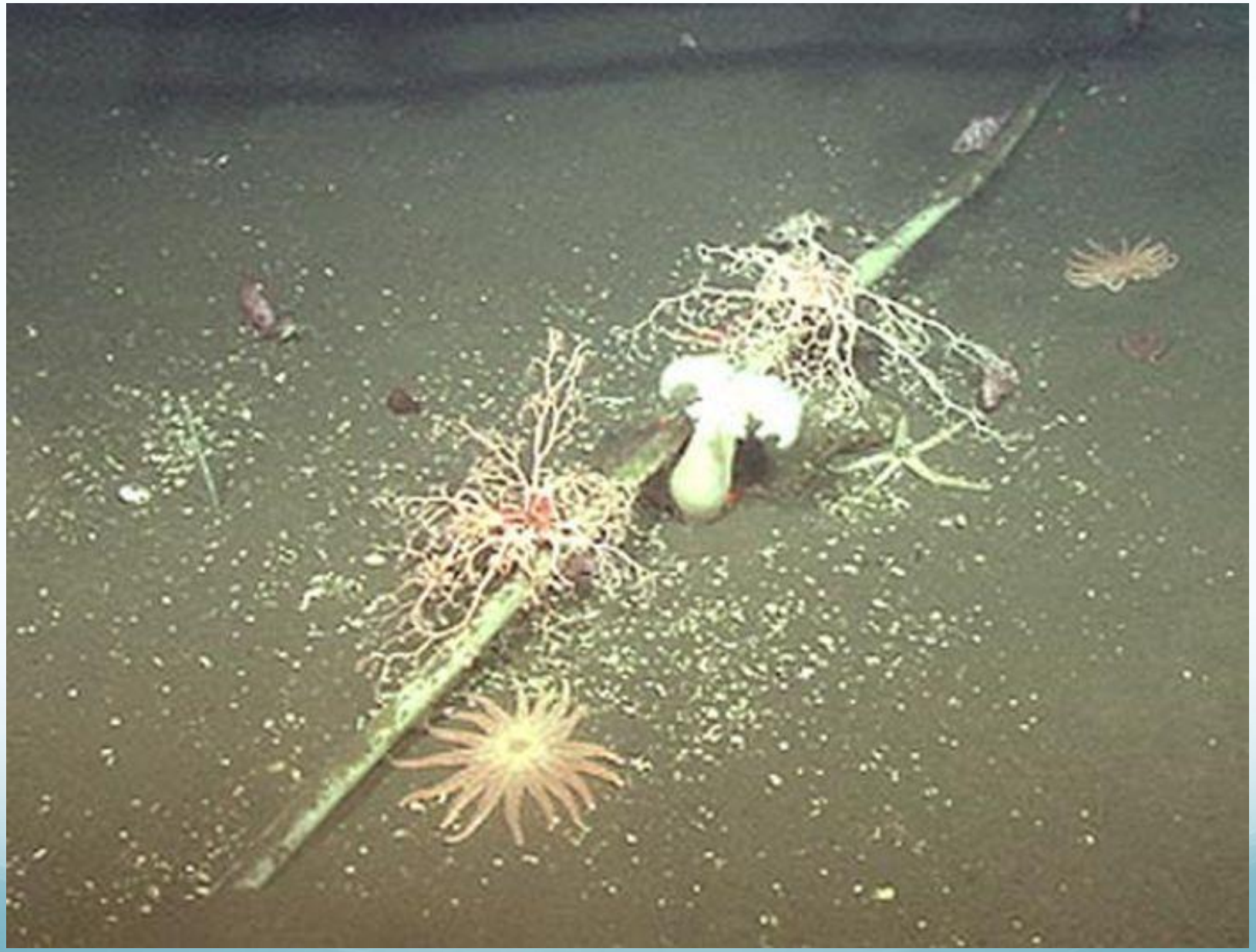
# TAT-14 Cable System
# Sprint Network Administration System

- The TAT-14 transatlantic cable system is in full service, connecting the United States to the United Kingdom, France, The Netherlands, Germany, and Denmark by 10 Gbs Direct Wave Access (DWA) or STM-16, STM-4, and STM-1 interfaces.

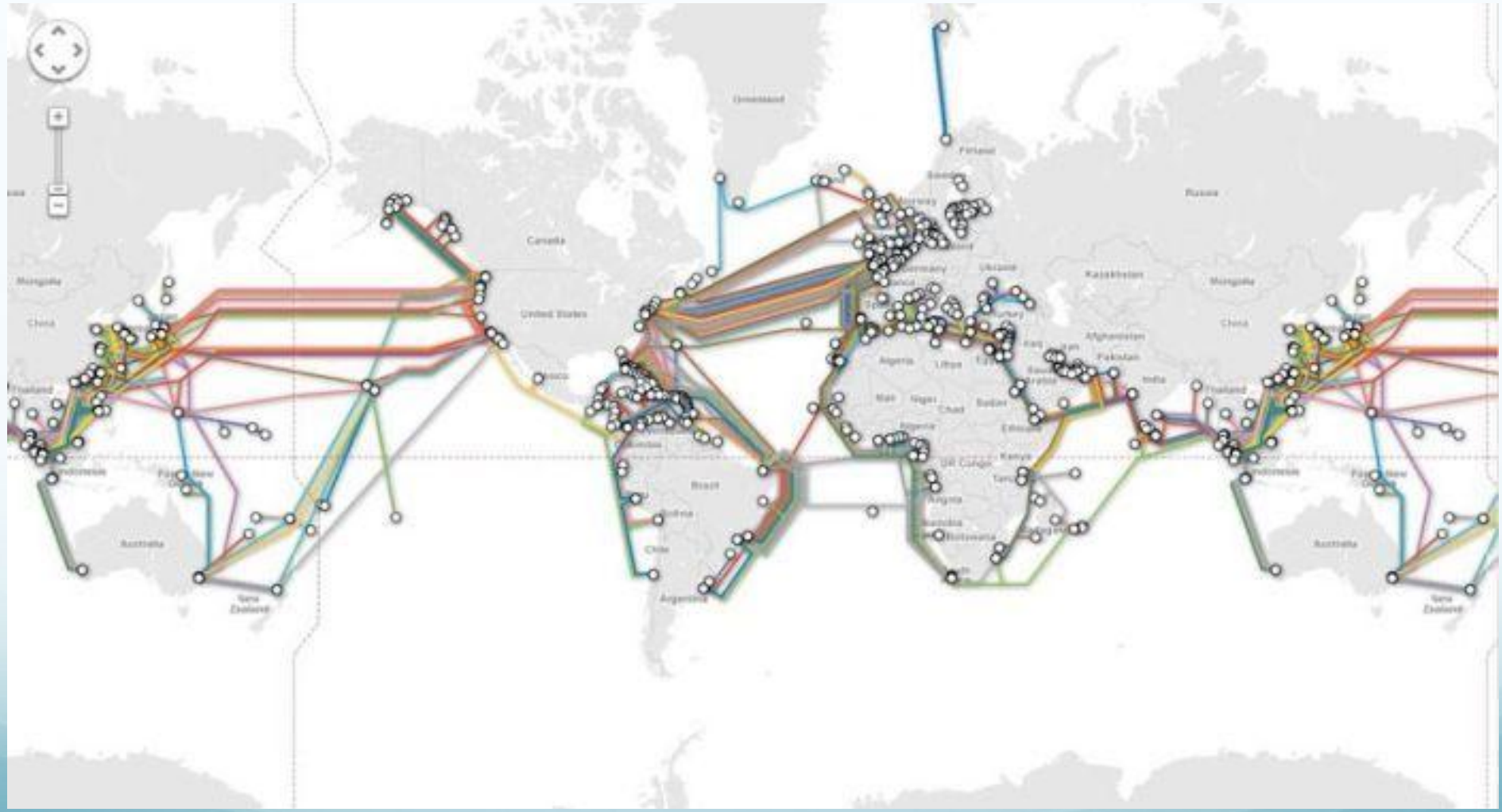
- The cable system is comprised of four fiber pairs configured for 47 x 10Gbs DWDM channels of which 10 are utilized for dual, bi-directional SDH rings.

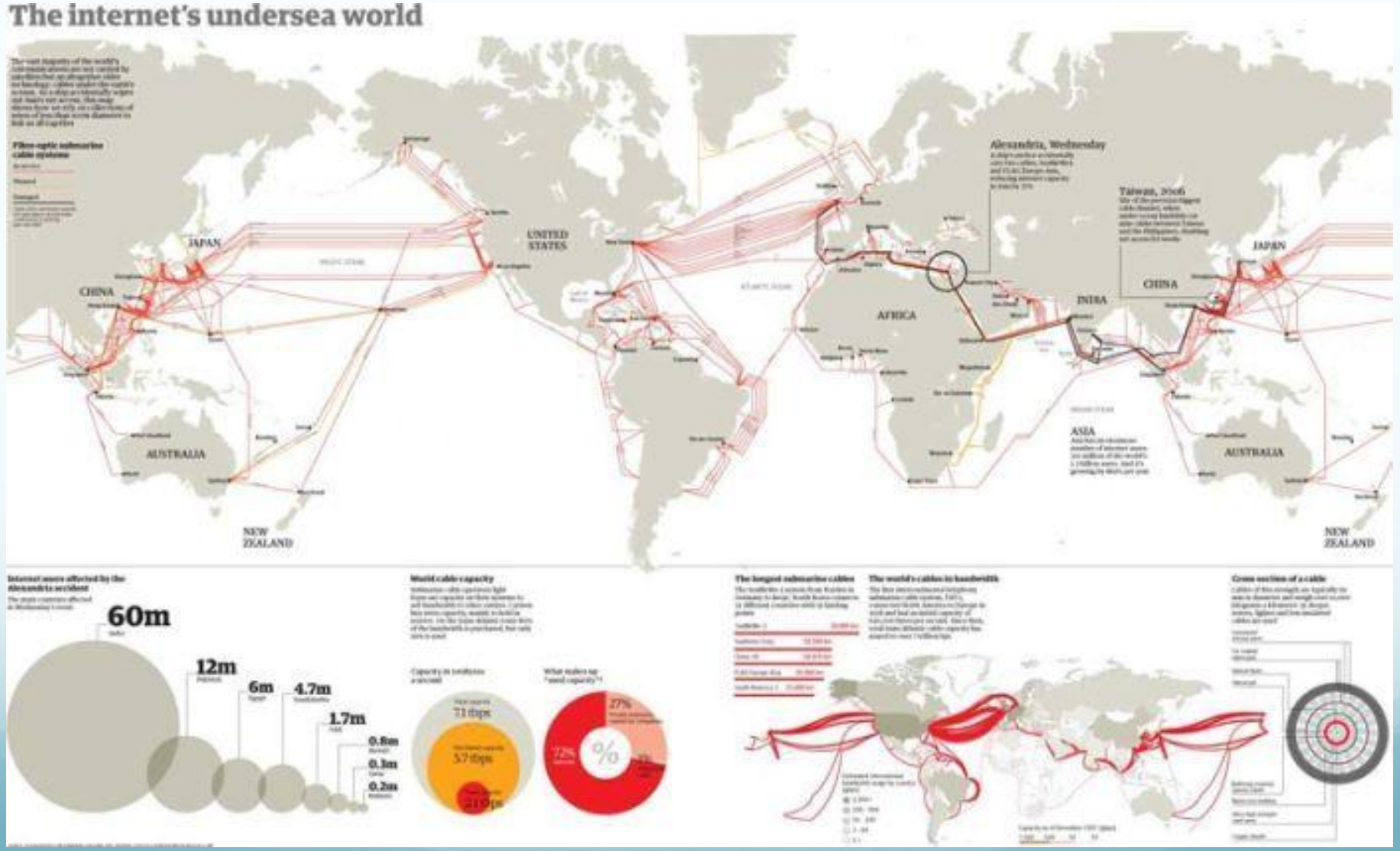



Power conductor
Fibre Optic Elements (8)
Protective Core
Insulator
Outer Armour




WARNING
SUBMARINE
CABLE
Google


Canada
United States
Mexico
Brazil
Chile
Argentina
Australia
New Zealand
Indonesia
Mongolia
China
Russia
Kazakhstan
Ukraine
Finland
Sweden
Norway
Germany
Algeria
Libya
Chad
Niger
Mali
Kenya
Angola
Namibia
Botswana
Afghanistan
Pakistan
India
Thailand


The internet's undersea world
Fibre-optic submarine cable systems
JAPAN
CHINA
UNITED STATES
AUSTRALIA
NEW ZEALAND
AFRICA
INDIA
ASIA
Alexandria, Wednesday
Taiwan, 2006
Internet users affected by the Alexandria accident
60m
12m
6m
4.7m
1.7m
0.8m
0.3m
0.2m
World cable capacity
71 tbps
57 tbps
21 tbps
What makes up "used capacity"?
27%
72%
The longest submarine cables
The world's cables in bandwidth
Cross section of a cable

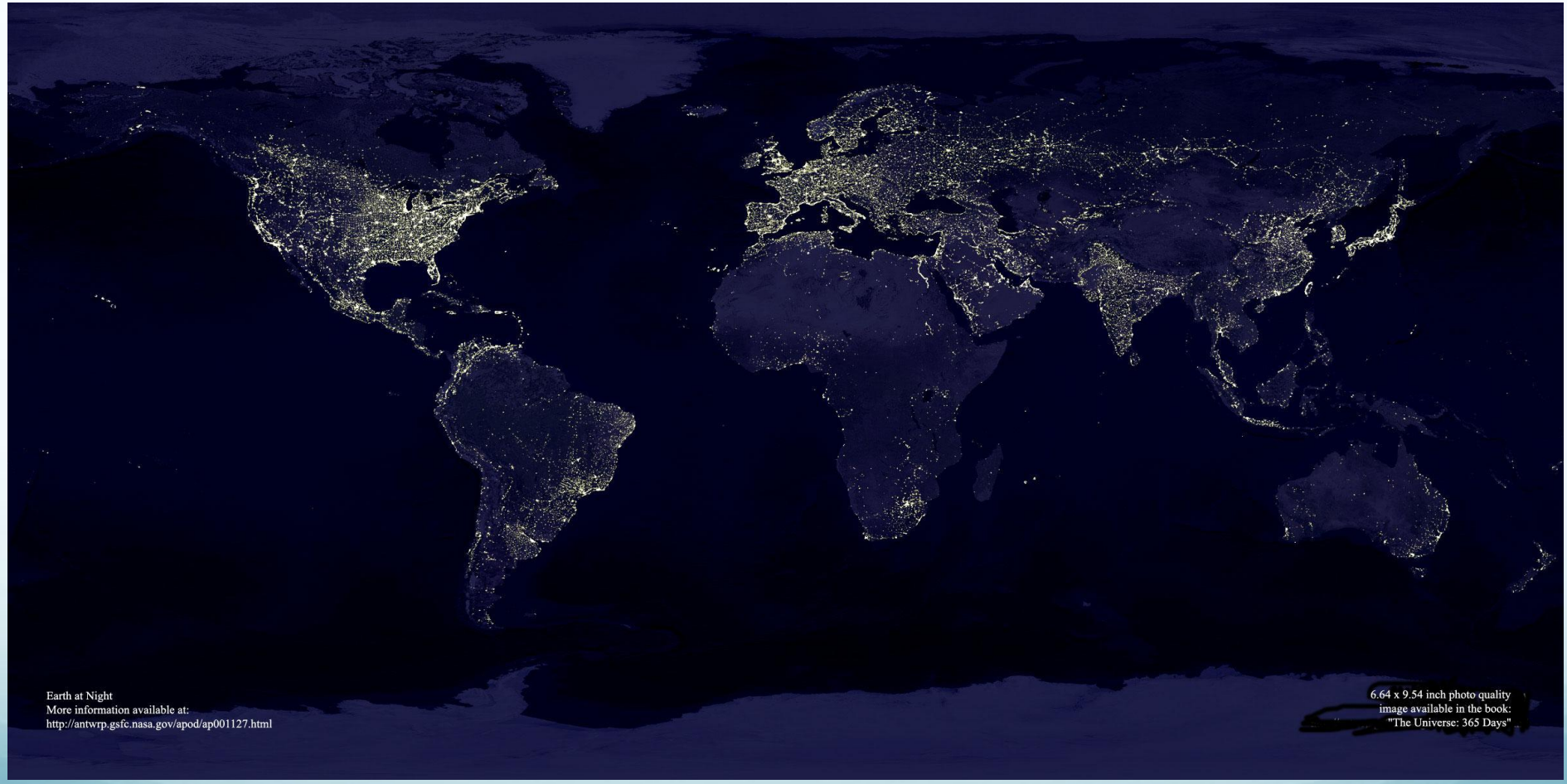
# CS Cable Innovator

- 1995 Finland (145m*24m), 8500 t fiber optic, 42 day of work (60).

## Национальная информационная супермагистраль

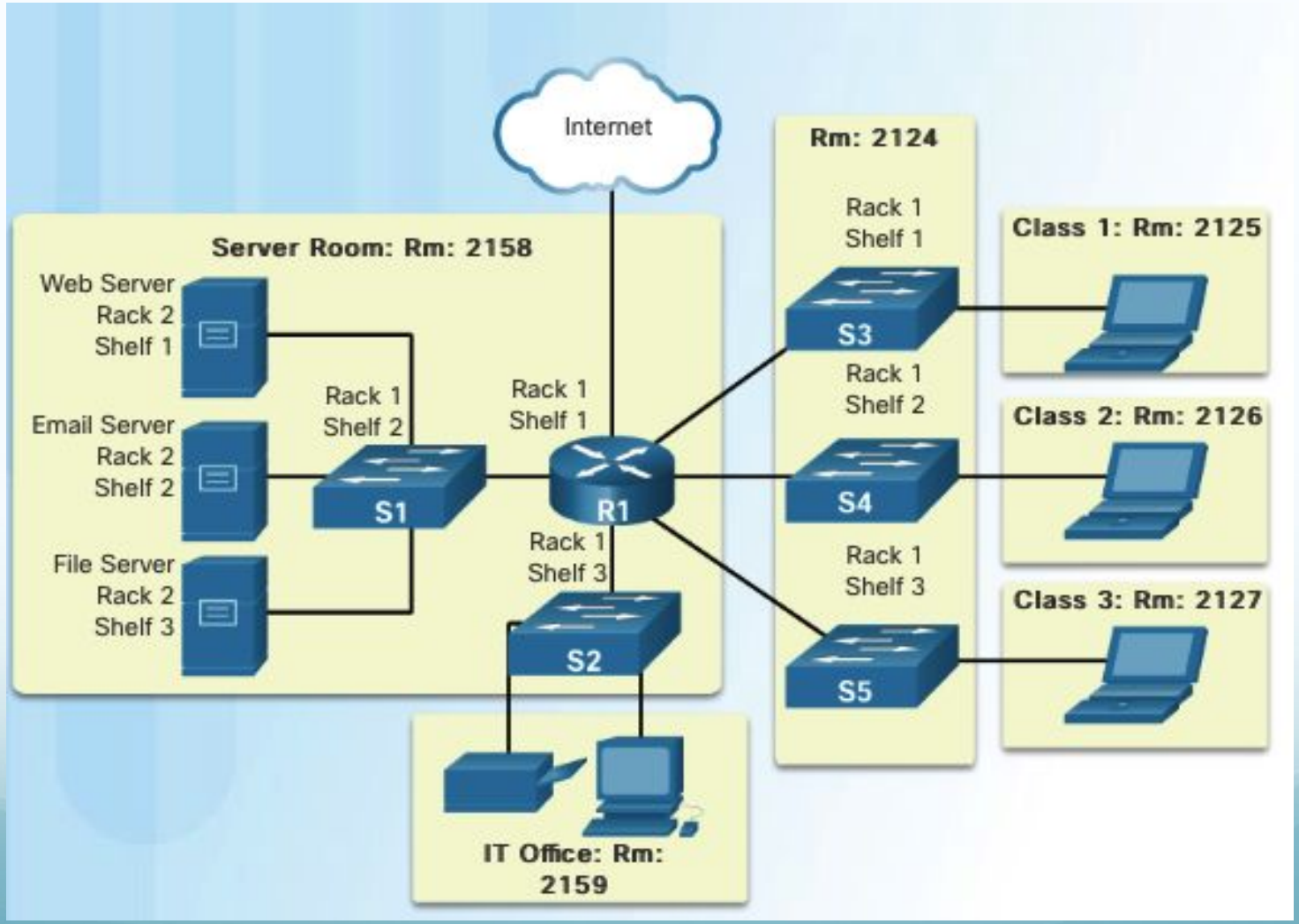

Рис. 1 Структура сети связи АО «Казахтелеком»

# Национальная Информационная Супермагистраль


Earth at Night
More information available at:
http://antwrp.gsfc.nasa.gov/apod/ap001127.html
6.64 x 9.54 inch photo quality
image available in the book:
"The Universe: 365 Days"

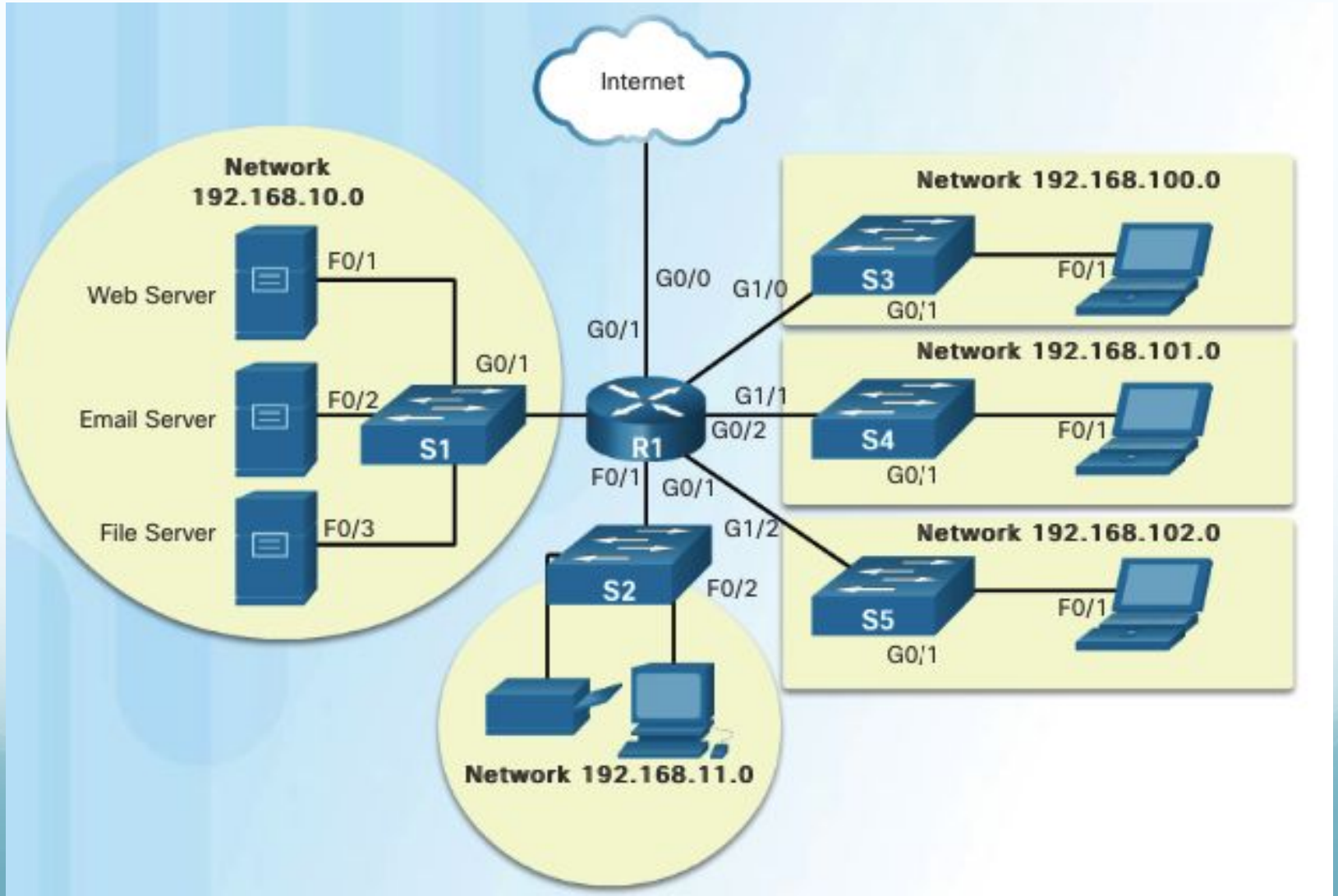
# Topology Diagrams

- Physical topology diagrams



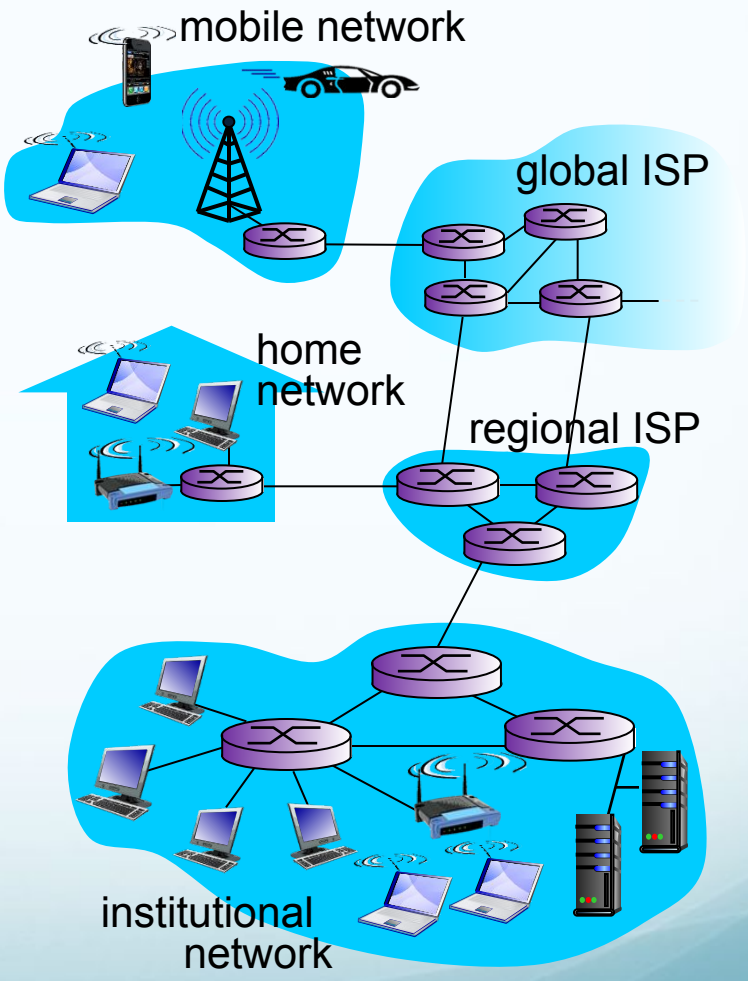
# Topology Diagrams

- Logical Topology



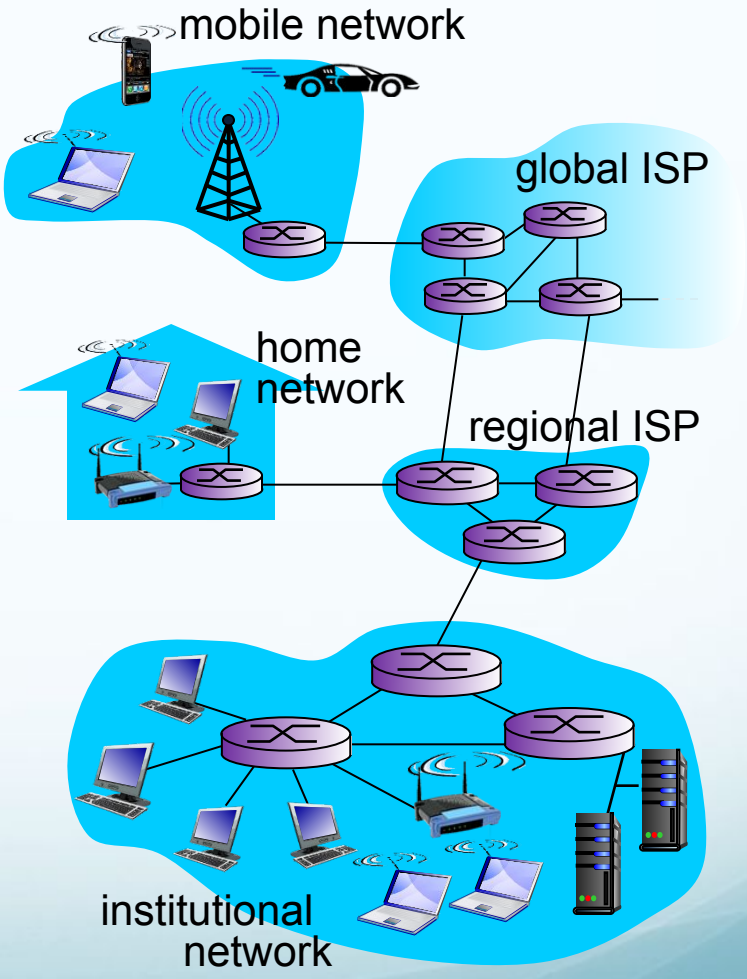
# What's the Internet: "nuts and bolts" view

