Data Communications and Networking

Course Overview and Introduction

Dario Vieira
Department of Computer Science
EFREI

Winter 2017

Agenda

- Overview
- Syllabus
- Academic integrity
- Homework expectations
- Introduction to computer networking
- Questions

Syllabus 2

- Instructor: Dario VIEIRA
  - Email: dario.vieira@efrei.fr
- Textbook
  - J.F. Kurose and K.W. Ross, “Computer Networking: A Top-Down Approach,” Addison-Wesley, 5th edition, 2009 (4th edition OK too)
  - “Lillian Goleniewski”, Telecommunications Essentials, Second Edition: The Complete Global Source (2nd Edition)
- Course website
  - All materials will be available at Campus Moodle
  - The Course Materials are mainly the slides given in class

Syllabus 3

- Instructor: Dario VIEIRA
  - Email: dario.vieira@efrei.fr
- Other Textbooks
  - LTE et les réseaux 4G (Yannick Bouguen; Eric Hardouin; François-Xavier Wolff
  - Halsall F., Data Communications, Computer Networks and Open Systems, Addison Wesley 1996
  - Tanenbaum A., **Network 4eme edition**, Pearson Education 2004

Syllabus 1

- Course goals
  - Get “feel” and terminology
  - Understand principles behides data communications and networking
  - Conceptual aspects of Cellular Network Generations
    - Basic of Network
    - CDMA, TDM, FDM…
    - Analog and Digital Transmission
    - Multiplexing
    - (GSM, UMTS, LTE, …)
    - Next Generation Network

Syllabus 2

- Course goals
  - Get "feel" and terminology
  - Understand principles behind network services
  - Conceptual, implementation aspects of network protocols
- Approach
  - Use Internet as example
  - Instantiation and implementation in the Internet
- This is not a Course about
  - Advanced Computer Network
  - Advanced Routing Protocol (BGP, OSPF, RIP…)
  - Advanced on Telecommunications

Syllabus 2

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  - Advanced Computer Network
  - Advanced Routing Protocol (BGP, OSPF, RIP…)
  - Advanced on Telecommunications

Syllabus

- Instructor: **Dario VIEIRA**
  - Office: 4th floor of the building A
  - Email: dario.vieira@efrei.fr

- DE
- Final project
  - Team of 5 students
  - “Soutenance”
  - Technical Repport

Syllabus 4

- Final Grade

  1. Exams
     - Material covered in class and homework
       - Material: Slides available at Moodle Campus

  2. Project
     - Soutenance
     - Technical Report
     - Team of 5 students

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Academic Integrity

- No teamwork is allowed
  - General discussion is acceptable, but your solutions must be your own work
- Academic rules
  - See the Academic Honor Code at Campus Moodle
  - See Academic Dishonesty at Campus Moodle
  - Appropriately cite the source (including code!)
  - Do not copy someone else's work
- Any occurrence of dishonesty: a zero grade for the assignment for all students involved

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Homework Expectations

- Handwritten submission is to be avoided
  - Write in word or LaTex (download MikTex and WinEdt)
- Homework is due at the beginning of class
  - Delays due to circumstances beyond your control must be requested well in advance
  - For late submission, 20% penalty per day (zero point after 5 days)
- Provide a detailed report on each programming assignment
  - Explain how your code fulfills the required functionality
  - Describe interesting parts of your implementation
  - Answer questions in the problem statement
  - <u>Sample runs</u>: capture screenshots of what your code does on test input data
  - Demonstrate in your report that you truly understood the material

Homework Expectations 2

- Homework submission requirements:
  - ZIP file named <your last name>-as#.zip
    - E.g., sirot-as1.zip, sicard-as6.zip
- Projet submission requirements:
  - ZIP file named <last name1>-<last name2>.zip
    - E.g., sirot-bouchon.zip
  - All cpp and h files must start with a commented section with your name and a brief description of the purpose or functions
  - The ZIP file must contain a README file providing detailed instructions on compilation and execution of your code
- Submit the ZIP at Campus Moodle

Projets

- Sujets: 8 equipes de 5 personnes

1. 2éme Génération: Global System for Mobile Communication
2. 2,5G ou 2G+: Global Packet Radio Service (GPRS)
3. Pré-3G - Enhanced Data Rates for GSM Evolution (EDGE)
4. 3ième Génération: Universal Mobile Télécommunications System (UMTS)
5. 3.5G, 3G+ (H ou encore turbo 3G) Génération: High Speed Downlink Packet Access (HSPDPA)
6. 3.75 Génération: HSPA+ et DC–HSPA+
7. 3.9 G (LTE) et 4G (LTE+)
8. Les défis de la 5G