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



# What's the Internet: a service view

- *Infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service

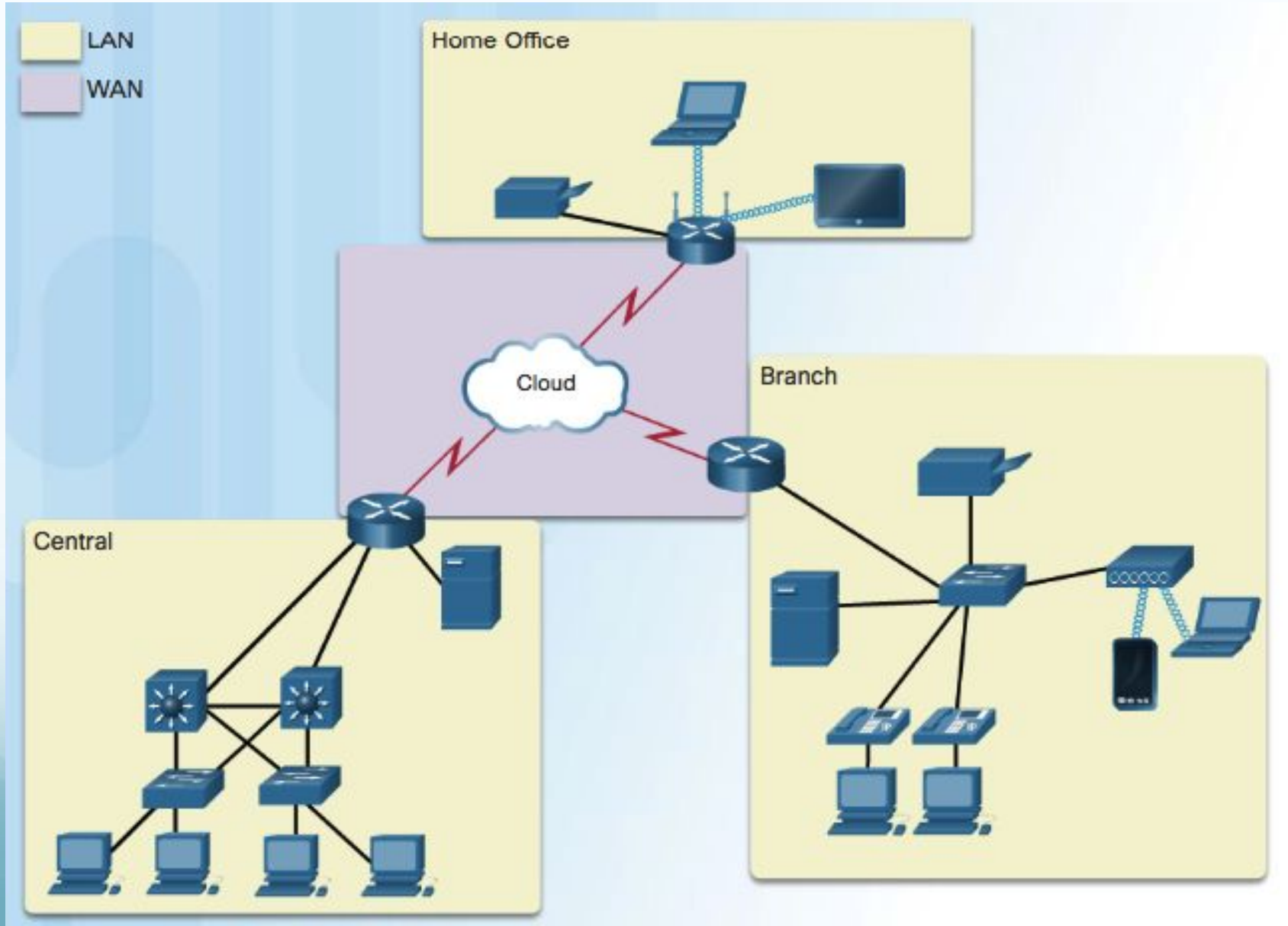


# Types of Network

Classification of interconnected processors by scale.

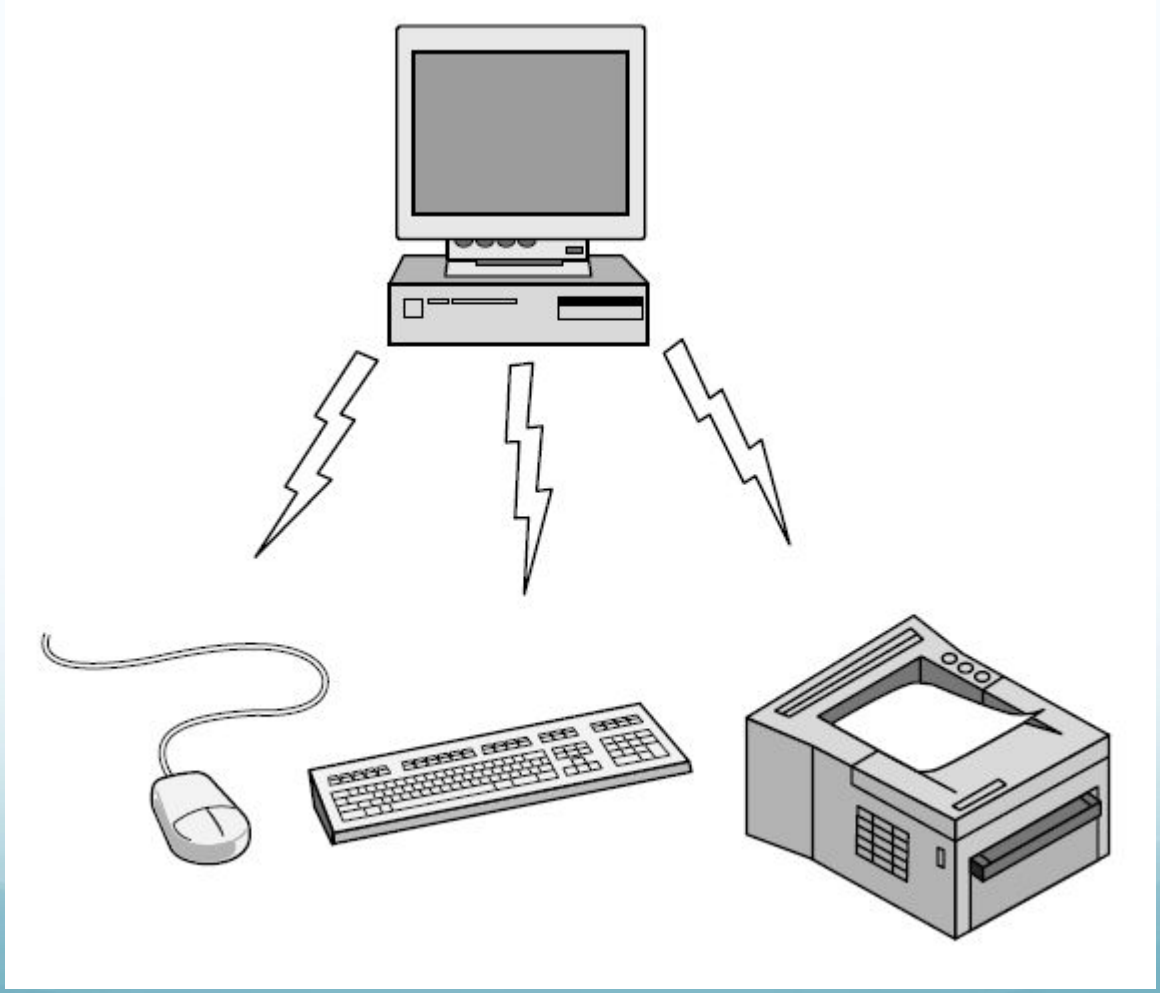
| Interprocessor distance | Processors located in same | Example |
|---|---|---|
| 1 m | Square meter | Personal area network |
| 10 m | Room | Local area network |
| 100 m | Building | |
| 1 km | Campus | |
| 10 km | City | Metropolitan area network |
| 100 km | Country | Wide area network |
| 1000 km | Continent | |
| 10,000 km | Planet | The Internet |

# Types of Networks

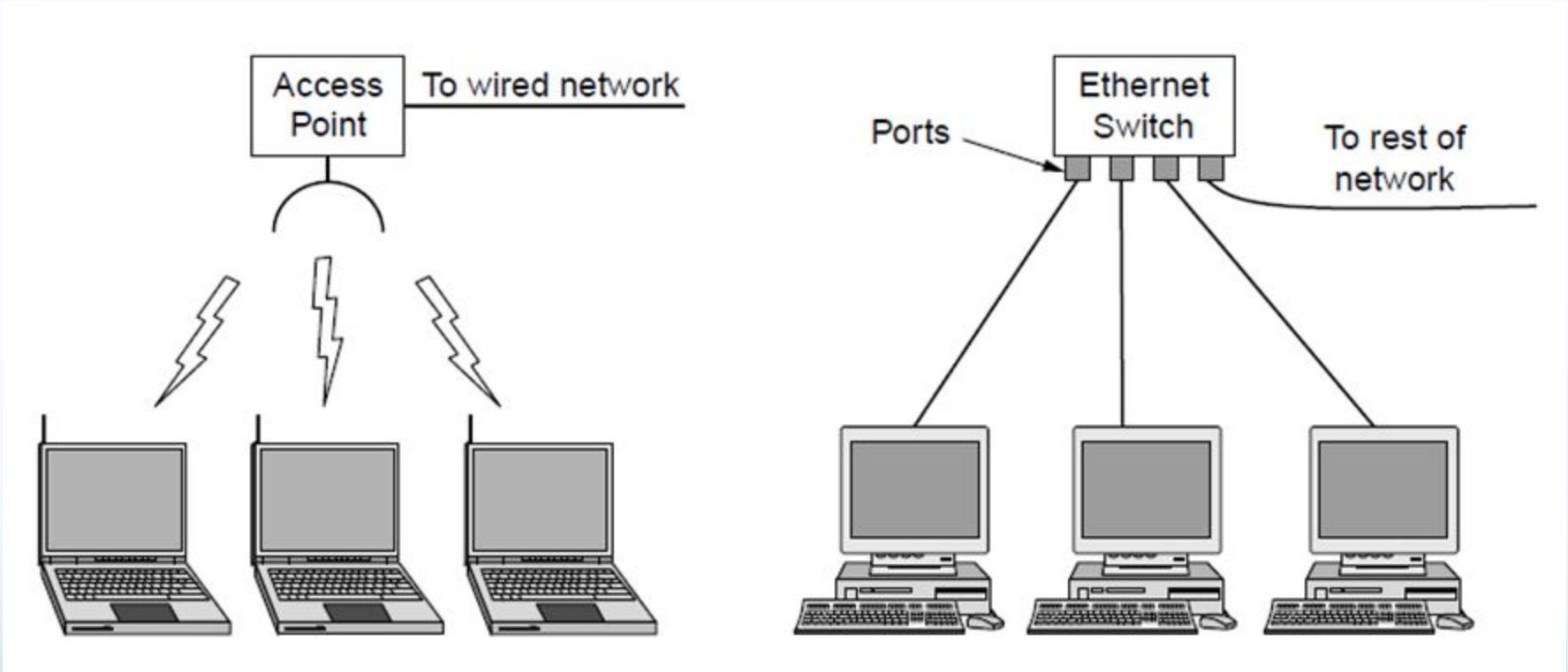


# Personal Area Network

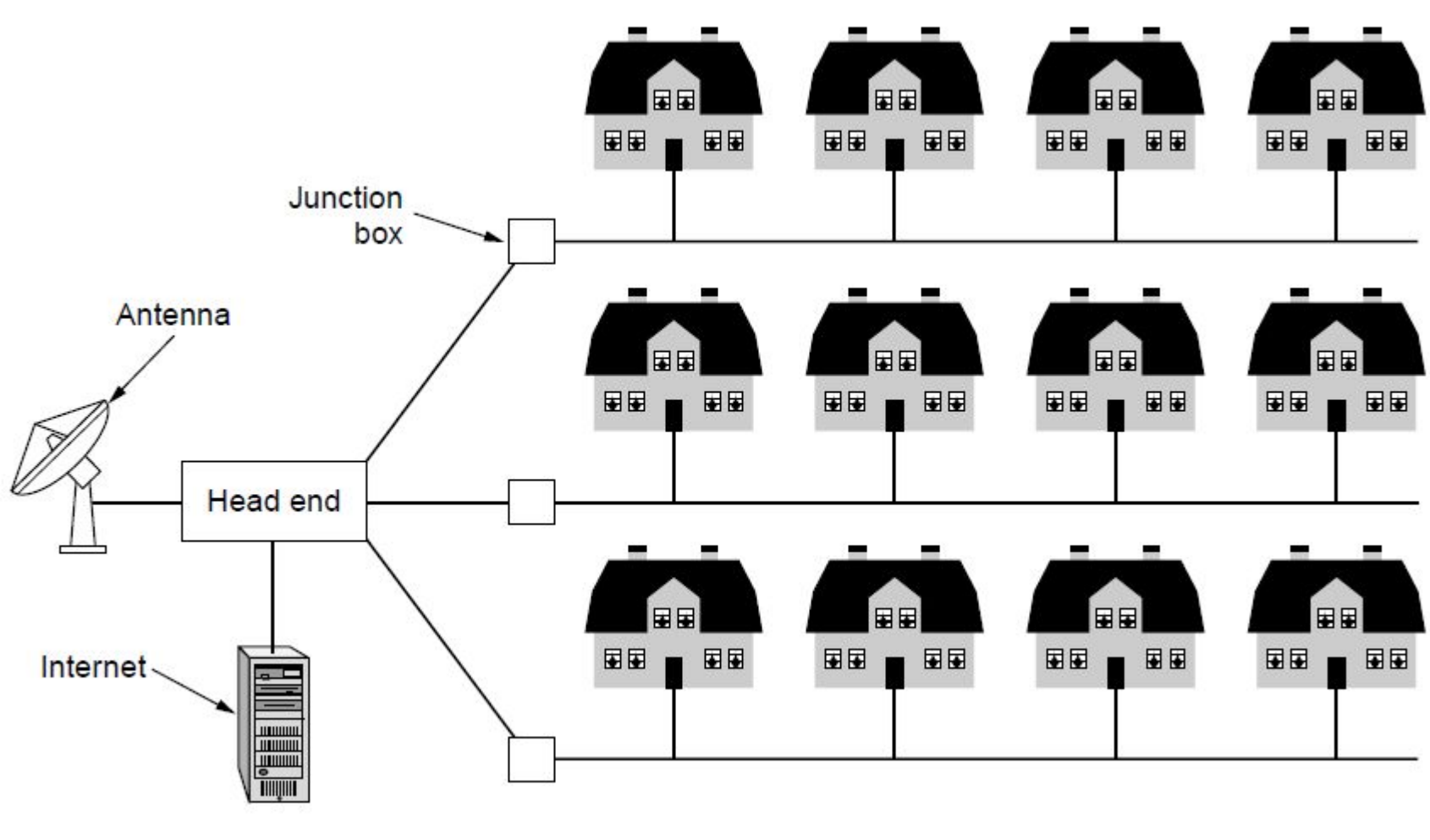
Bluetooth PAN configuration



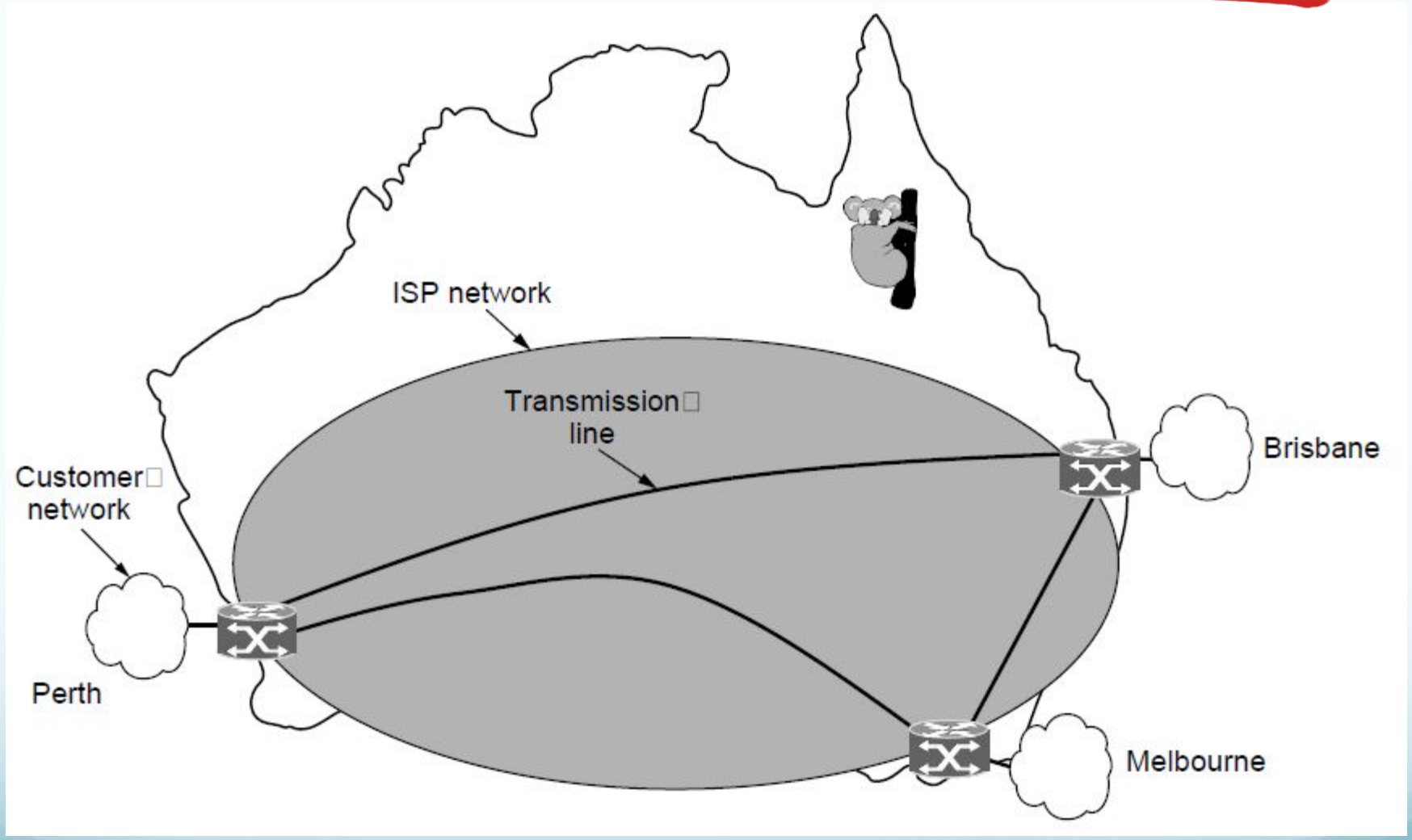
# Local Area Networks



# Metropolitan Area Networks

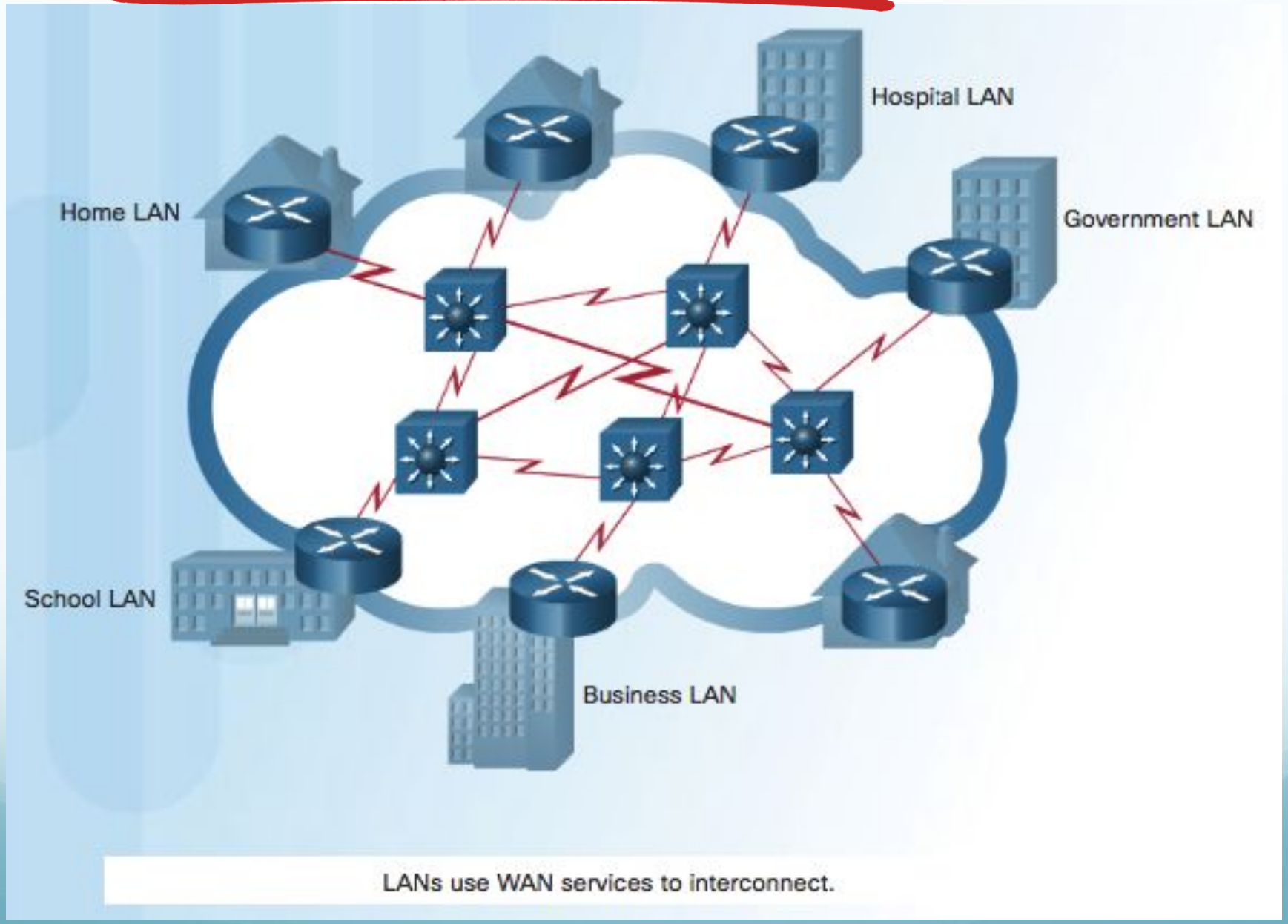


# Wide Area Networks



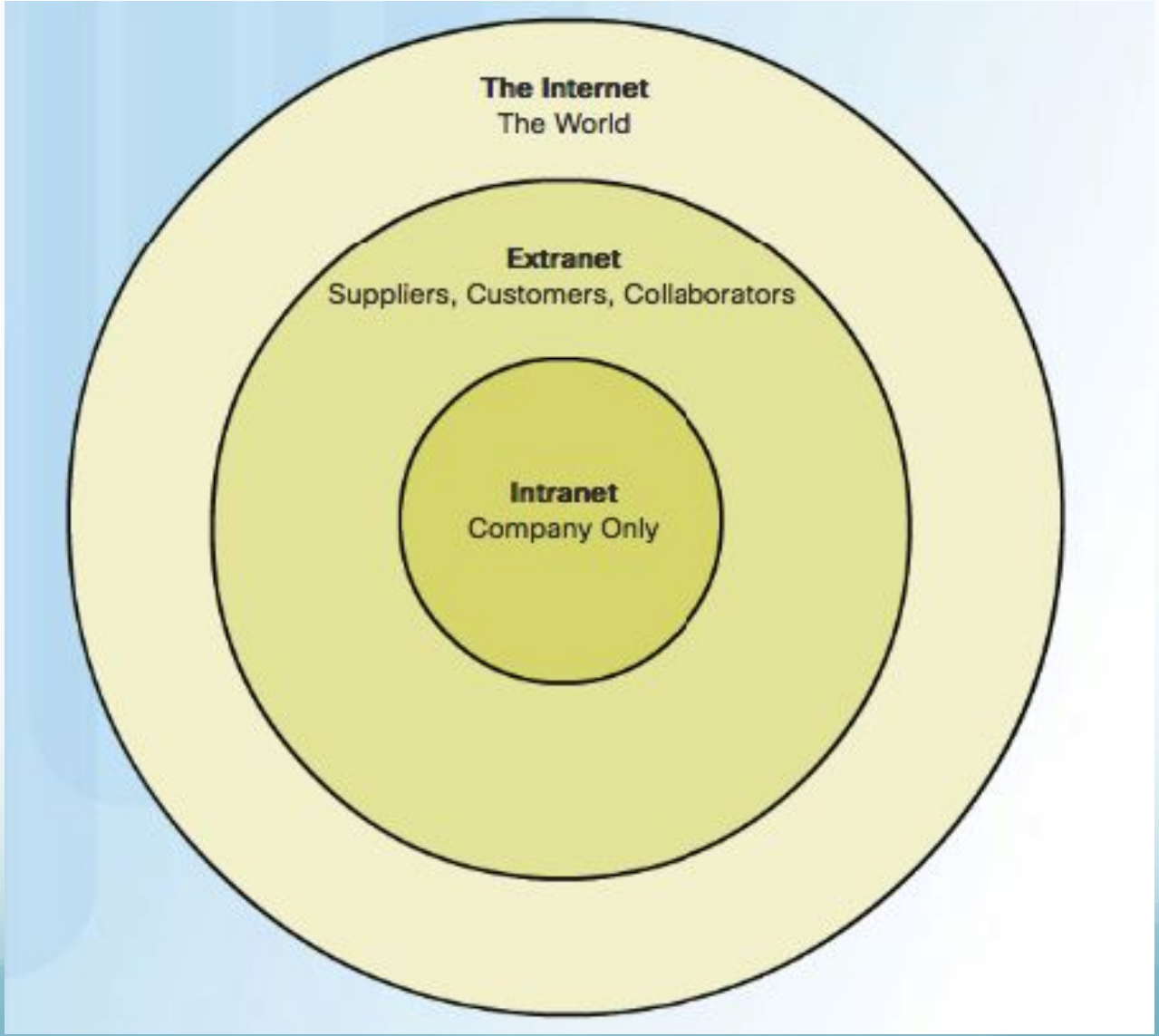

WAN using an ISP network.

# The Internet




LANs use WAN services to interconnect.

# Intranets and Extranets



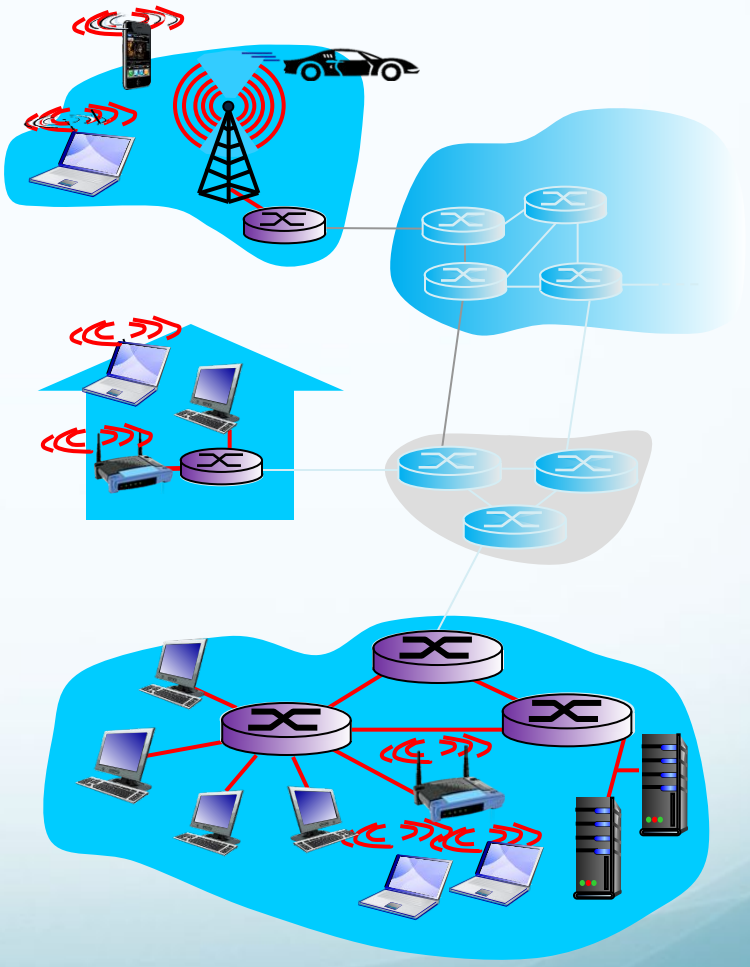
# Access networks and physical media

*Q: How to connect end systems to edge router?*

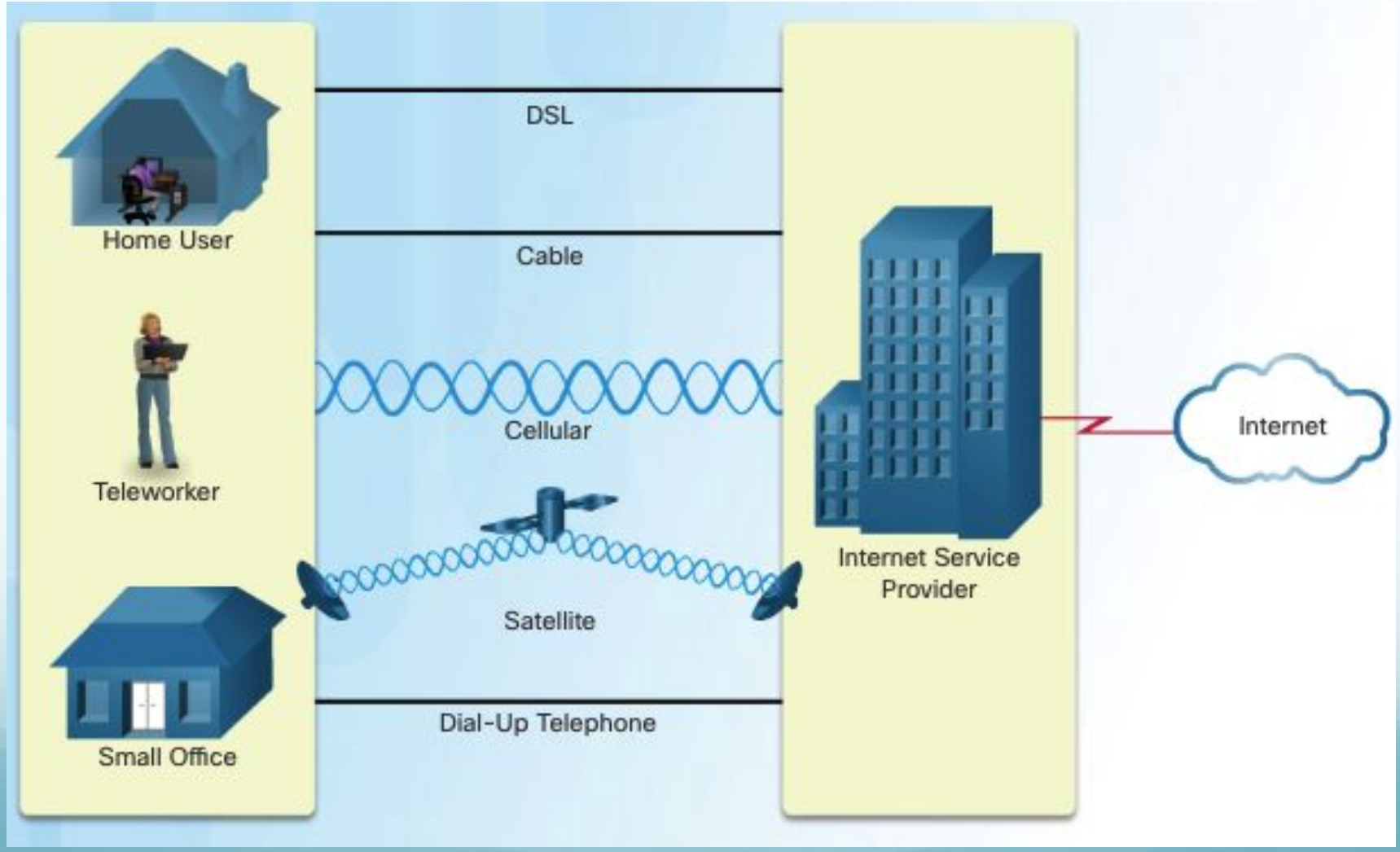
- residential access nets
- institutional access networks (school, company)
- mobile access networks

*keep in mind:*

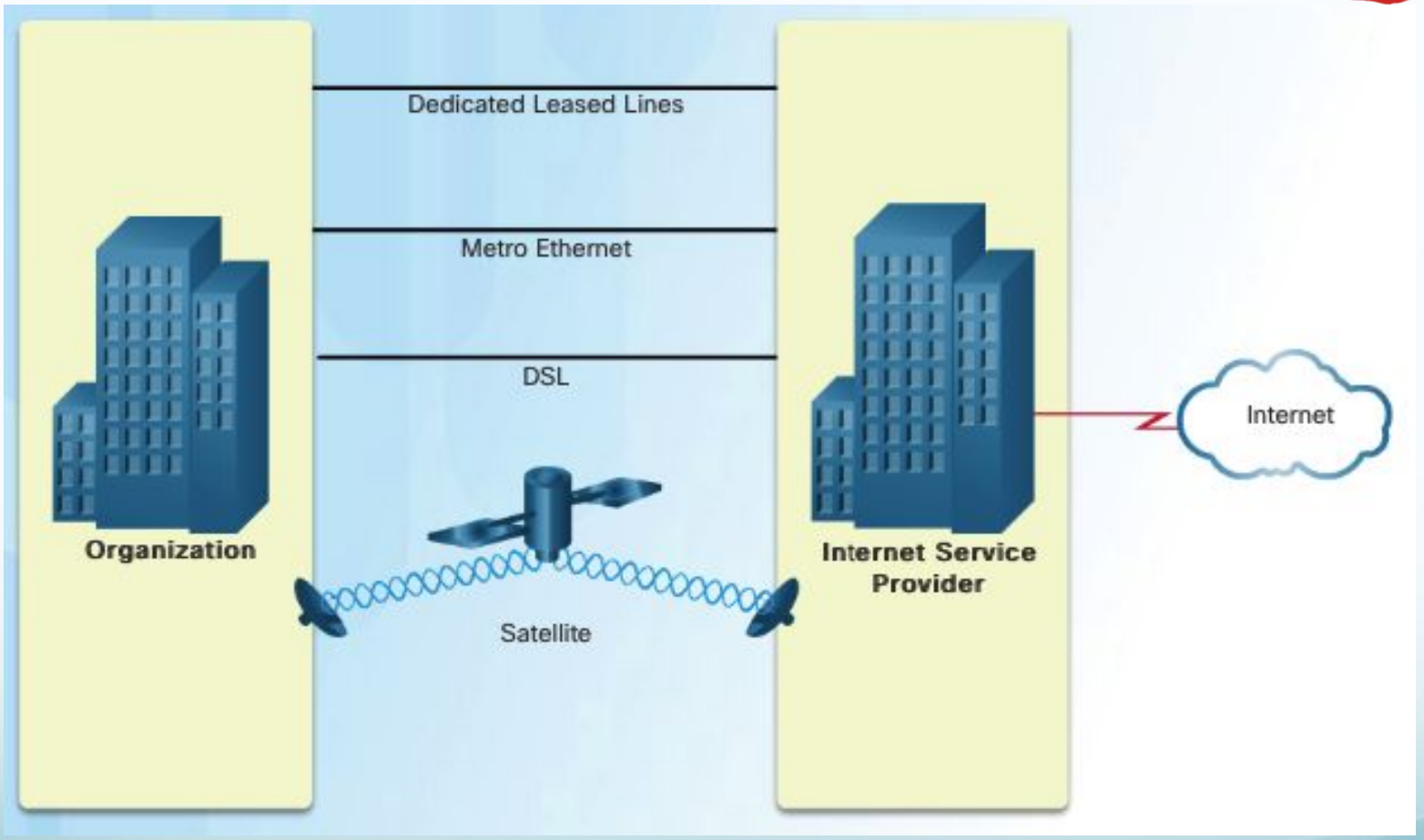
- bandwidth (bits per second) of access network?
- shared or dedicated?



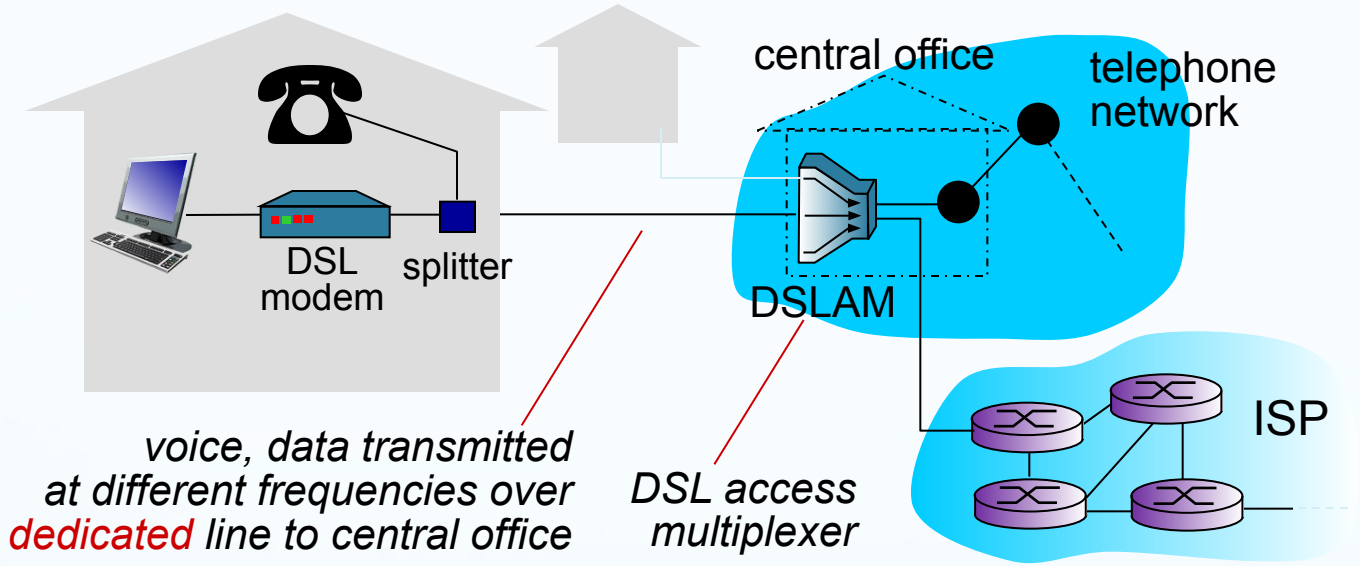
# Home and Small Office Internet Connections



# Businesses Internet Connections

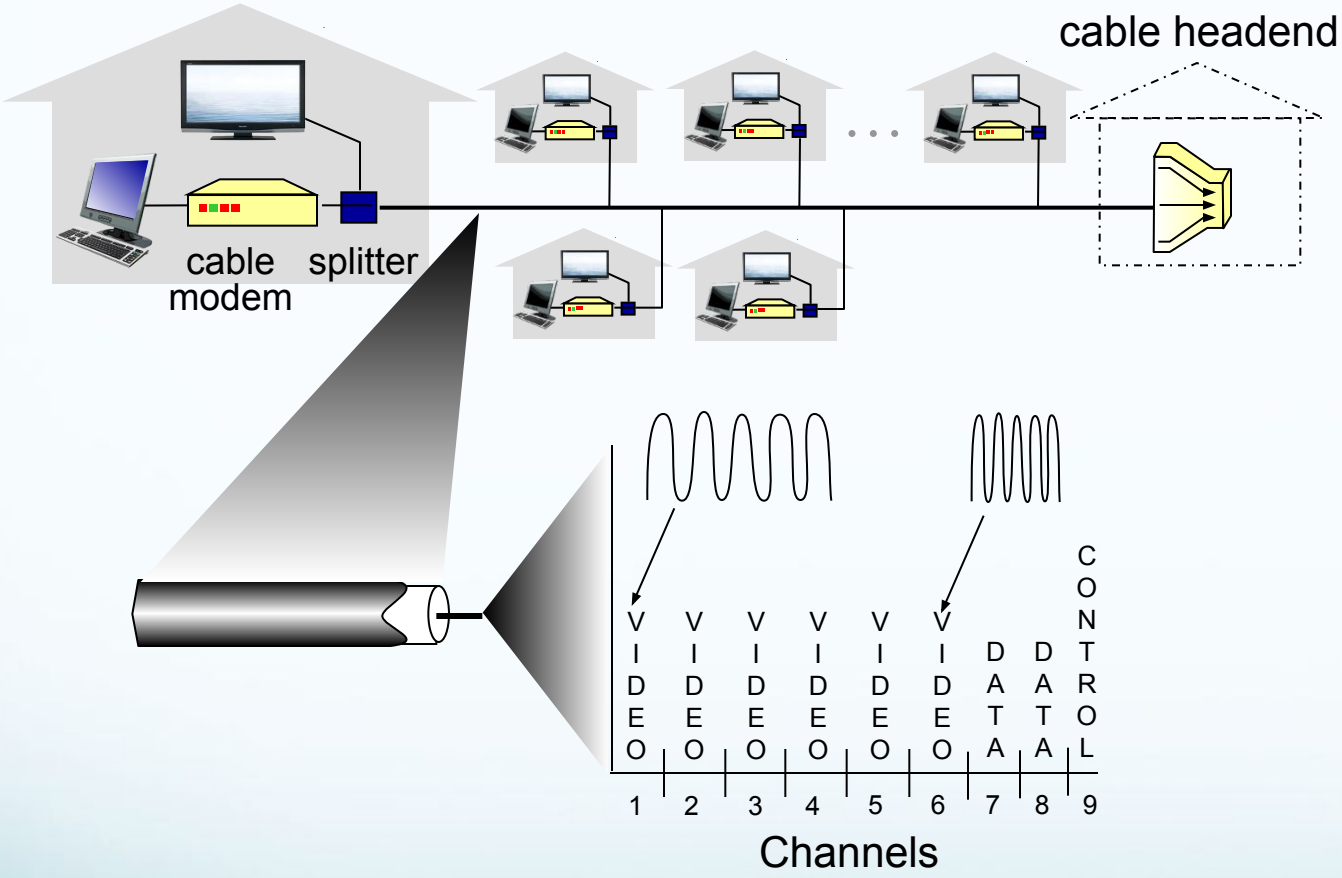


# Access net: digital subscriber line (DSL)



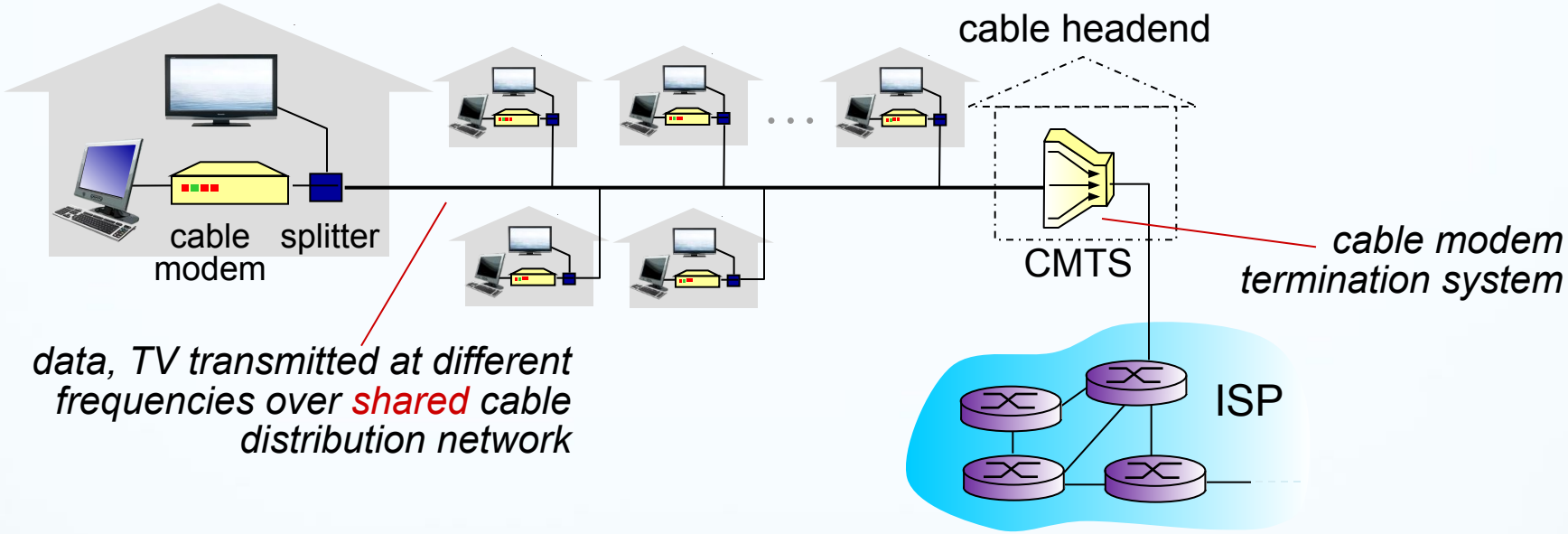

- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

# Access net: cable network



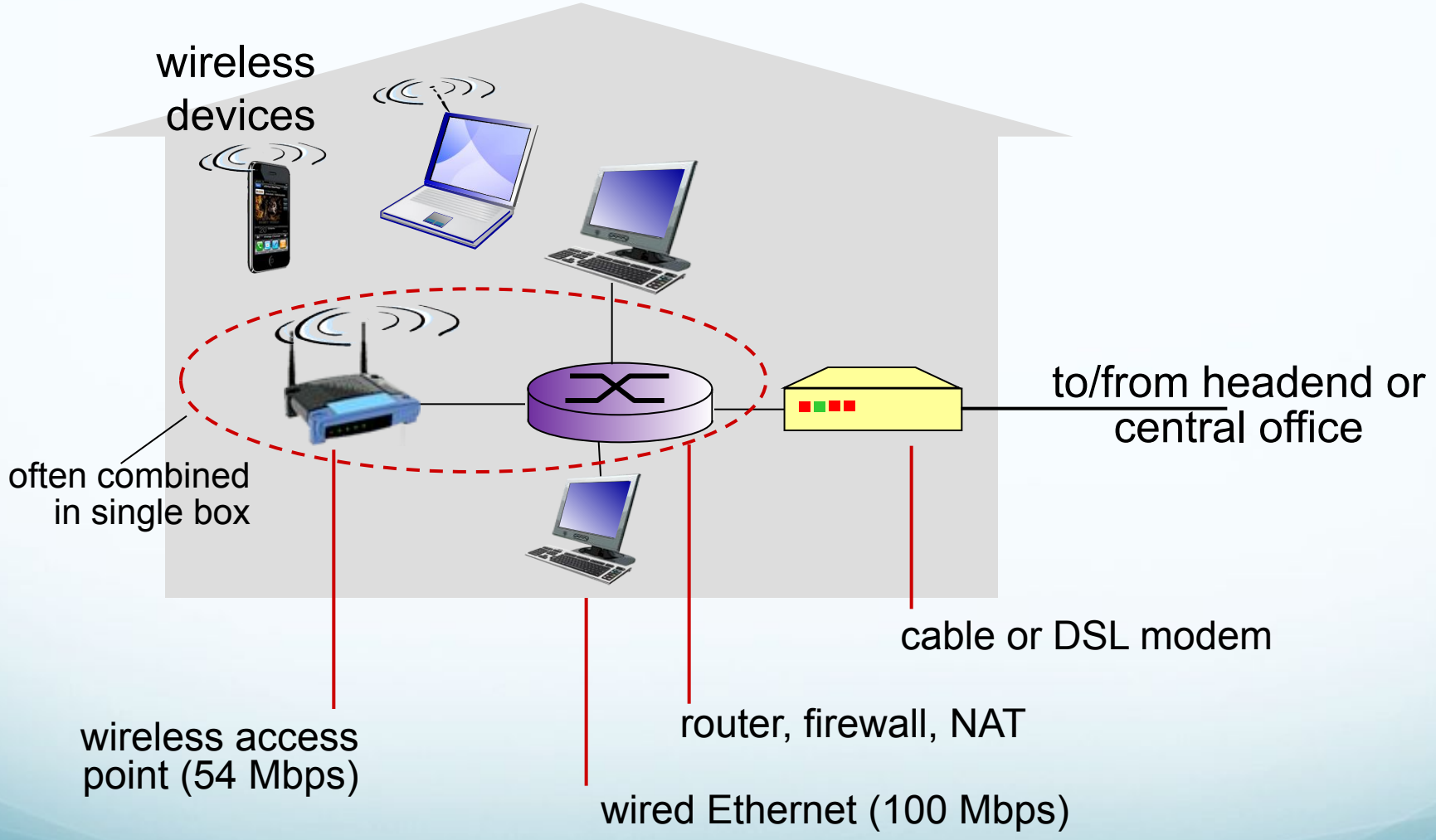

*frequency division multiplexing:* different channels transmitted
in different frequency bands