Projets

- Travail en Equipe
  - 08/11/2016
- Soutenances
  - 15/11/2016
  - 22/11/2016
  - 30 minutes plus 15 minutes de questions/réponses
- Deliverable
  - Rapport technique (**deadline: 22/11/2016**)
  - Présentation (ppt ou pdf) (**deadline: 22/11/2016**)

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"The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point"

- *The Mathematical Theory of Communication*, Claude Shannon

Introduction

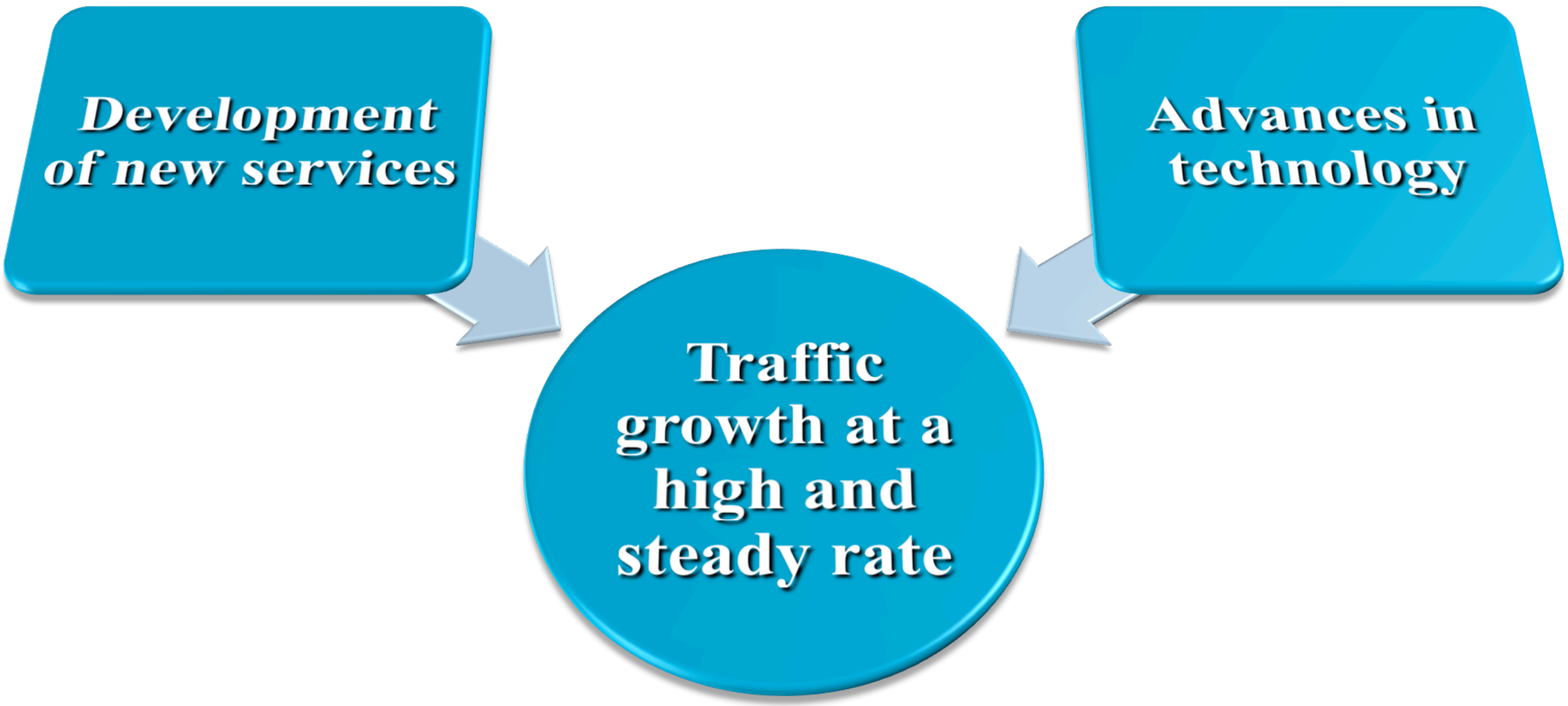
1) **Data Communications:** Deals with the transmission of signals in a reliable & efficient manner.
   Topics: Signal Transmission; Transmission Media; Signal Encoding; Interfacing; Data Link Control; Multiplexing