# Access net: cable network

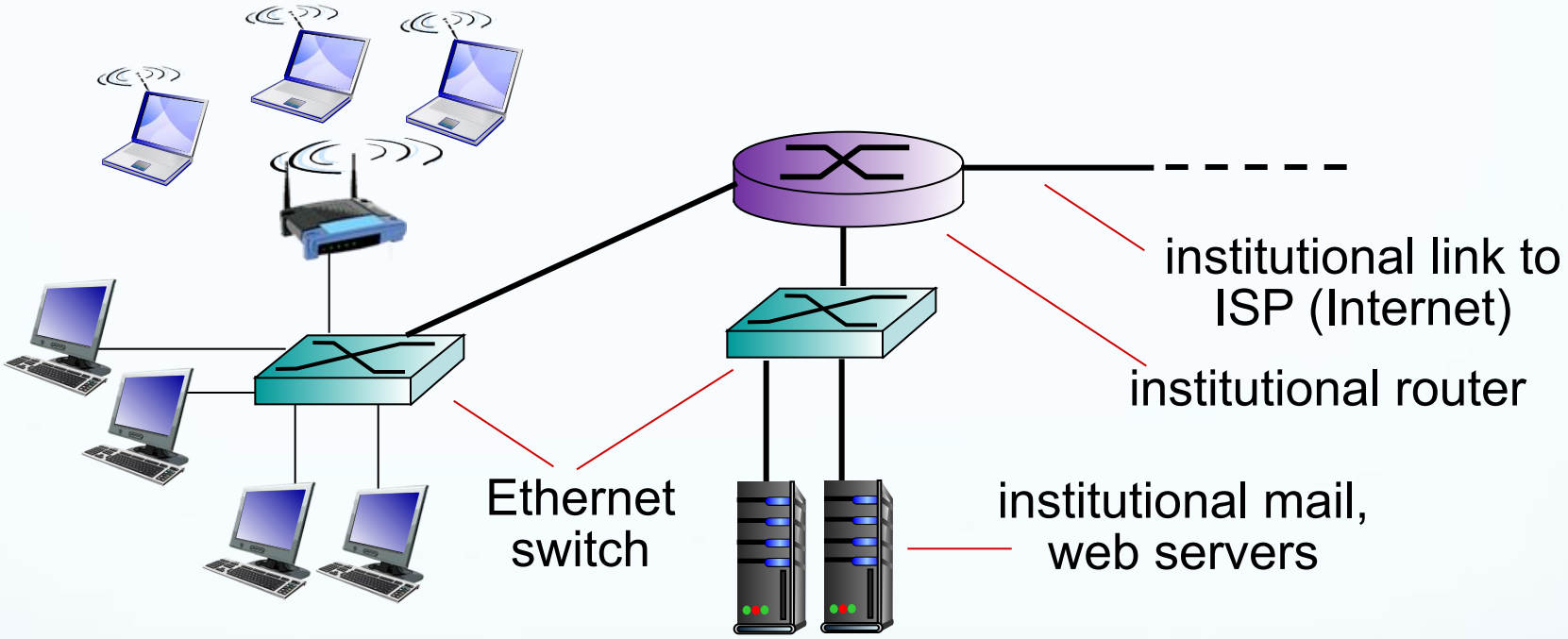



- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

# Access net: home network



# Enterprise access networks (Ethernet)



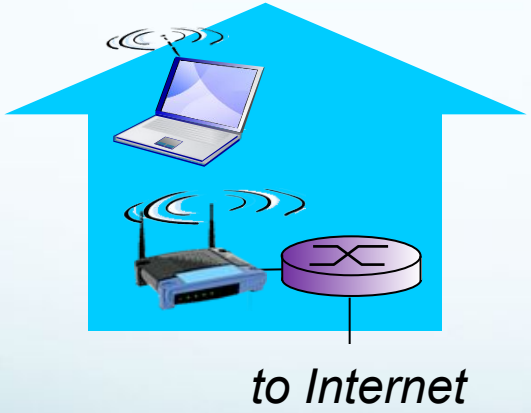

- typically used in companies, universities, etc
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

# Wireless access networks

- shared *wireless* access network connects end system to router
  - via base station aka "access point"

*wireless LANs:*

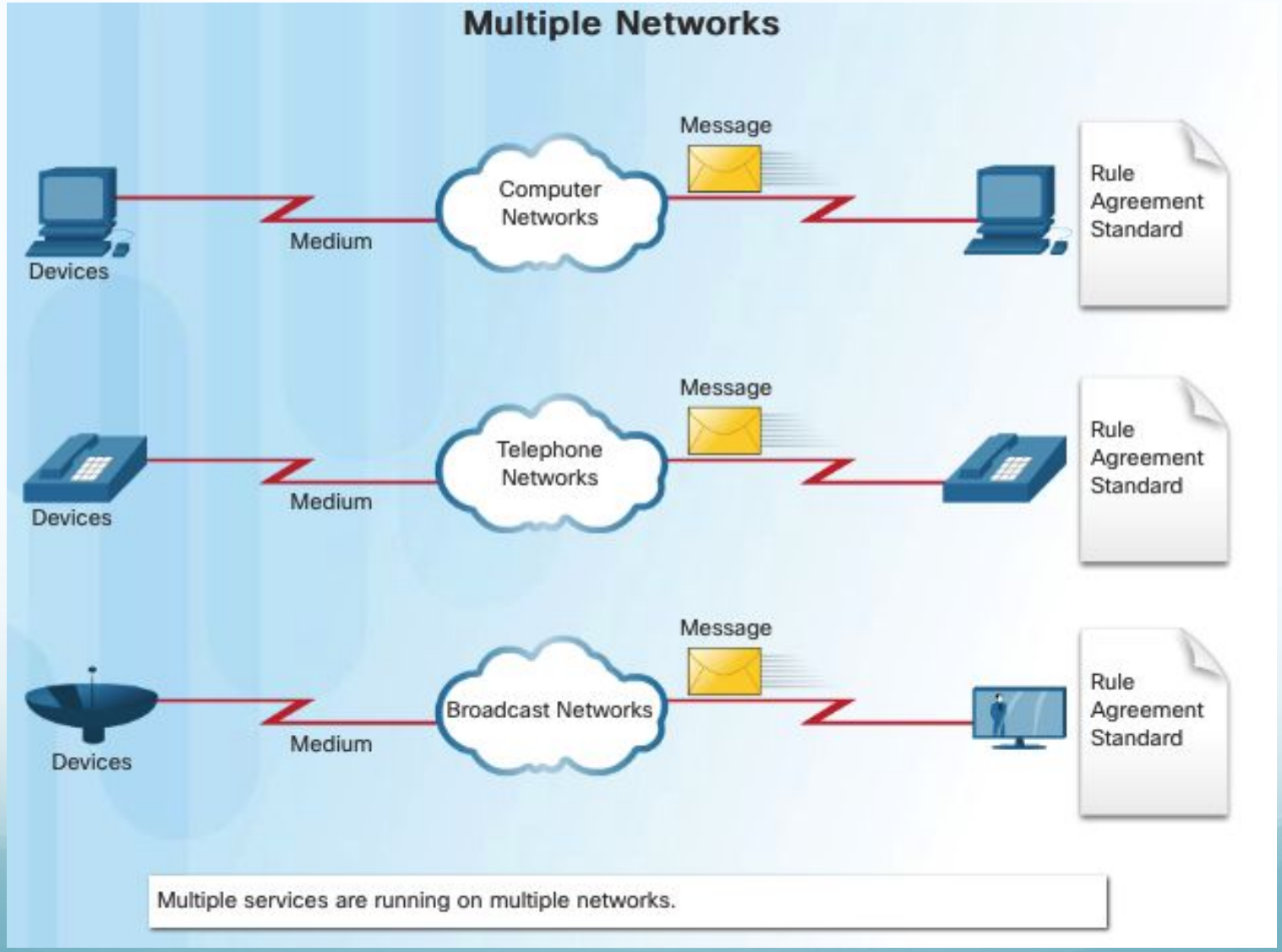
- within building (100 ft)
- 802.11b/g (WiFi): 11, 54 Mbps transmission rate



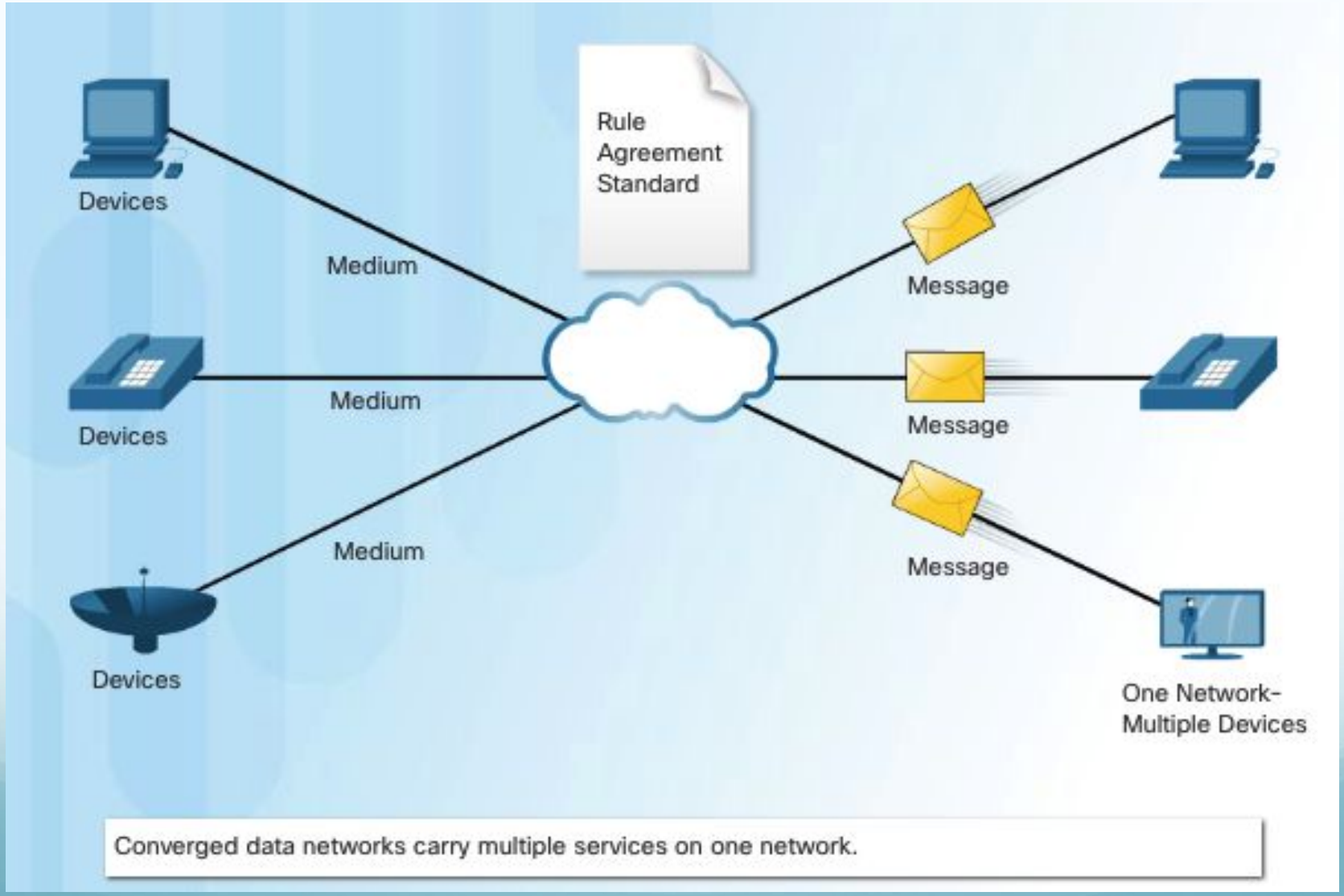

wide-area wireless access

- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE

# Traditional Separate Networks

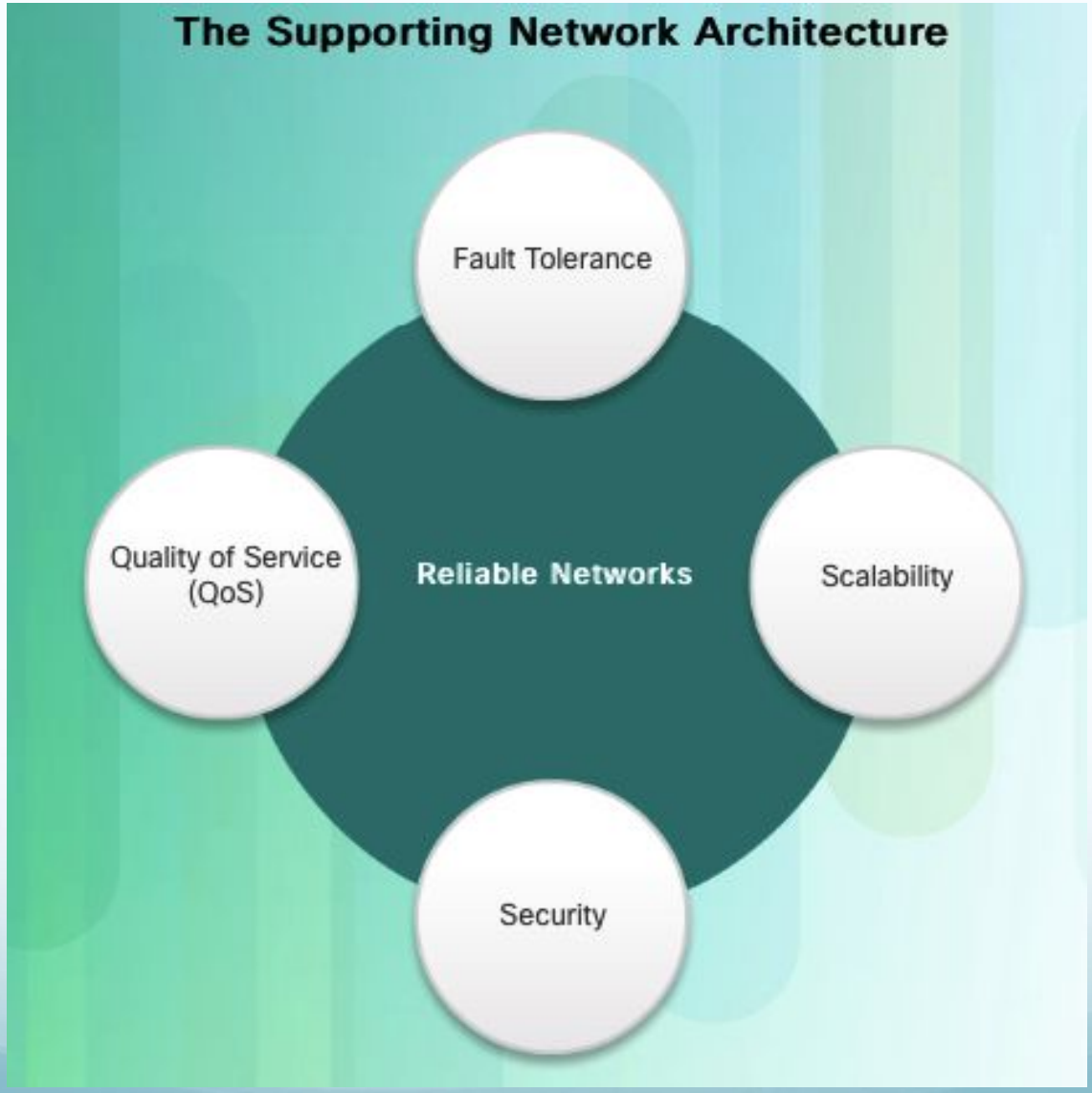


# The Converging Network

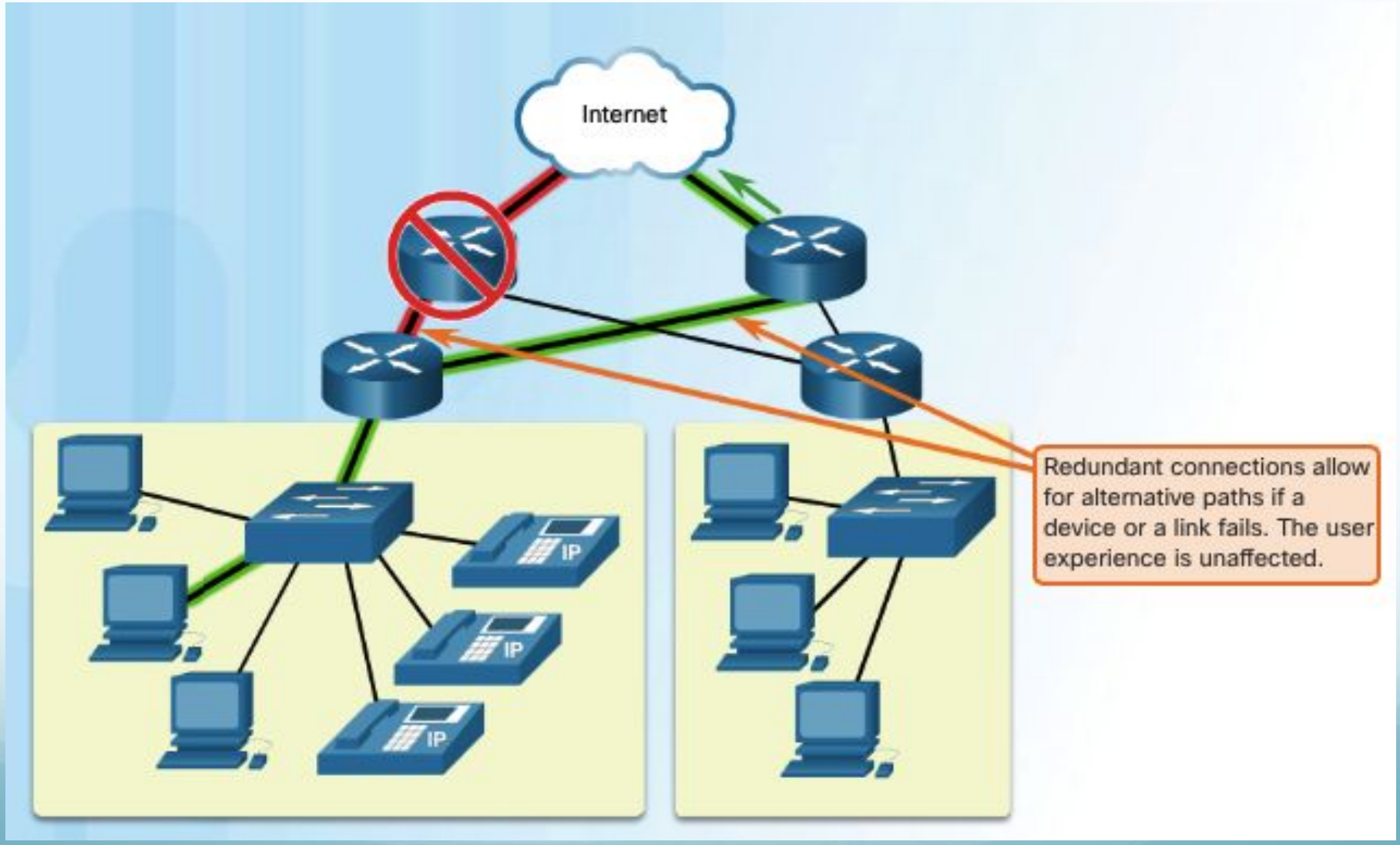



Converged data networks carry multiple services on one network.

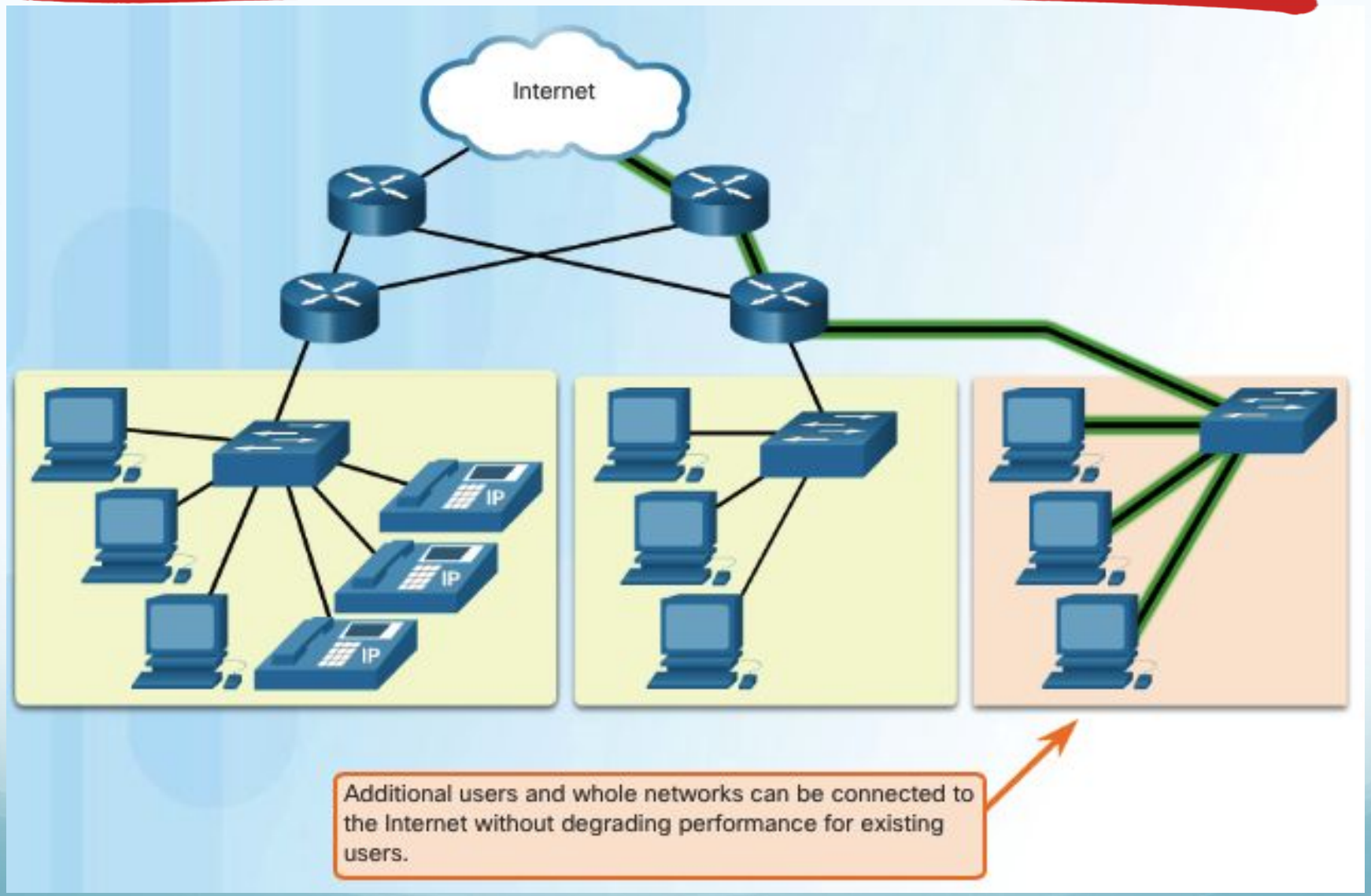
# Network Architecture



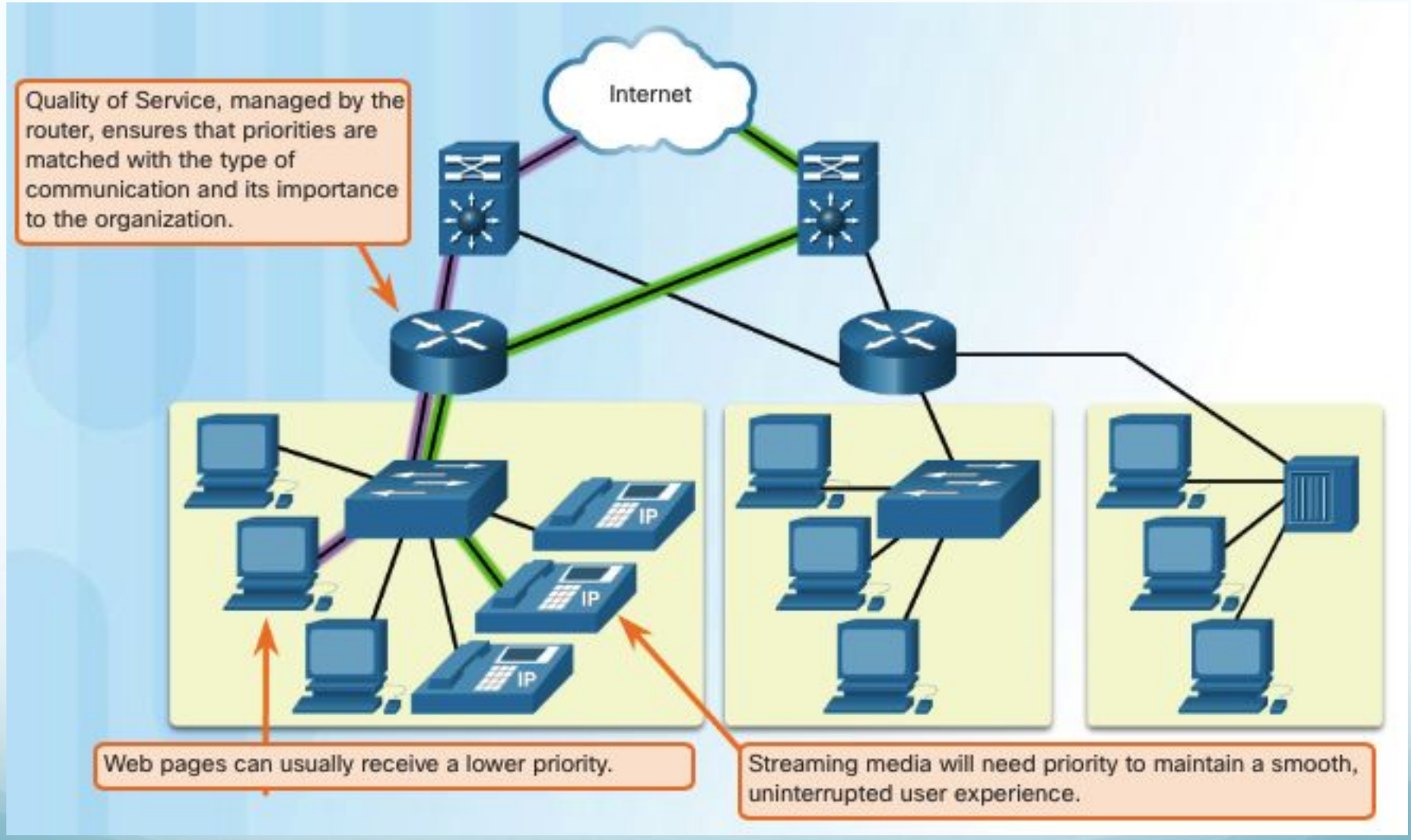
# Fault Tolerance



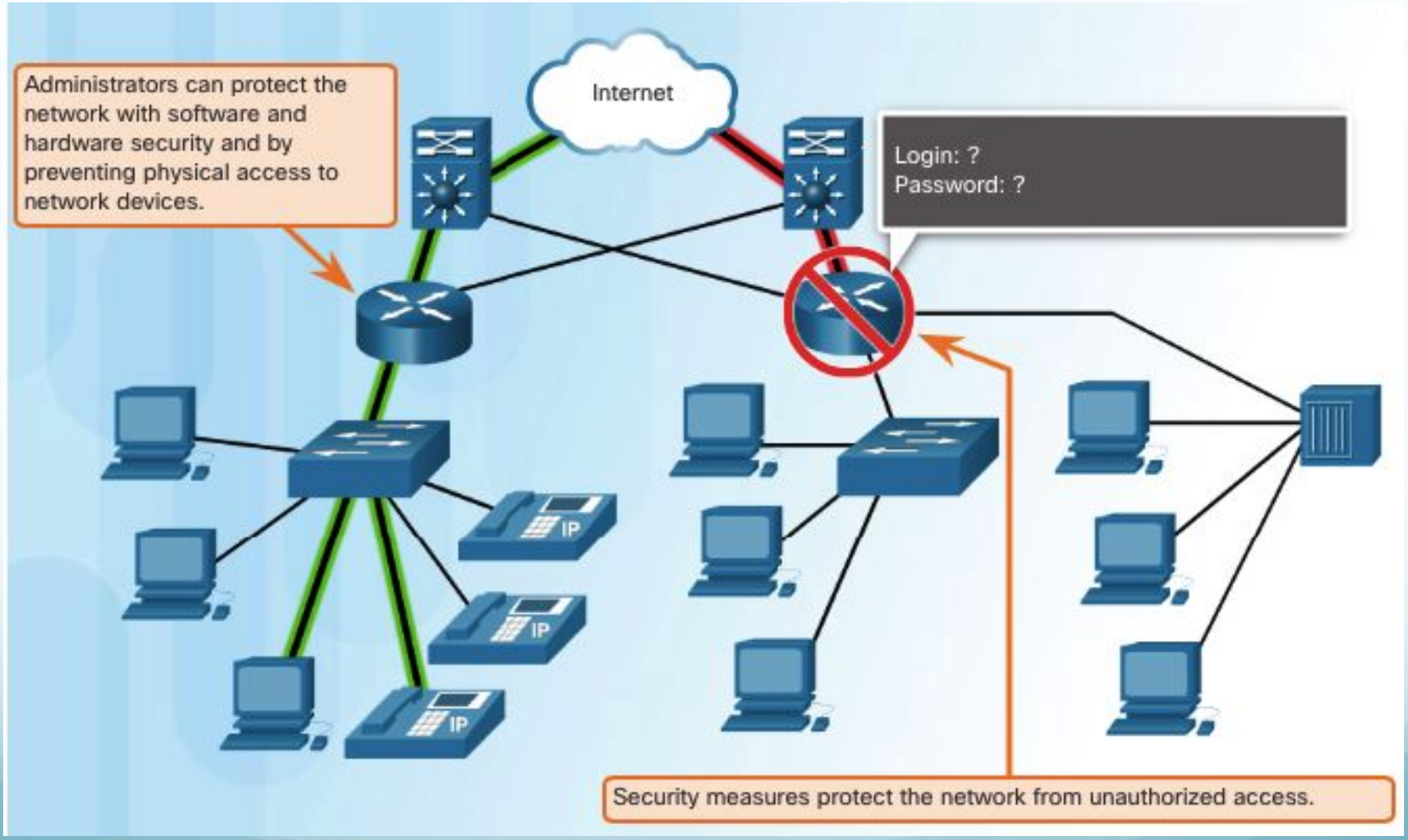
# Scalability



# QoS


Quality of Service, managed by the router, ensures that priorities are matched with the type of communication and its importance to the organization.
Internet
IP
IP
IP
Web pages can usually receive a lower priority.
Streaming media will need priority to maintain a smooth, uninterrupted user experience.

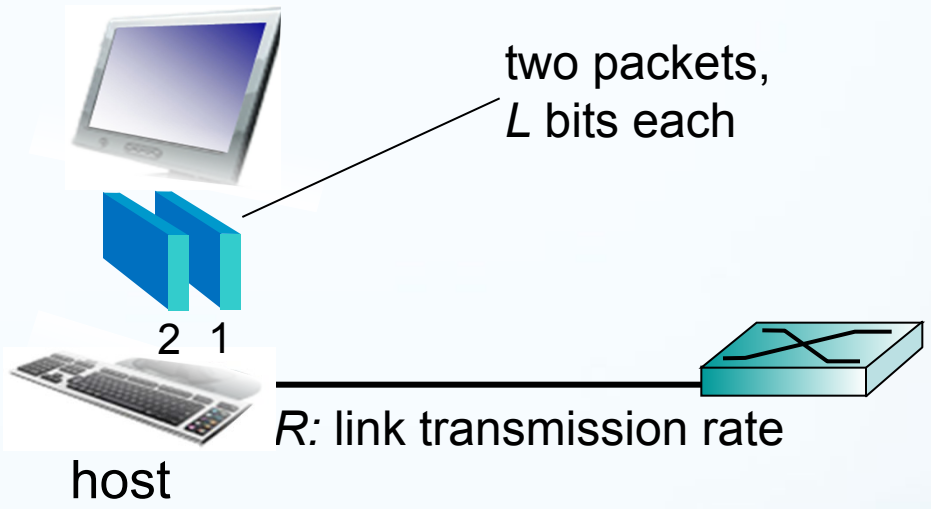
# Security


Administrators can protect the network with software and hardware security and by preventing physical access to network devices.
Internet
Login: ?
Password: ?
IP
IP
IP
Security measures protect the network from unauthorized access.

# Host: sends *packets* of data

host sending function:

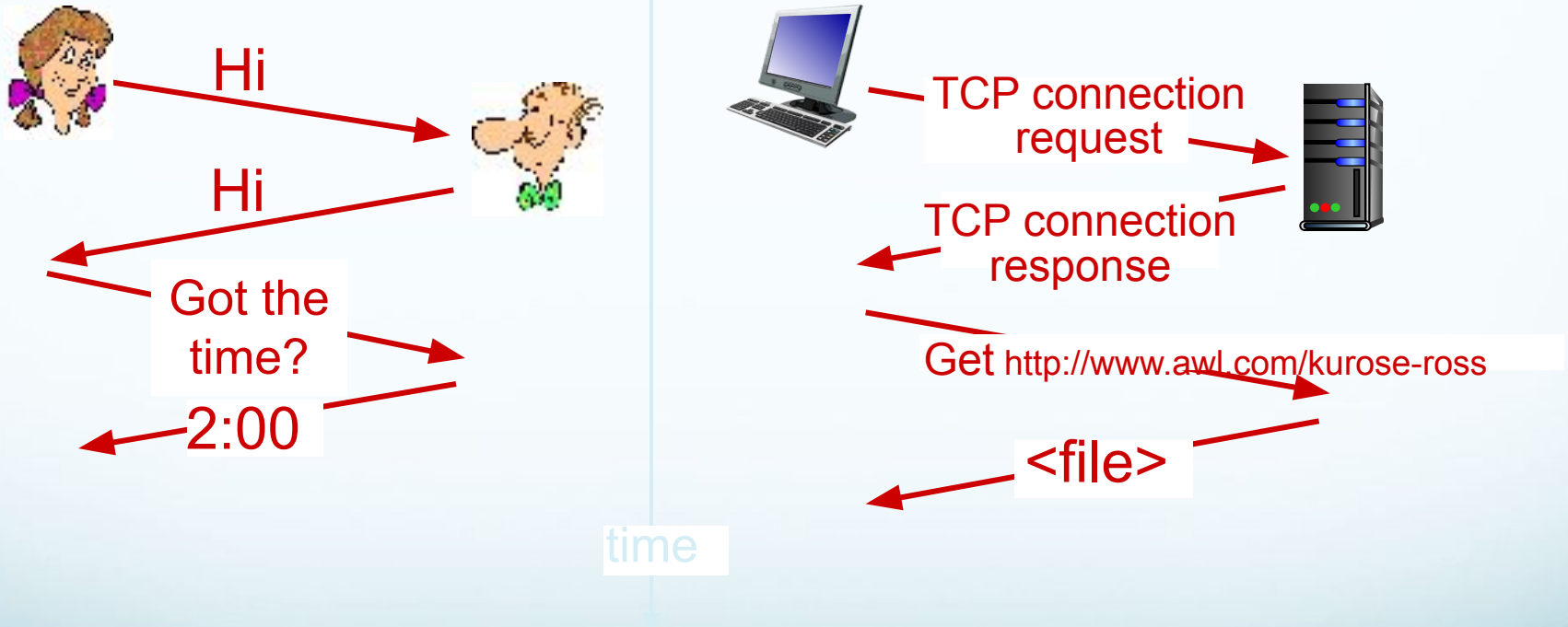
- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka link *capacity, aka link bandwidth*




$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

# What's a protocol?

a human protocol and a computer network protocol:



# What's a protocol?

*human protocols:*

- "what's the time?"
- "I have a question"
- introductions

… specific msgs sent

… specific actions taken when msgs received, or other events

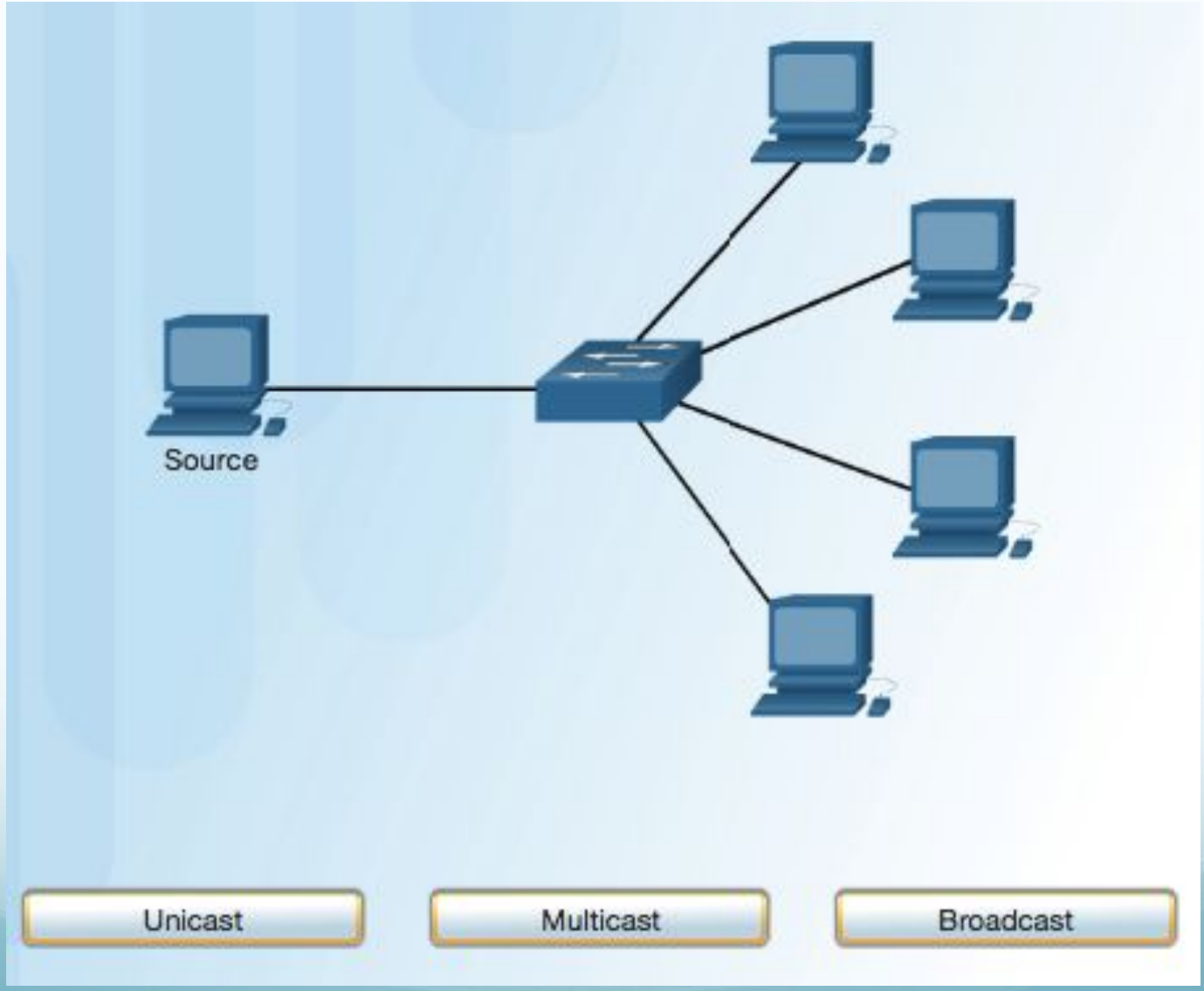
*network protocols:*

- machines rather than humans
- all communication activity in Internet governed by protocols

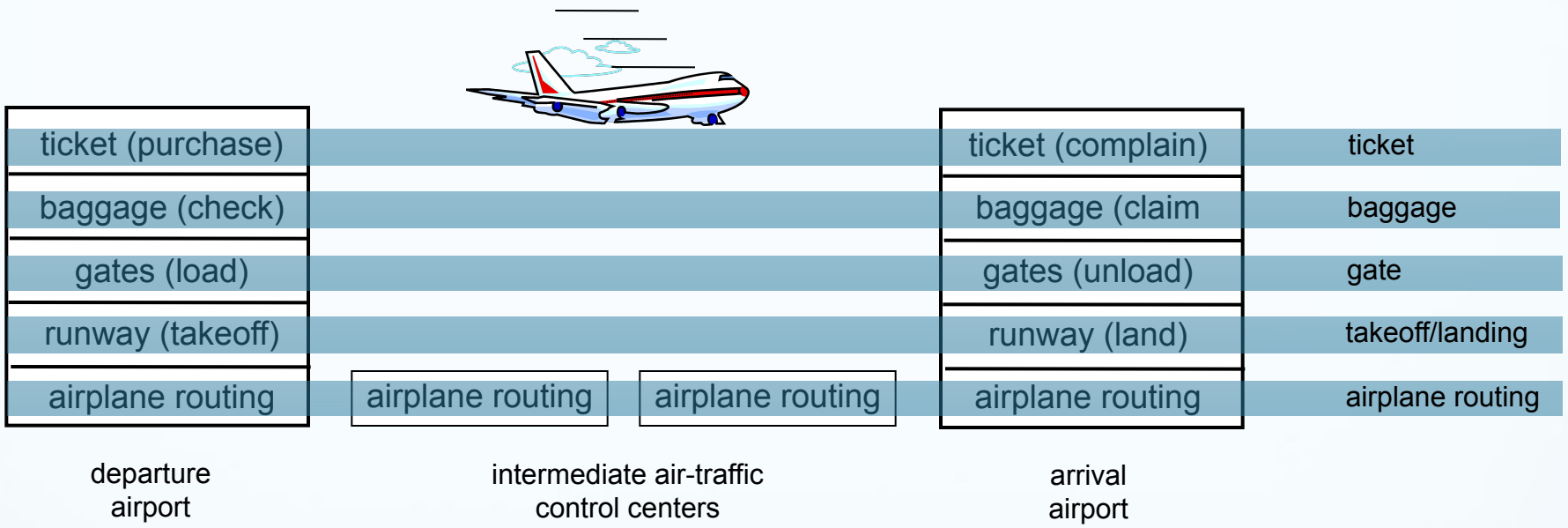
*protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt*

# Rule Establishment

# Message Delivery Options



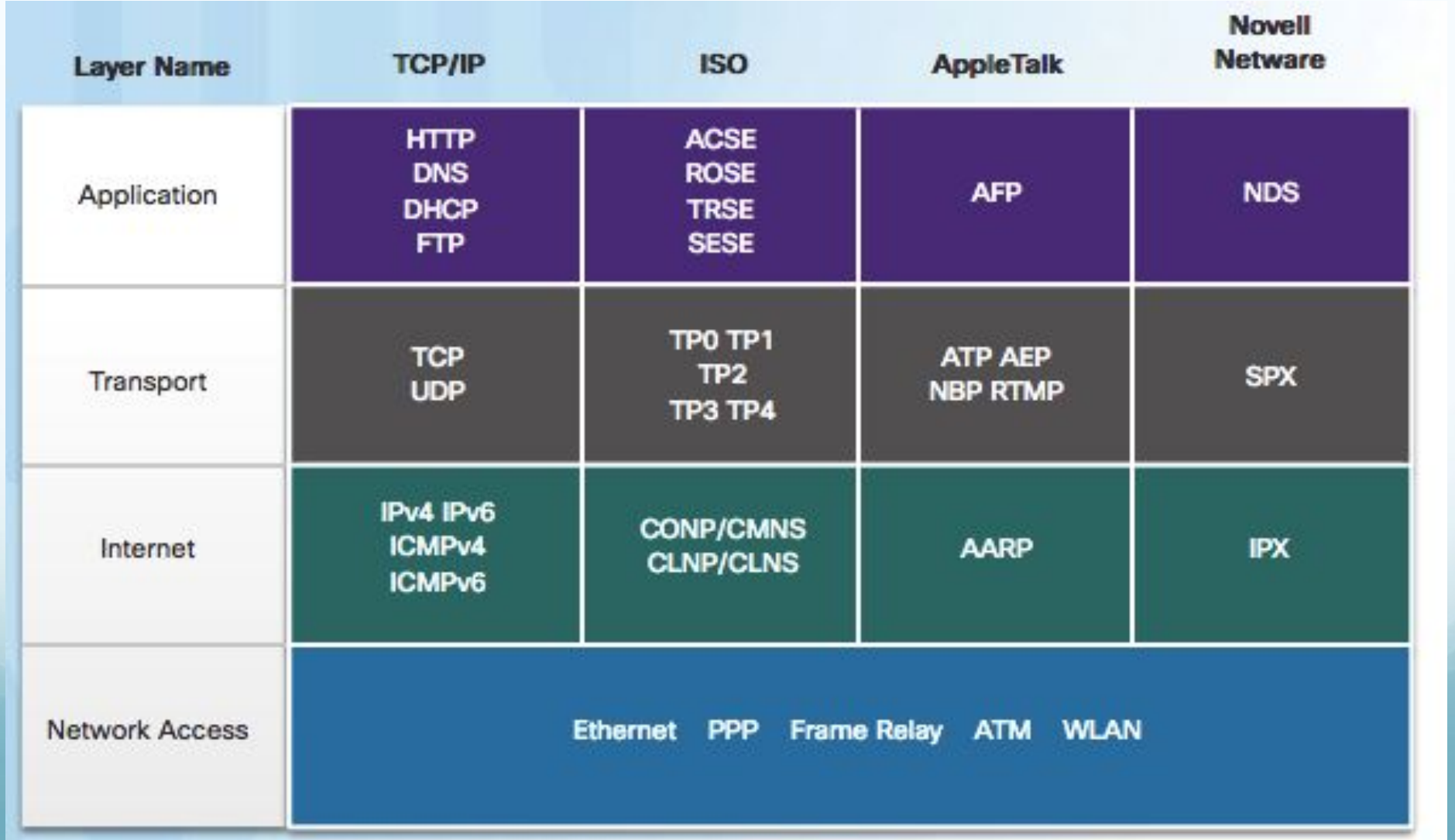
# Layering of airline functionality




*layers:* each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

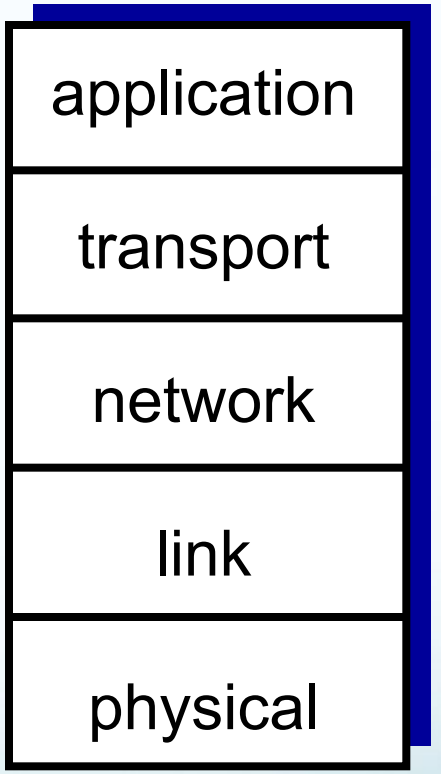
# Protocol Suites and Industry Standards