2) **Networking:** Deals with the **technology & architecture** of the communications networks used to **interconnect** communicating devices
   Topics: LANs; WANs;

3) **Communications Protocols:** Protocol Architectures; Analysis of individual protocols at various layers of the architecture

4) **Mobile Network:** Cellular Network Generations (GSM, UMTS, LTE, …)

Technological Advancement Driving Forces



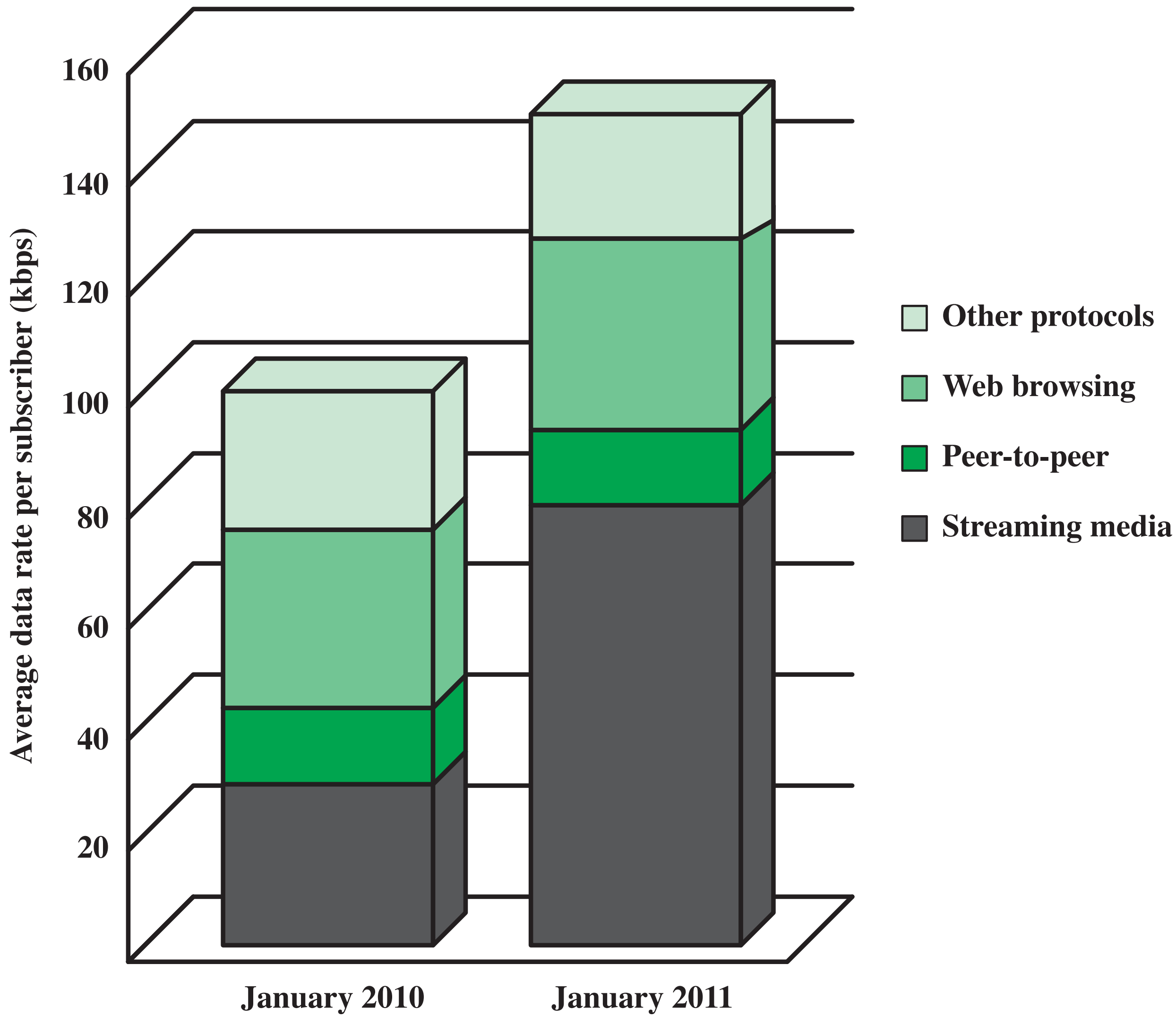


Figure 1.1 Average Downstream Traffic per Internet Subscriber

Notable Trends

Trend toward faster and cheaper, in both computing and communication

- More powerful computers supporting more demanding applications
- The increasing use of optical fiber and high-speed wireless has brought transmission prices down and greatly increased capacity