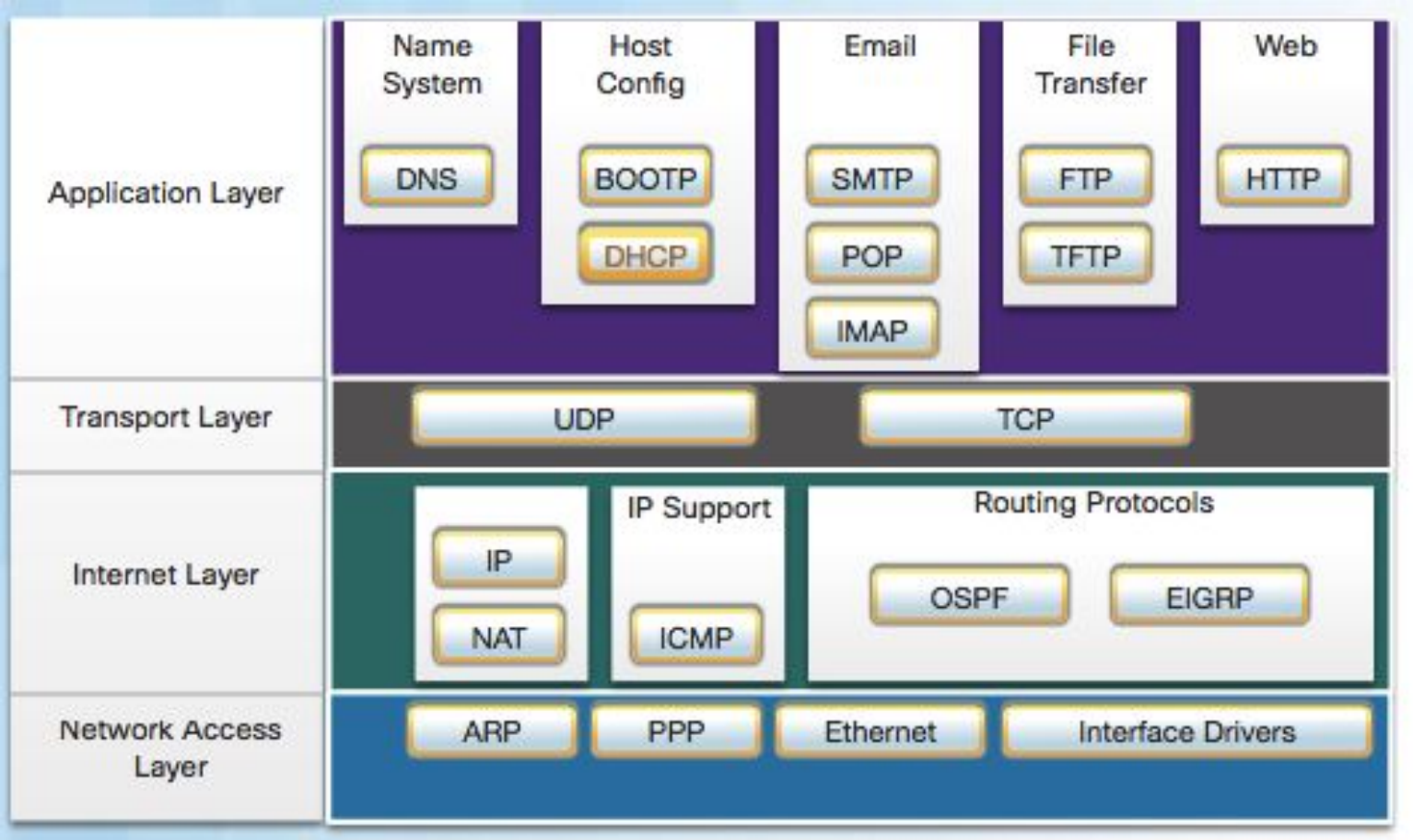
| Layer Name | TCP/IP | ISO | AppleTalk | Novell Netware |
|---|---|---|---|---|
| Application | HTTP<br>DNS<br>DHCP<br>FTP | ACSE<br>ROSE<br>TRSE<br>SESE | AFP | NDS |
| Transport | TCP<br>UDP | TP0 TP1<br>TP2<br>TP3 TP4 | ATP AEP<br>NBP RTMP | SPX |
| Internet | IPv4 IPv6<br>ICMPv4<br>ICMPv6 | CONP/CMNS<br>CLNP/CLNS | AARP | IPX |
| Network Access | Ethernet PPP Frame Relay ATM WLAN | | | |

# Internet protocol stack

- *application:* supporting network applications
  - FTP, SMTP, HTTP
- *transport:* process-process data transfer
  - TCP, UDP
- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.111 (WiFi), PPP
- *physical:* bits "on the wire"

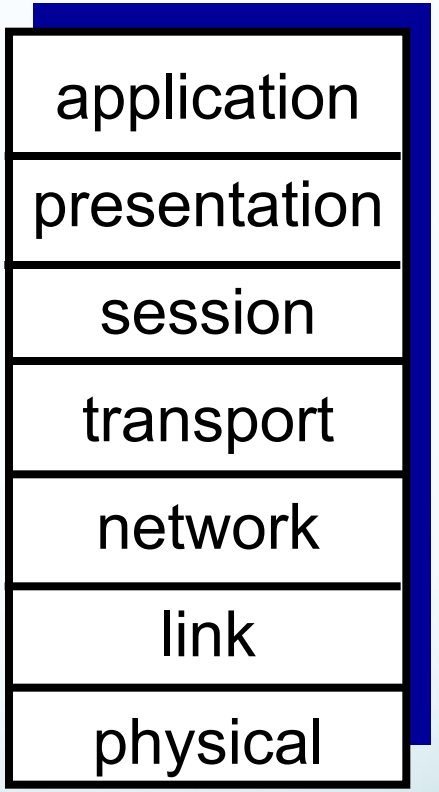


# TCP/IP Protocol Suite

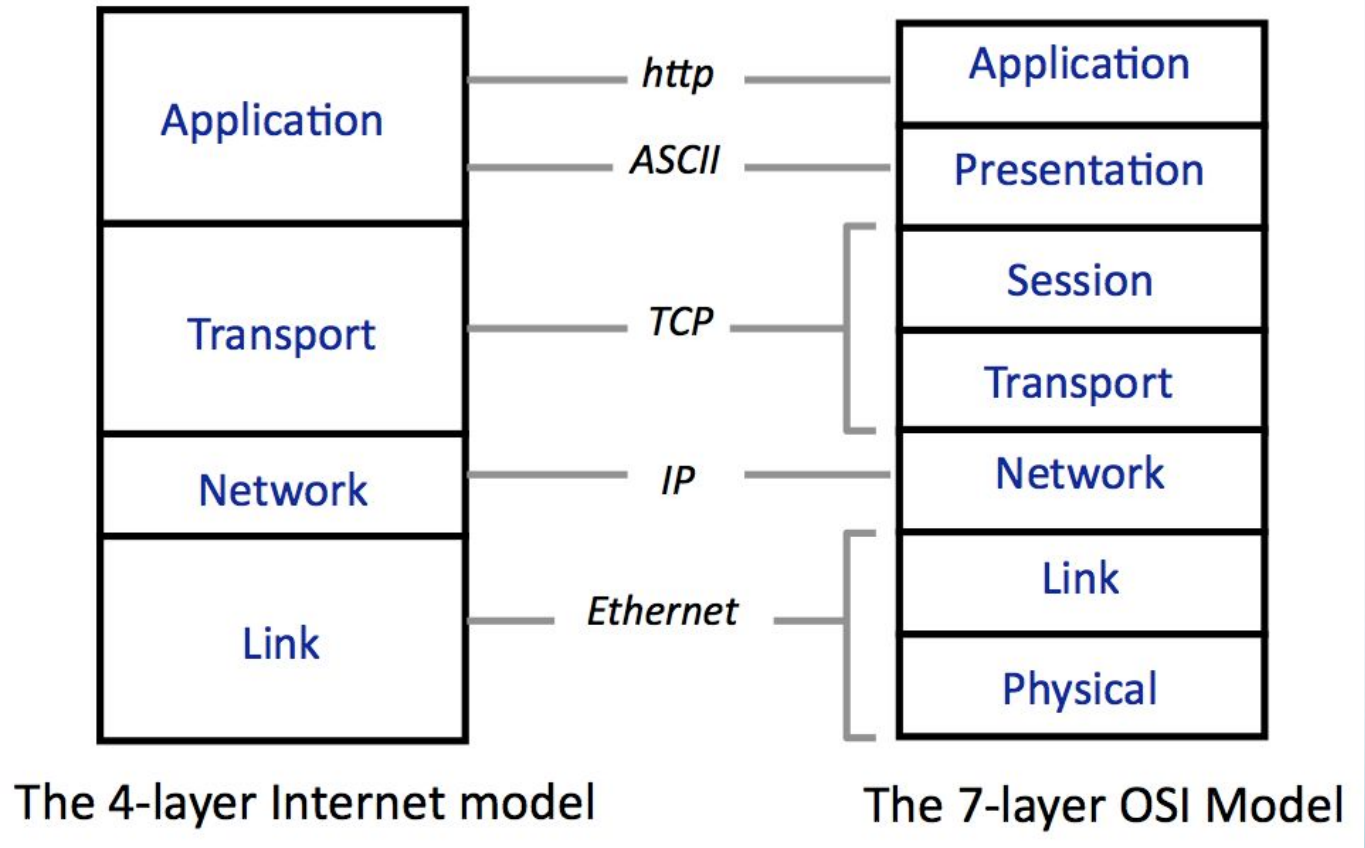


# ISO/OSI reference model

- *presentation:* allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session:* synchronization, checkpointing, recovery of data exchange
- Internet stack "missing" these layers!
  - these services, *if needed,* must be implemented in application
  - needed?



# Why is the Network Layer often called “Layer 3”?

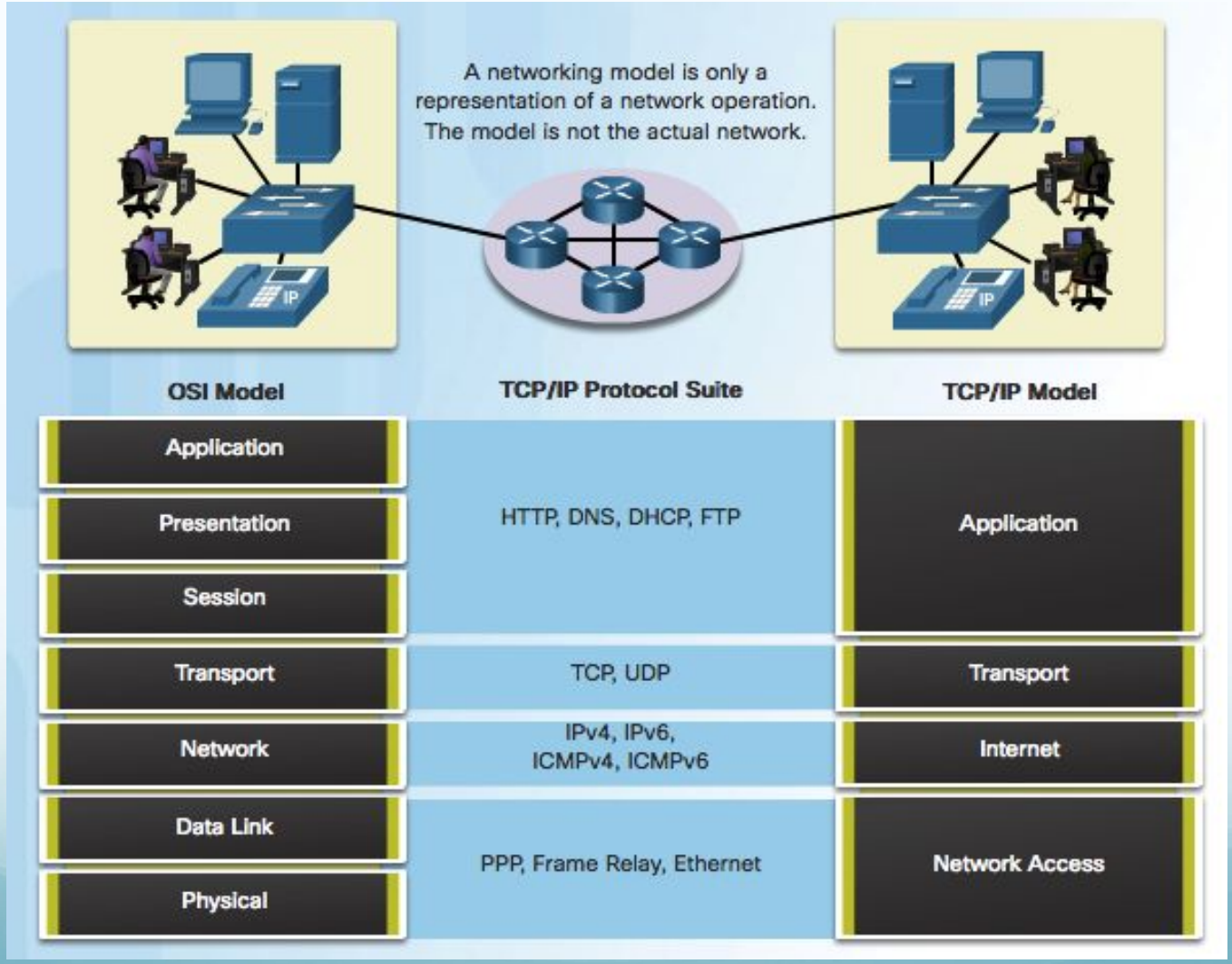


# Distinguishing Points

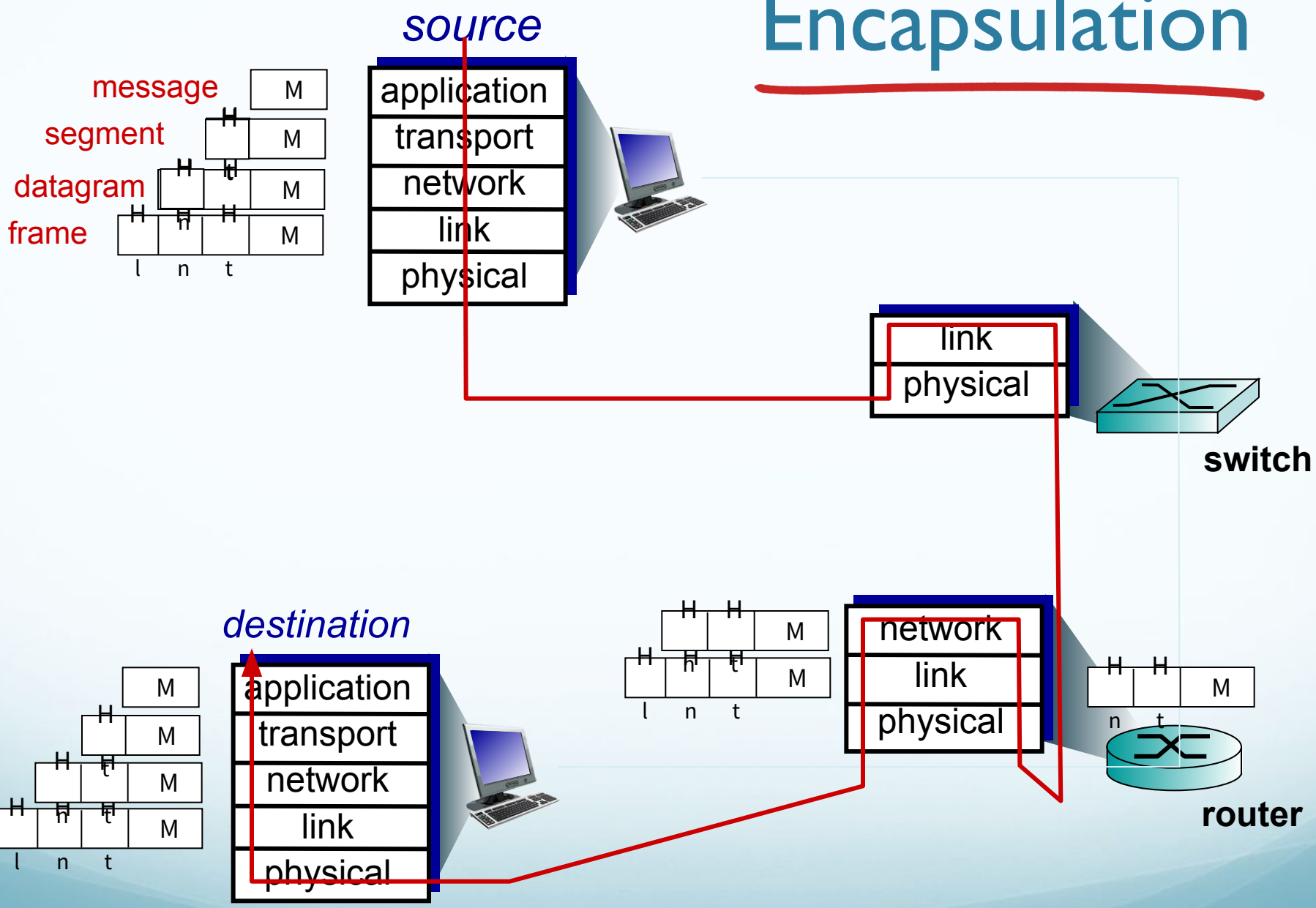
| TCP/IP | OSI |
|---|---|
| Implementation of OSI model | Reference model |
| Model around which Internet is developed | This is a theoretical model |
| Has only 4 layers | Has 7 layers |
| Considered more reliable | Considered a reference tool |
| Protocols are not strictly defined | Stricter boundaries for the protocols |
| Horizontal approach | Vertical approach |
| Combines the session and presentation layer in the application layer | Has separate session and presentation layer |
| Protocols were developed first and then the model was developed | Model was developed before the development of protocols |
| Supports only connectionless communication in the network layer | Supports connectionless and connection-oriented communication in the network layer |
| Protocol dependent standard | Protocol independent standard |

| OSI Model (7 layers) | | Internet Model (4 layers) | | |
|---|---|---|---|---|
| *Layer Name* | | *Layer Name* | *Protocol* | *Address* |
| **Application** | | **Application** | Telnet, SSH | hostname |
| **Presentation** | | | E-mail | user@domain |
| **Session** | | | Web Browser | URL |
| **Transport** | | **Transport** | Transmission Control Protocol<br>or<br>User Datagram Protocol | Port Numbers |
| **Network** | | **Network** | Interrnet Protocol | IP Address |
| **Data Link** | | **Network Interface** | Network Interface Device<br>FastEthernet, GigE, WiFi (802.11a, b, g, n) | MAC Address |
| **Physical** | | | | |