Today's networks are more "intelligent"

- Differing levels of quality of service (QoS)
- Variety of customizable services in the areas of network management and security

The Internet, the Web, and associated applications have emerged as dominant features for both business and personal network landscapes

- "Everything over IP"
- Intranets and extranets are being used to isolate proprietary information

Mobility

- iPhone, Droid, and iPad have become drivers of the evolution of business networks and their use
- Enterprise applications are now routinely delivered on mobile devices
- Cloud computing is being embraced
- Internet of Things

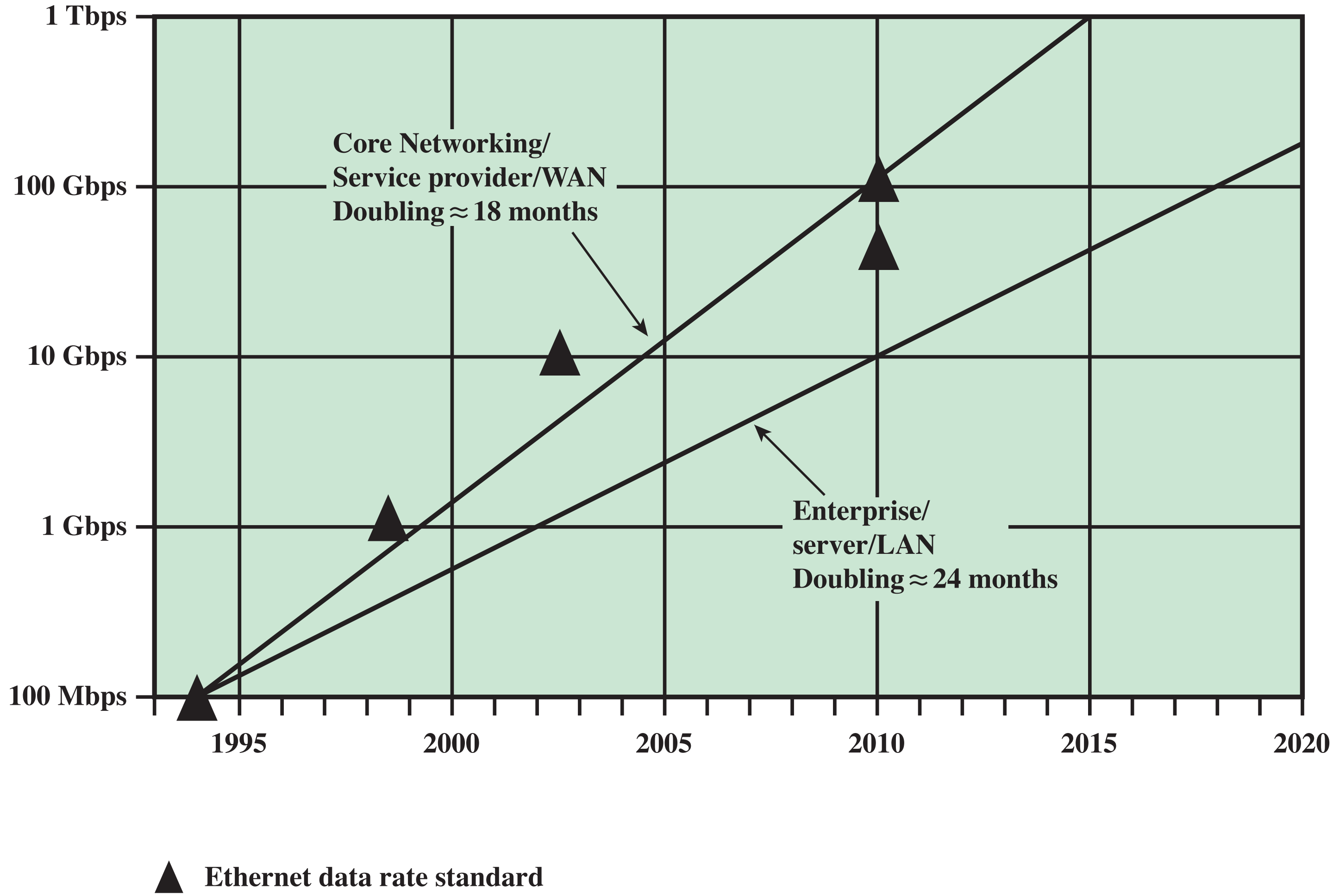


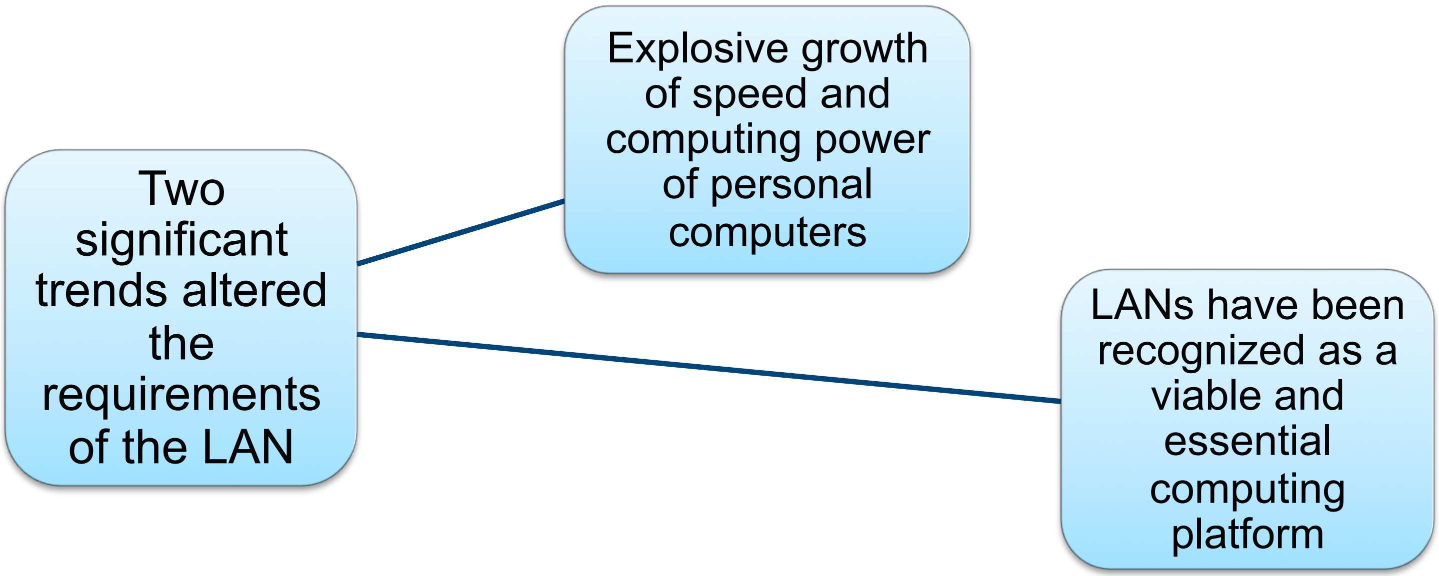
Figure 1.2 Past and Projected Growth in Ethernet Data Rate Demand Compared to Existing Ethernet Data Rates

Changes in Networking Technology

* Emergence of high-speed LANs
* Corporate WAN needs
* Digital electronics

Emergence of High-Speed LANs

- Personal computers and microcomputer workstations have become an essential tool for office workers



- Examples of requirements that call for higher-speed LANs:
  - Centralized server farms
  - Power workgroups
  - High-speed local backbone

Corporate Wide Area Networking Needs

Changes in corporate data traffic patterns are driving the creation of high-speed WANs	Growing use of telecommuting
	Nature of the application structure has changed
	Intranet computing
	More reliance on personal computers, workstations, and servers
	More data-intensive applications
	Most organizations require access to the Internet
	Traffic patterns have become more unpredictable
	Average traffic load has risen
	More data is transported off premises and into the wide area

Convergence

Layers:

- The merger of previously distinct telephony and information technologies and markets
  - Involves:
    - Moving voice into a data infrastructure
    - Integrating all the voice and data networks inside a user organization into a single data network infrastructure
    - Then extending that into the wireless arena
  - Foundation is packet-based transmission using the Internet Protocol (IP)
  - Increases the function and scope of both the infrastructure and the application base

Applications

These are seen by the end users

With convergence, applications provide features that incorporate voice, data, and video in a seamless, organized, and value-added manner.

Enterprise services

Services the information network supplies to support applications

At this level, the manager deals with the information network in terms of the services it provides to support applications. The network manager needs design, maintenance, and support services related to the deployment of convergence-based facilities.

Infrastructure

Communication links available to the enterprise;

A key aspect of convergence at this level is the ability to carry voice, image, and video over networks that were originally designed to carry data traffic.

Communications Tasks

1. **Transmission system** utilization: refers to the need to make efficient use of transmission facilities (ex, multiplexing; congestion control that are typically shared among a number of communicating devices.

2. To communicate, a device must **interface** with the transmission system.

3. Thus, once an interface is established, **signal generation** is required for communication. The signal must be:
   I. capable of being propagated through the transmission system,
   II. and interpretable as data at the receiver.

4. There must be some form of **synchronization** between transmitter and receiver. The receiver must be able to determine when a signal begins to arrive and when it ends. It must also know the duration of each signal element.

Communications Tasks

5. If data are to be exchanged in both directions over a period of time, the **two parties must cooperate**. For data processing devices, more will be needed than simply establishing a connection; certain conventions must be decided on. These conventions might include:

    - whether both devices may transmit simultaneously or must take turns,
    - the amount of data to be sent at one time,
    - the format of the data, and
    - what to do if certain contingencies such as an error arise.

6. In all communications systems, there is a potential for error; transmitted signals are distorted to some extent before reaching their destination. **Error detection** and **correction** are required in circumstances where errors cannot be tolerated.

Communications Tasks

10. **Addressing**: When more than two devices share a transmission facility, a source system must indicate the identity of the intended destination.

11. **Routing**: the transmission system may itself be a network through which various paths may be taken. A specific route through this network must be chosen.

12. **Recovery** is a concept distinct from that of error correction. Recovery techniques are needed in situations in which an information exchange, such as a database transaction or file transfer, is interrupted due to a fault somewhere in the system.

13. Frequently, it is important to provide some measure of **security** in a data communications system.

14. **Network management** capabilities are needed to configure the system, monitor its status, react to failures and overloads, and plan intelligently for future growth.