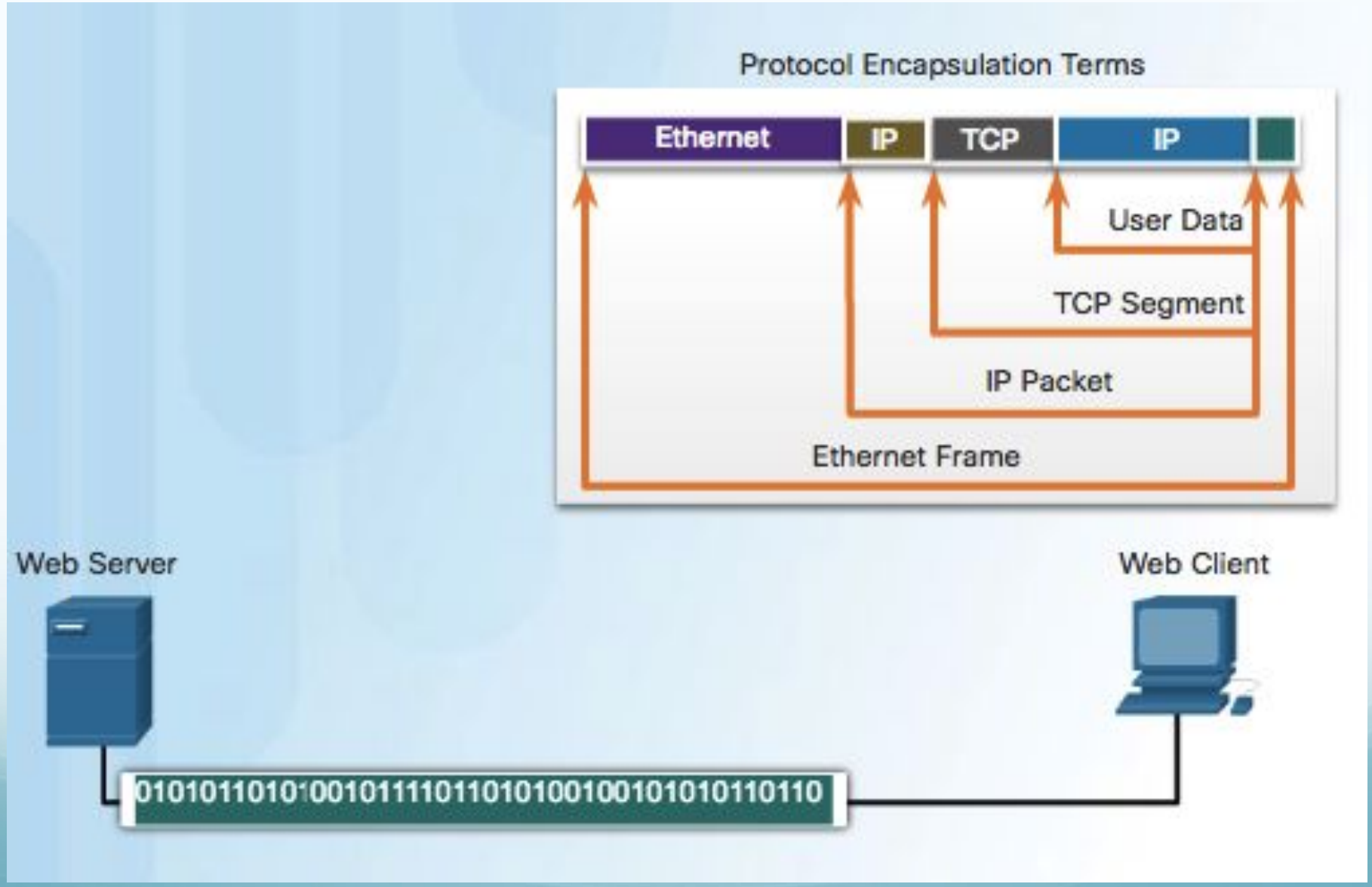
# The Benefits of Using a Layered Model



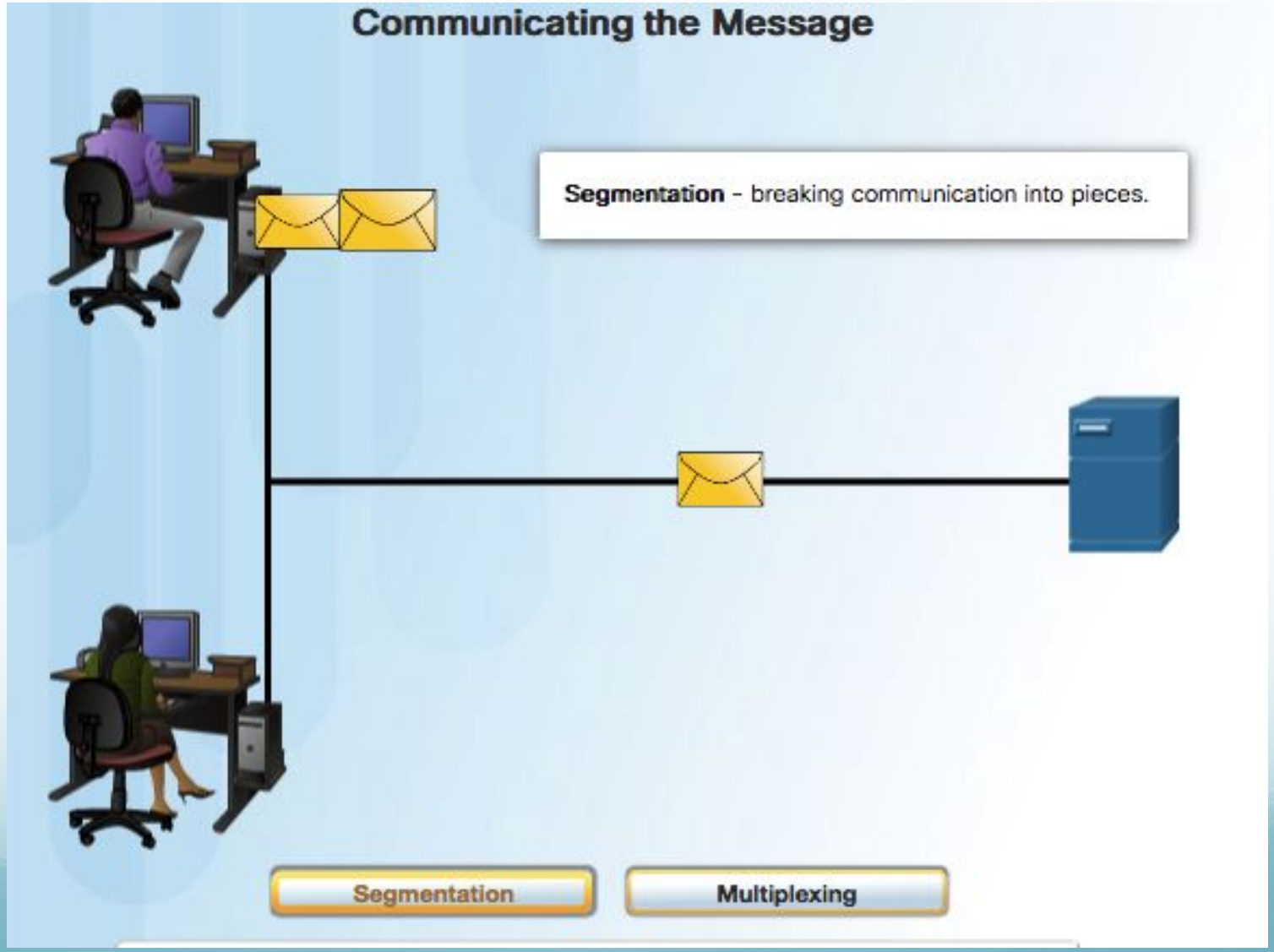
# Encapsulation



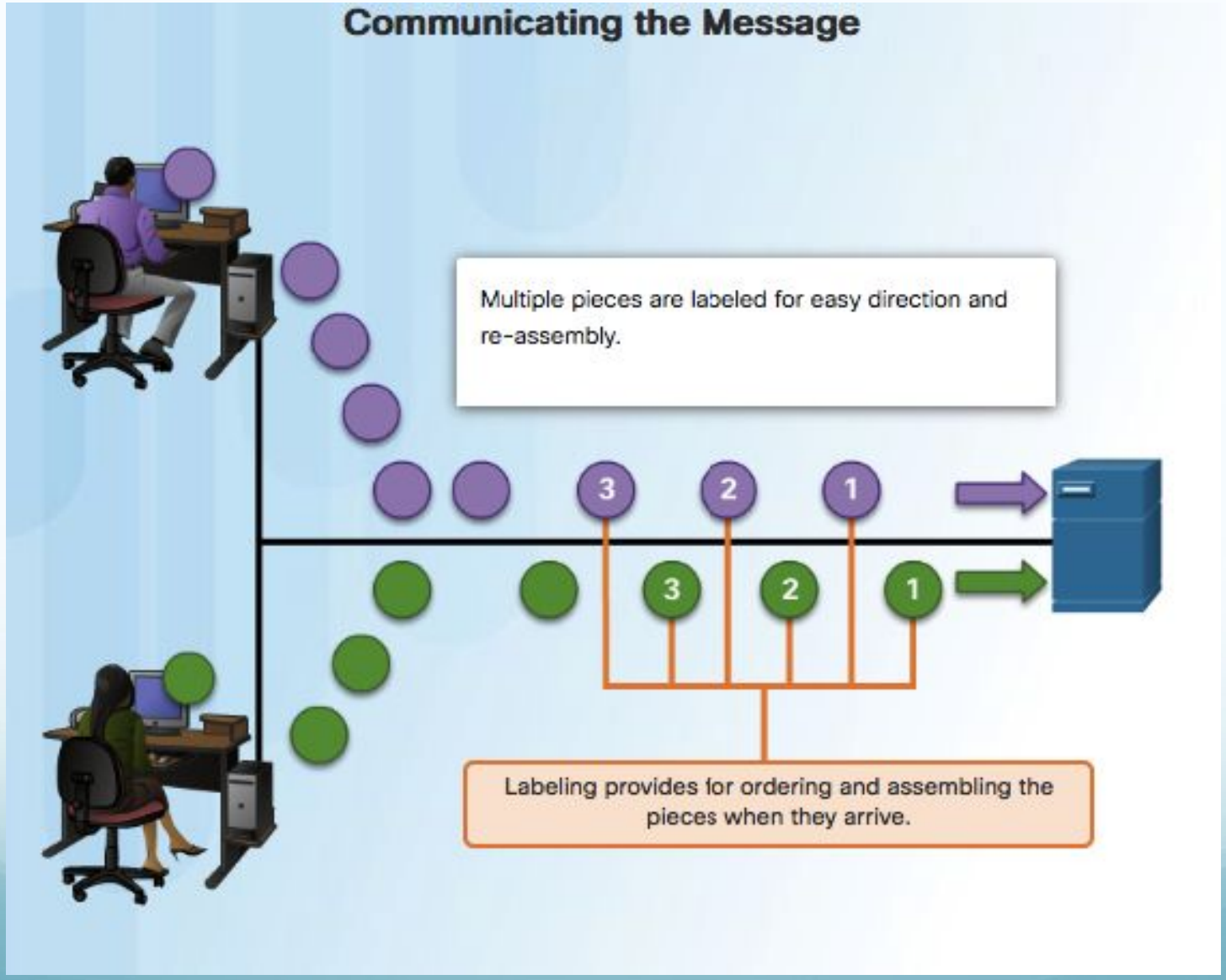
# De-encapsulation



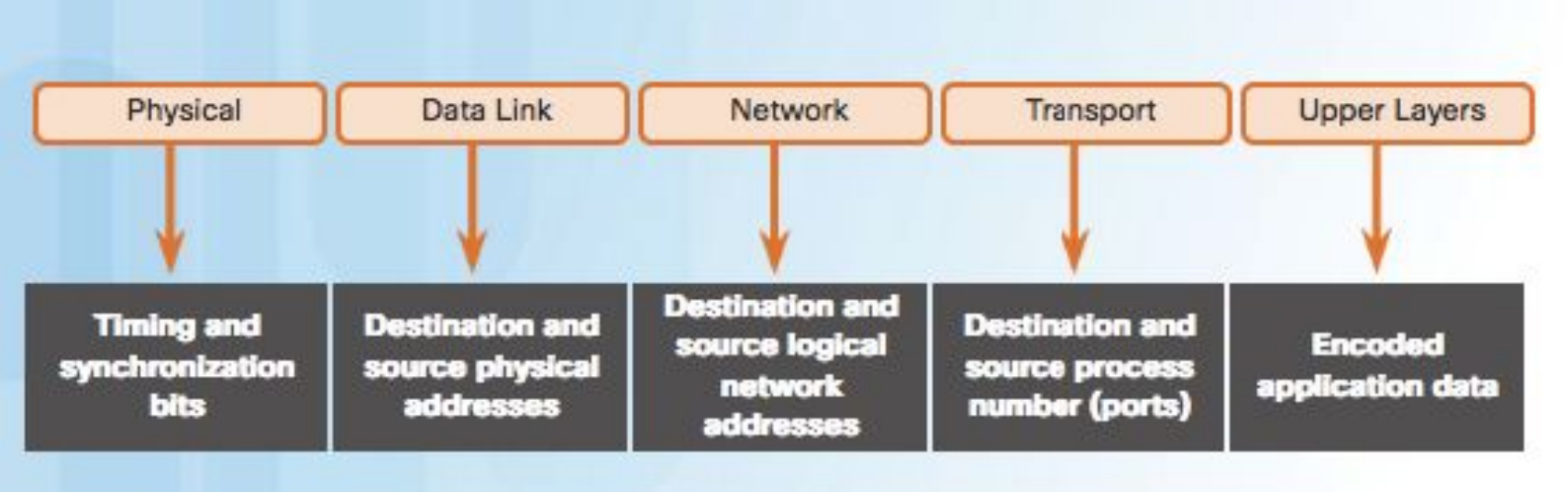
# Message Segmentation



# Message Segmentation



# Network Addresses



**In the Internet model how are frames at one layer encapsulated by the next layer? (There could be more than one answer. Enter the correct choice(s) as a comma-separated list in alphabetical order. For instance, if a, b, and c are right, enter "a,b,c".)**

a. A frame at one layer consists of a data field - consisting solely of the entire frame from the layer above - and a header portion describing the data field and how it is to be demultiplexed at the other end.
b. In the outbound direction, a frame is constructed by reading a combination of information from the layers above and below.
c. In the inbound direction, the data portion of a frame is passed to the layer above, and typically carries information to identify which service should receive the frame.
d. In the Internet, all data arriving from the link layer must pass through the TCP layer before reaching the application.

**What are the advantages of the network layers abstraction? (There could be more than one answer. Enter the correct choice(s) as a comma-separated list in alphabetical order. For instance, if a, b, and c are right, enter "a,b,c".)**

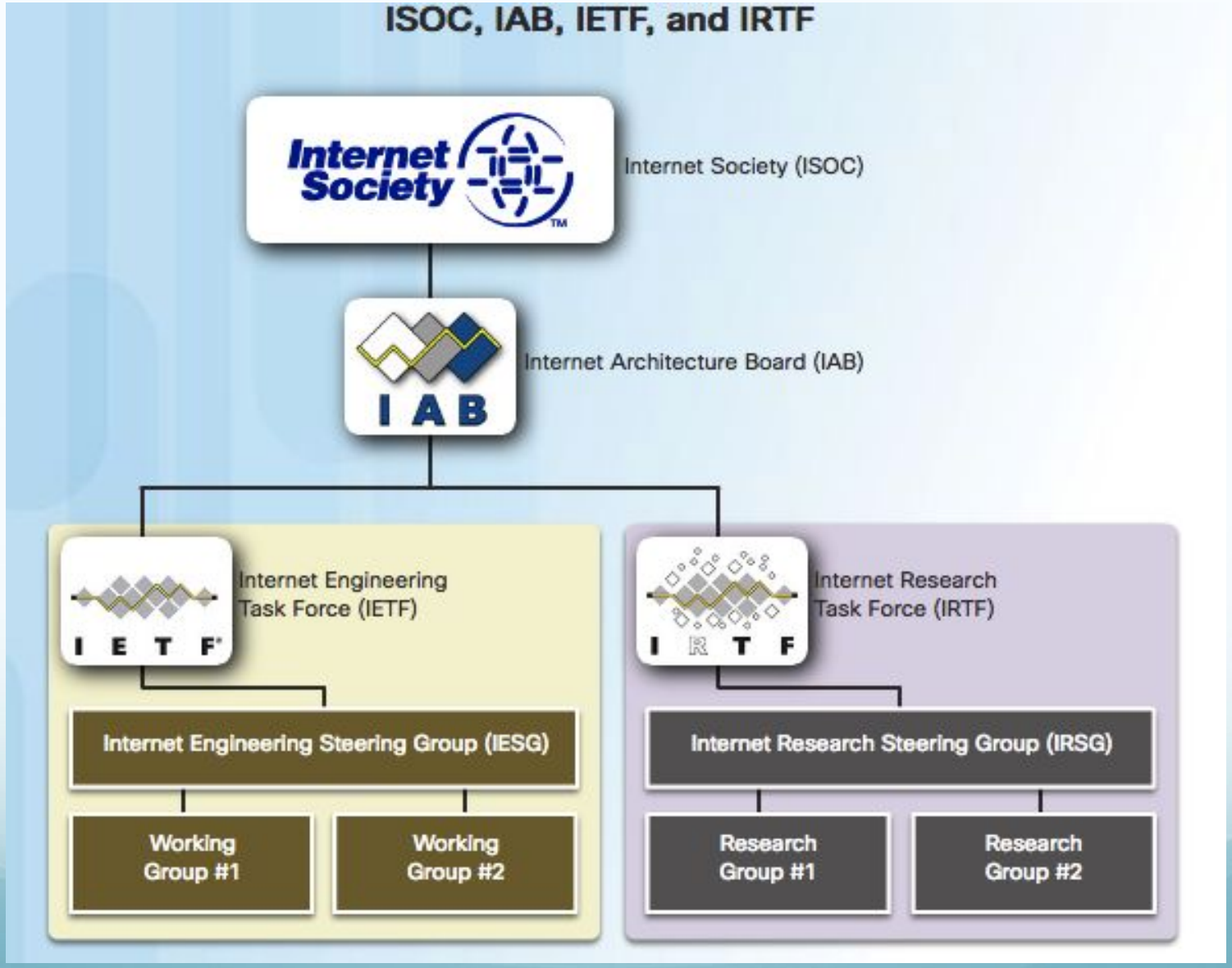
a. Break a complex task of communication into smaller pieces.
b. Lower layers hide the implementation details from higher layers.
c. Upper layers can provide a service to the layers below.
d. Lower layers can change implementation without affecting upper layers as long as the interface between layers remains the same.

**What happens when a packet is received by a layer-2 ethernet switch? (There could be more than one answer. Enter the correct choice(s) as a comma-separated list in alphabetical order. For instance, if a, b, and c are right, enter "a,b,c".)**

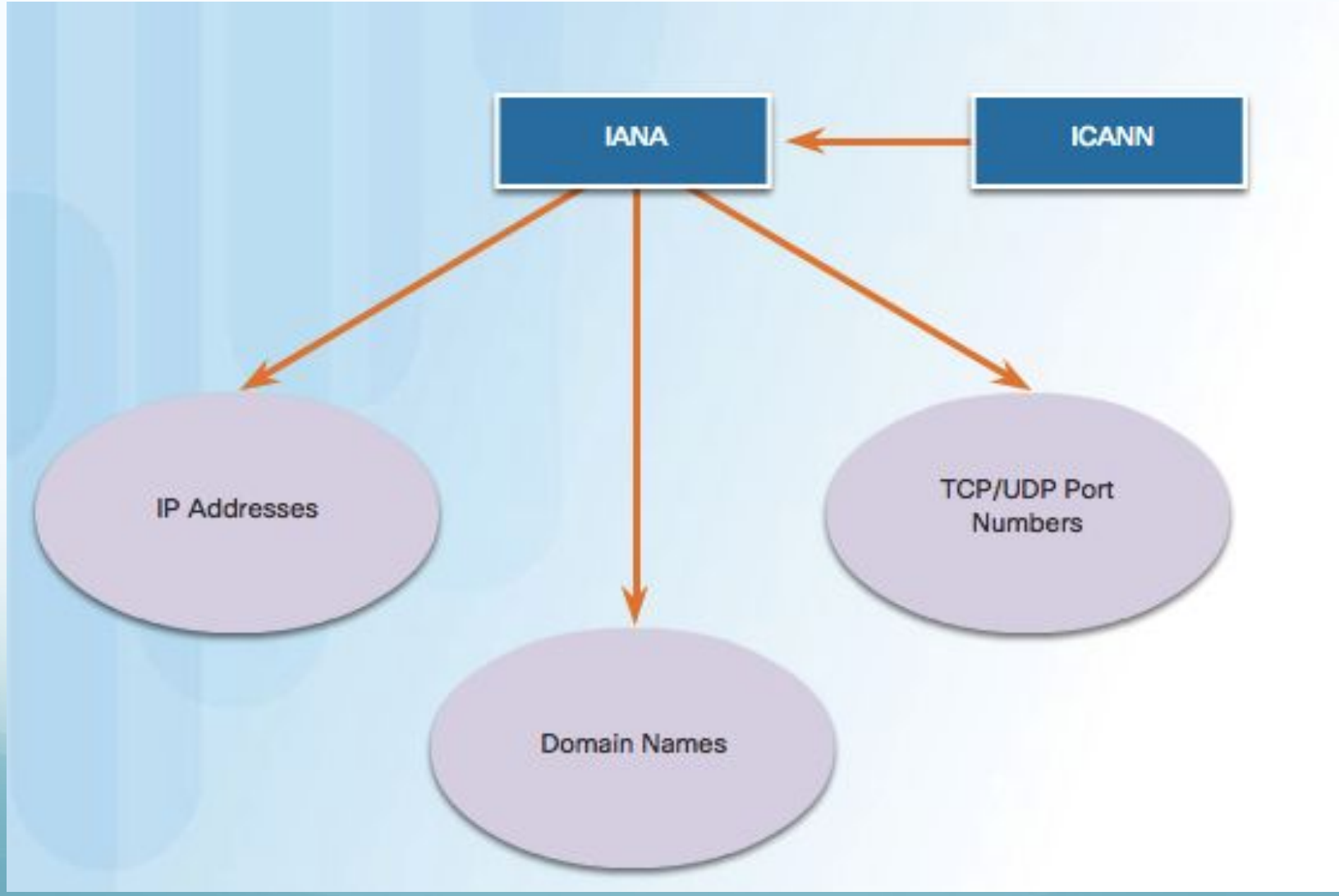
a. The switch will make a forwarding decision based on the destination address in the Ethernet header.
b. The switch will then encapsulate the packet again with a new Ethernet header, where the source ethernet address will now be the switch's Ethernet address.
c. The switch will need to learn the destination IP address from the layer-3 IP header in order to make forwarding decision.
d. In order to check the data integrity, the switch will need to extract the application data out from the packet.

# Open Standards

# Internet Standards



# Internet Standards



# Electronics and Communications Standard Organizations

## IEEE 802 Working Groups and Study Groups

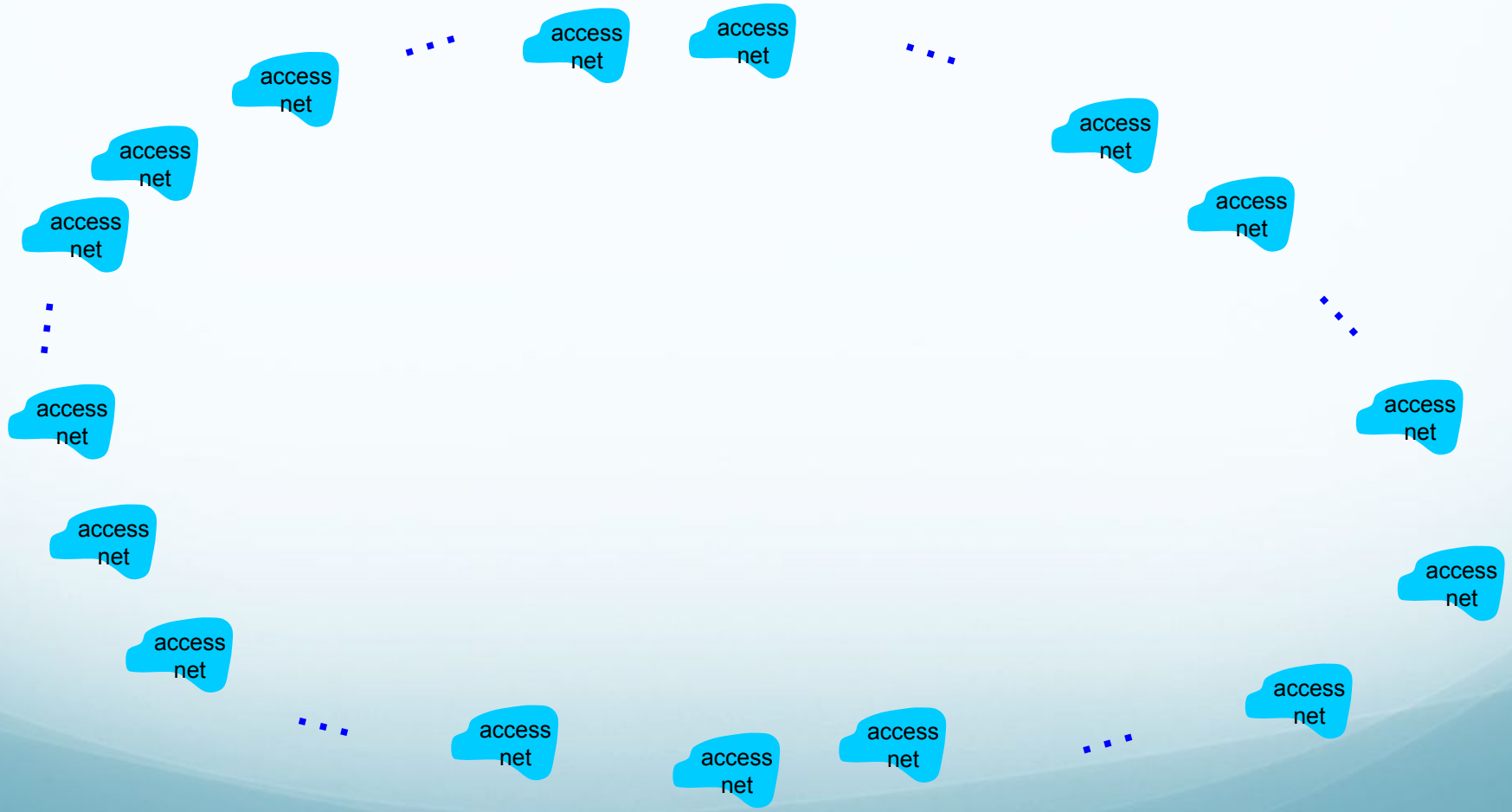
- 802.1 Higher Layer LAN Protocols Working Group
- 802.3 Ethernet Working Group
- 802.11 Wireless LAN Working Group
- 802.15 Wireless Personal Area Network (WPAN) Working Group
- 802.16 Broadband Wireless Access Working Group
- 802.18 Radio Regulatory TAG
- 802.19 Wireless Coexistence Working Group
- 802.21 Media Independent Handover Services Working Group
- 802.22 Wireless Regional Area Networks
- 802.24 Smart Grid TAG

# Internet structure: network of networks

- End systems connect to Internet via access ISPs (Internet Service Providers)
  - Residential, company and university ISPs
- Access ISPs in turn must be interconnected.
  - So that any two hosts can send packets to each other
- Resulting network of networks is very complex
  - Evolution was driven by economics and national policies
- Let's take a stepwise approach to describe current Internet structure

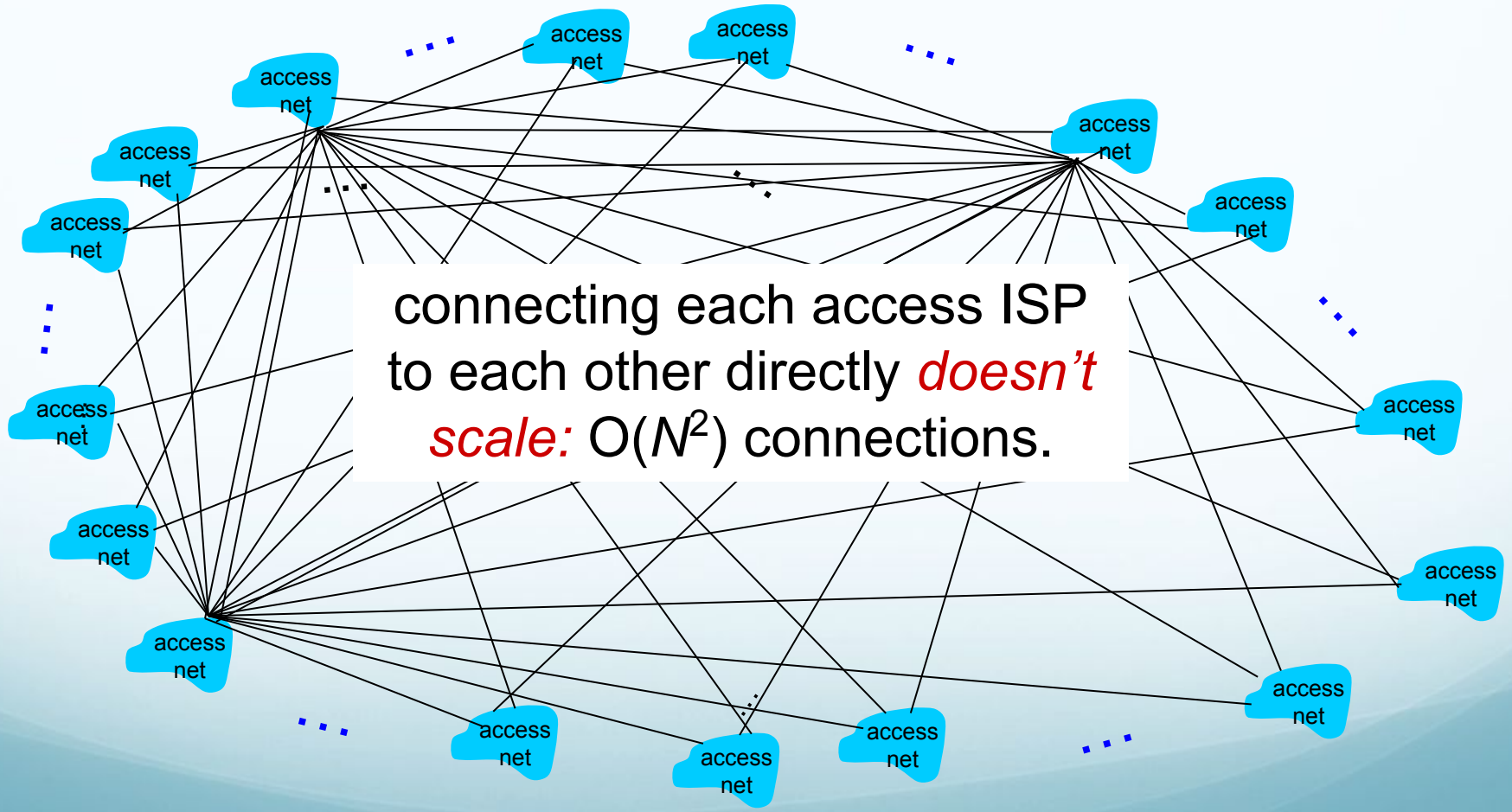
# Internet structure: network of networks

*Question:* given *millions* of access ISPs, how to connect them together?