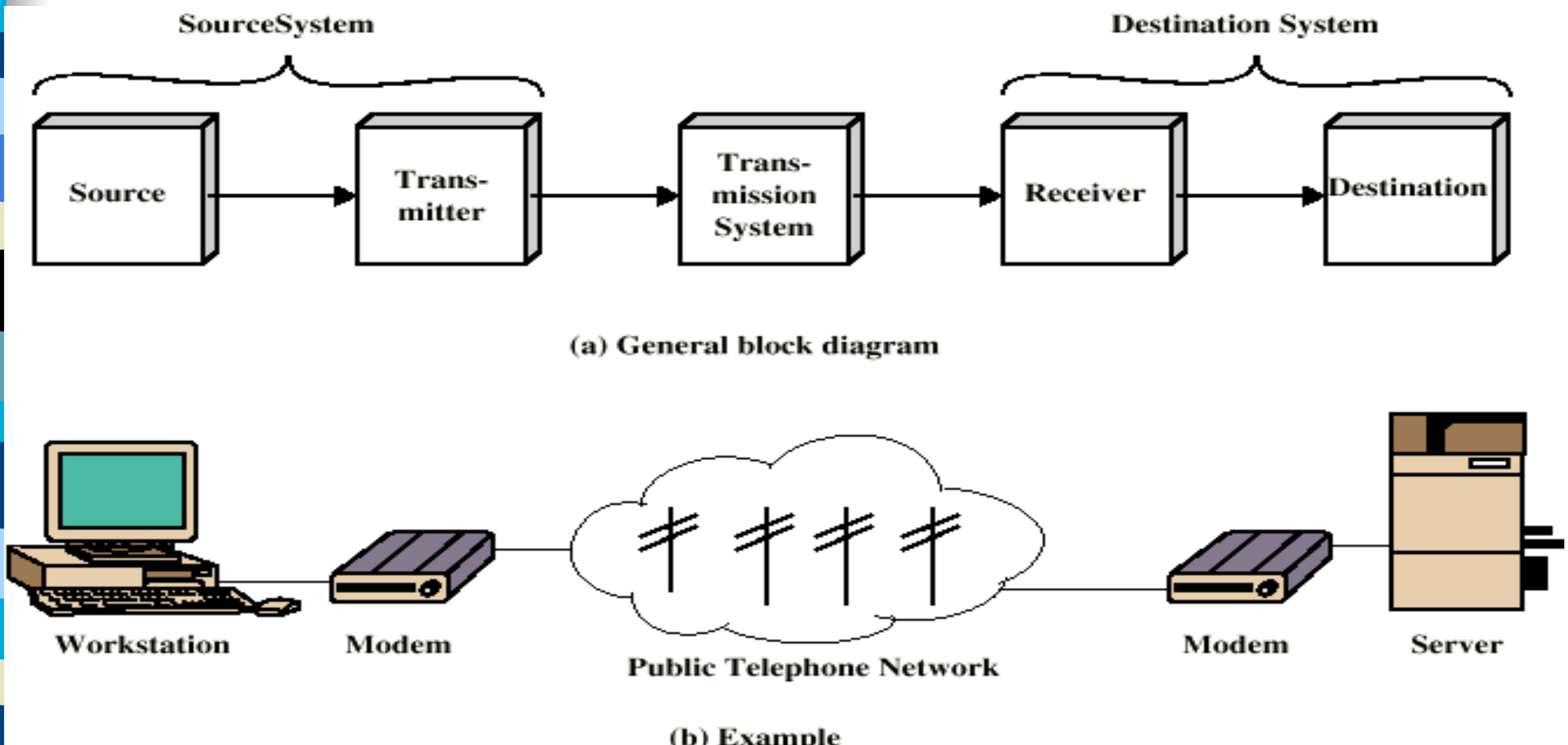
Table: Communications Tasks

Transmission system utilization	Addressing
Interfacing	Routing
Signal generation	Recovery
Synchronization	Message formatting
Exchange management	Security
Error detection and correction	Network management
Flow control	

The table above lists some of the key tasks that must be performed in a data communications system.

Simplified Communications Model - Diagram

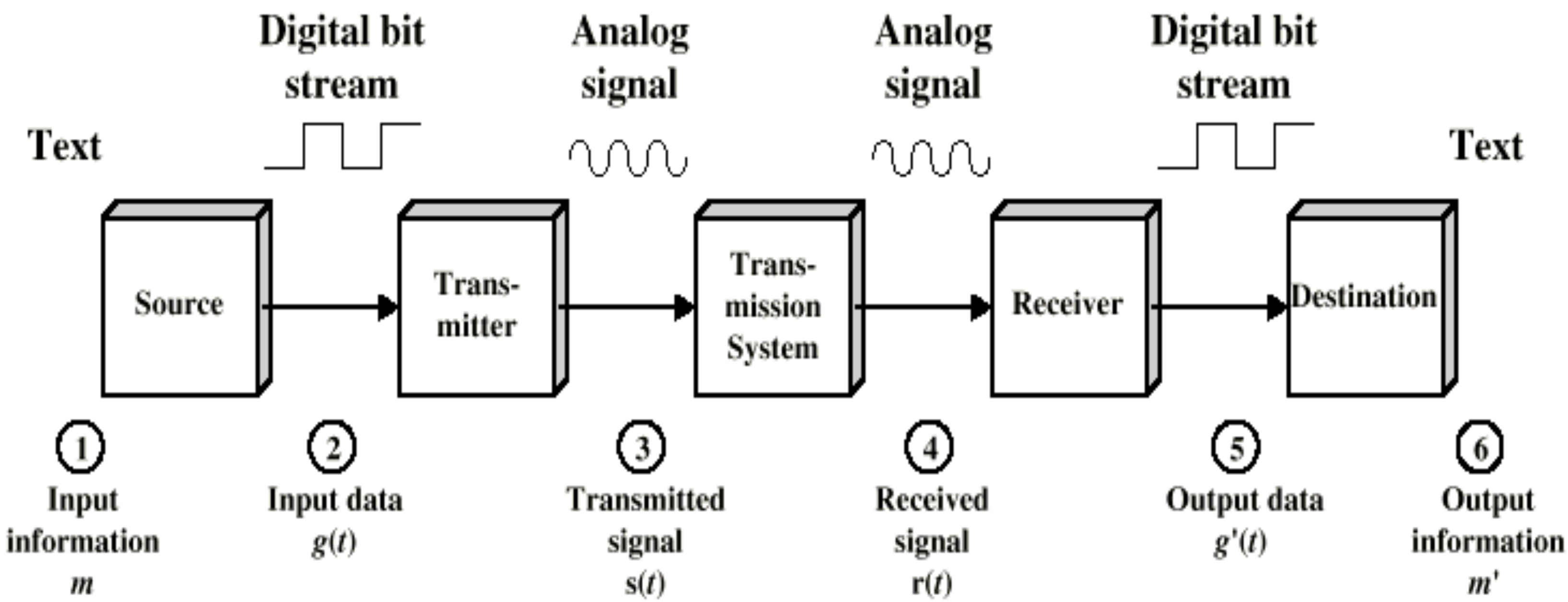
Purpose of Com. Sys.: Exchange of data between parties