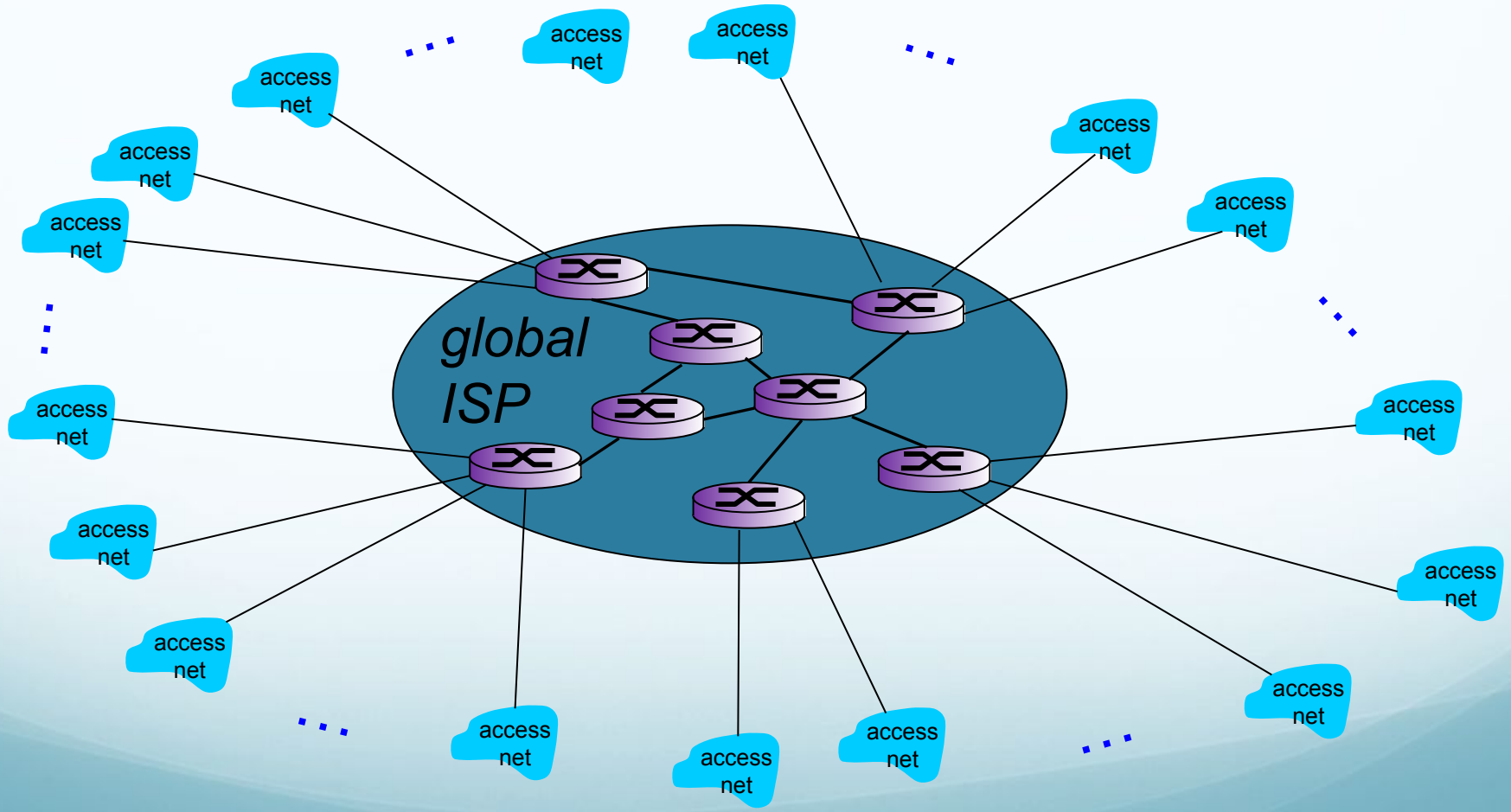
# Internet structure: network of networks

*Option: connect each access ISP to every other access ISP?*



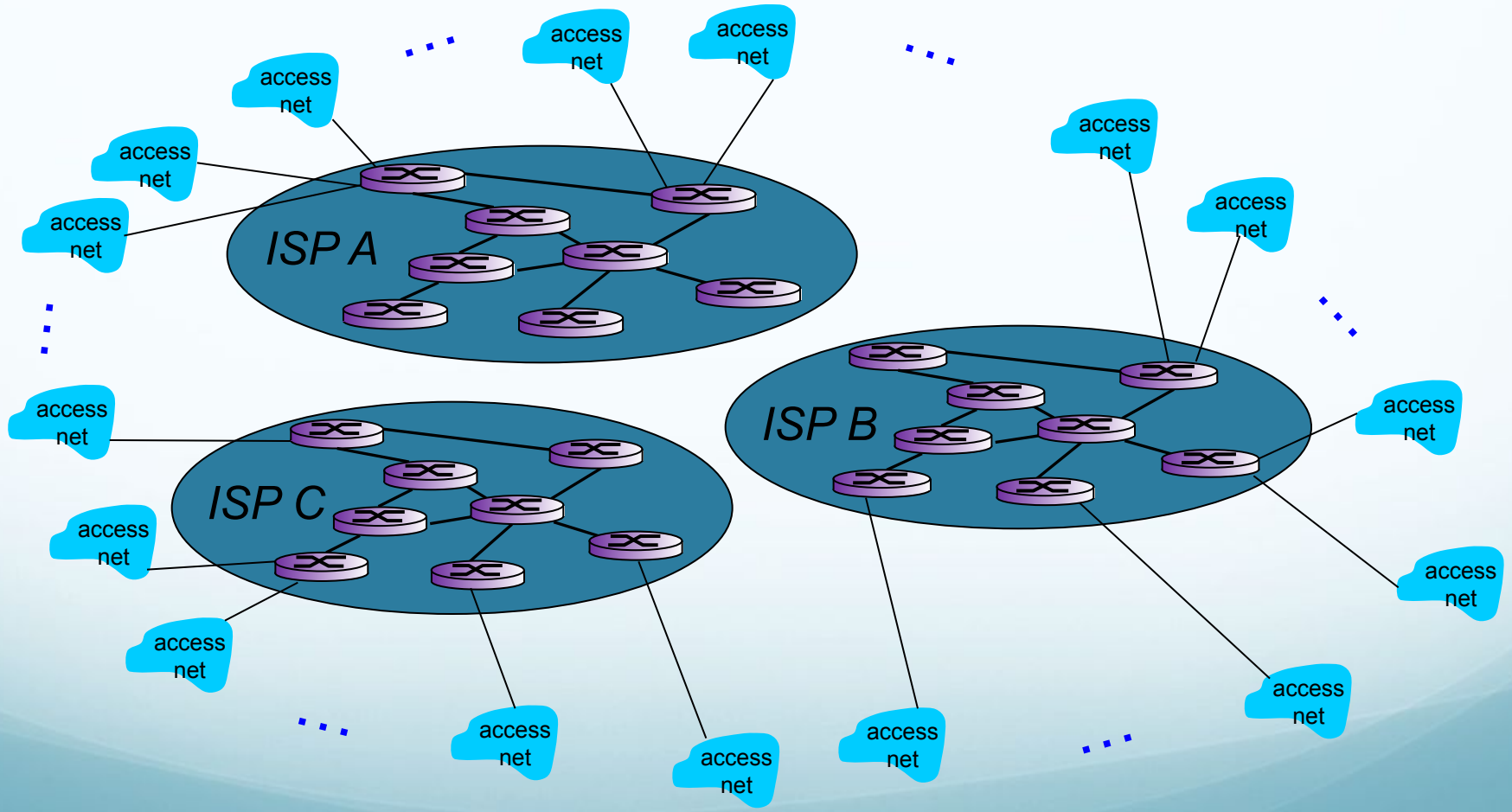
# Internet structure: network of networks

*Option: connect each access ISP to a global transit ISP?*
*Customer and provider ISPs have economic agreement.*



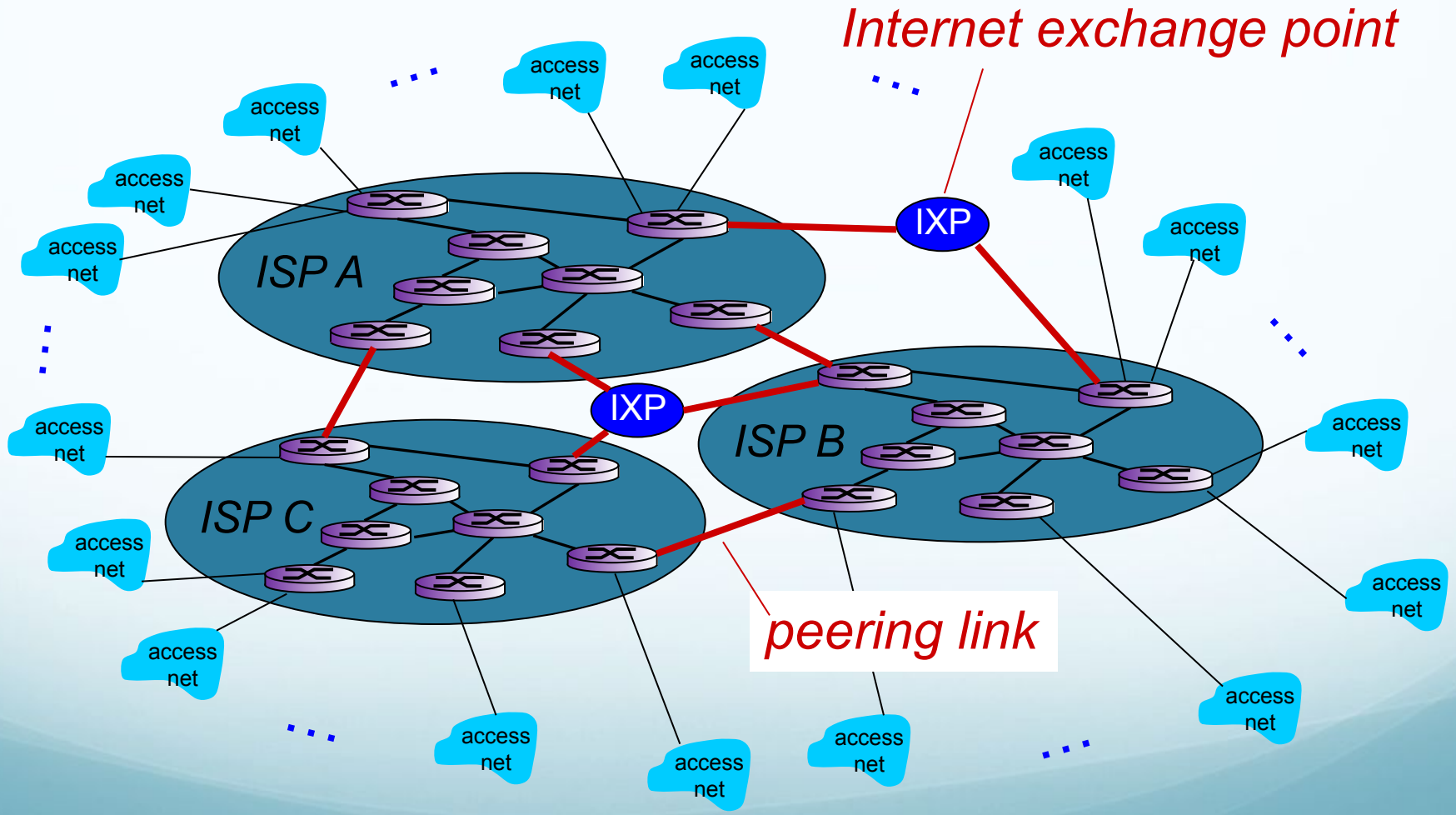
# Internet structure: network of networks

But if one global ISP is viable business, there will be competitors ….



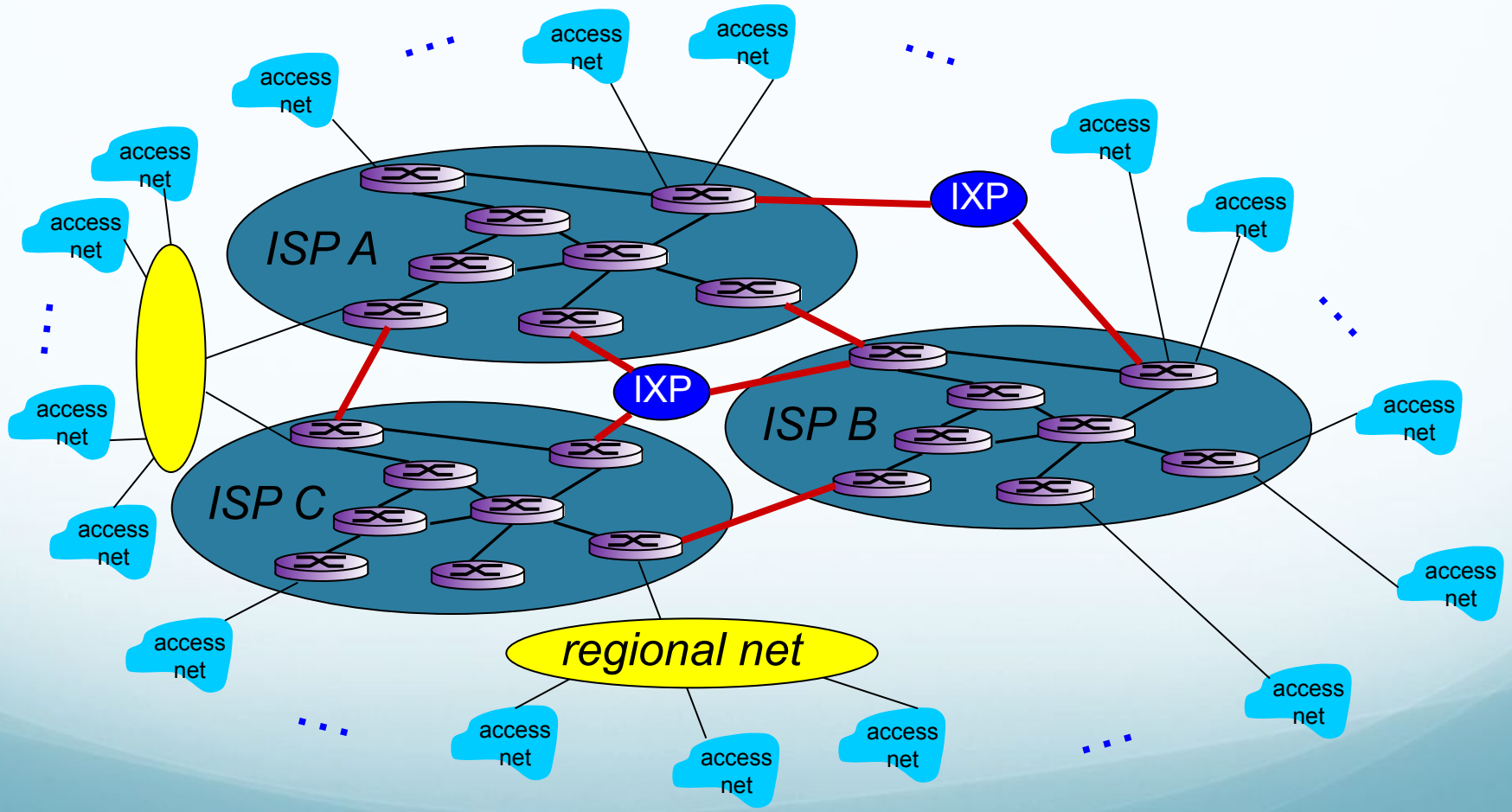
# Internet structure: network of networks

But if one global ISP is viable business, there will be competitors …. which must be interconnected



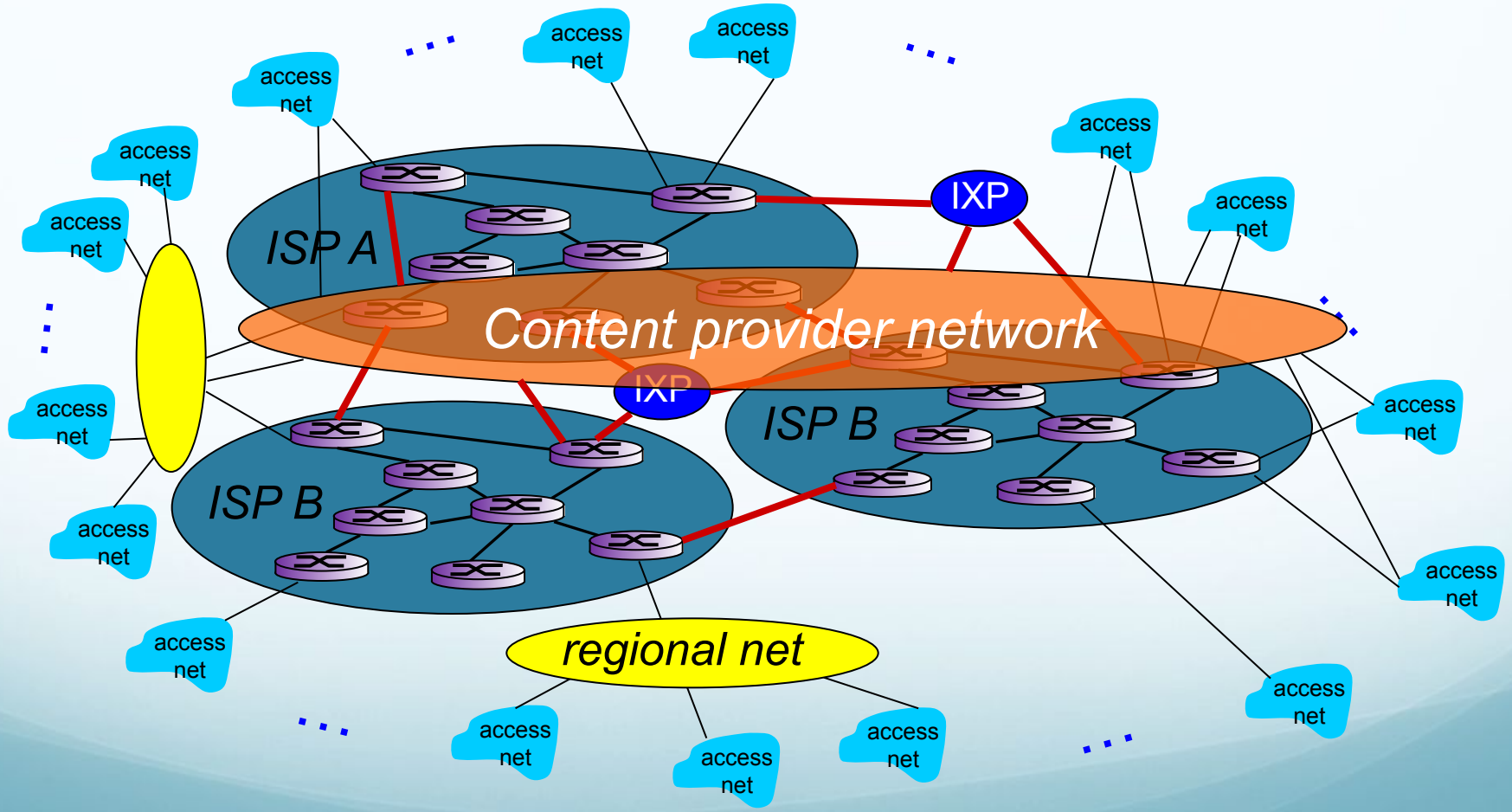
# Internet structure: network of networks

… and regional networks may arise to connect access nets to ISPS

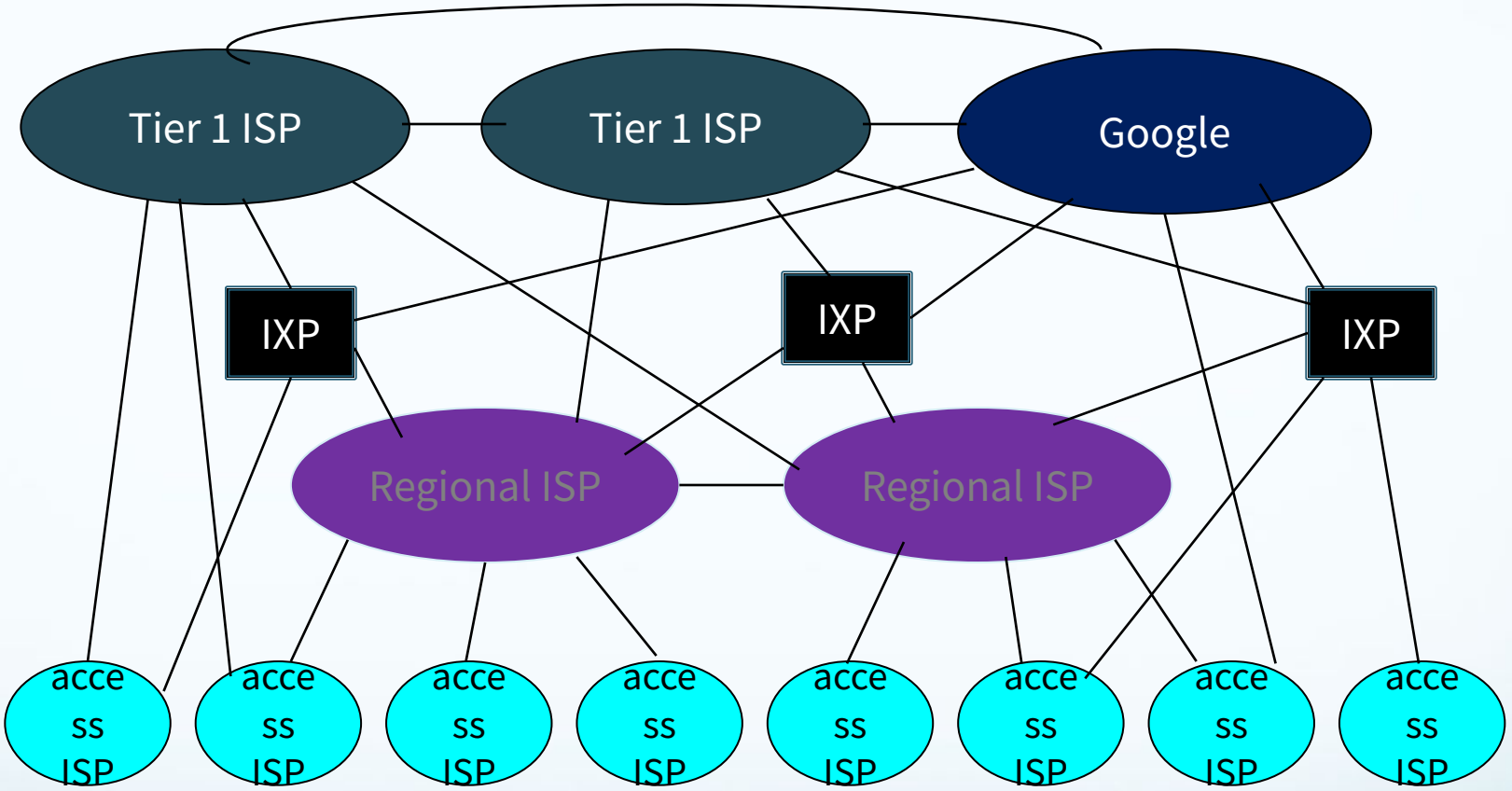


# Internet structure: network of networks

… and content provider networks (e.g., Google, Microsoft, Akamai ) may run their own network, to bring services, content close to end users

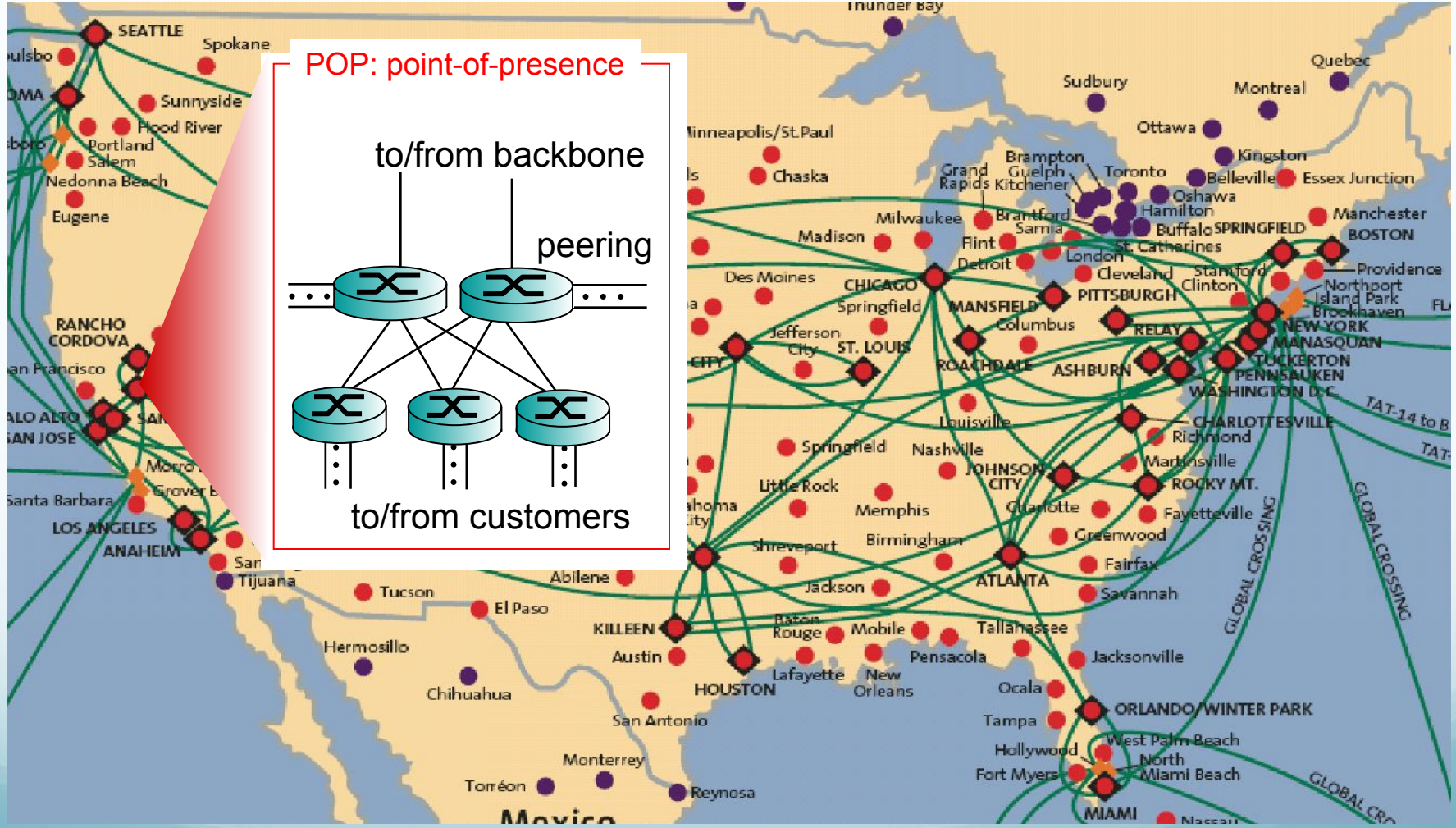


# Internet structure: network of networks




- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
  - content provider network (e.g, Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs

# Tier-1 ISP: e.g., Sprint



# Readings

- Kurose, James F.
  Computer networking : a top-down approach / James F. Kurose, Keith W. Ross.—6th ed.
- **Chapter 1**
- 1.1 What Is the Internet?
- 1.2 The Network Edge
- 1.3 The Network Core
- 1.5 Protocol Layers and Their Service Models
- 1.7 History of Computer Networking and the Internet

Thank you for attention!