A Communications Model

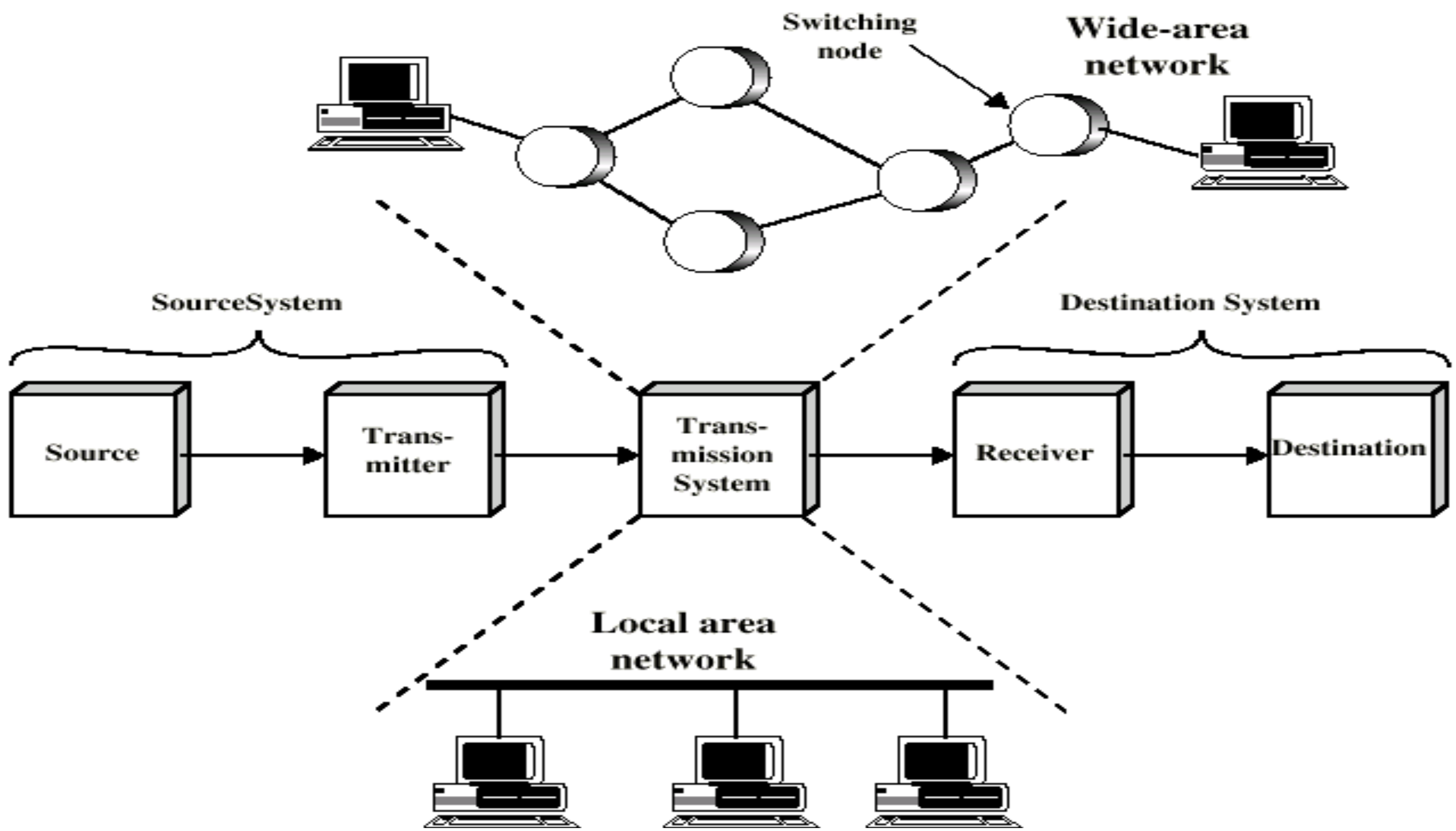
- **Source**
  - Generates data to be transmitted. E.g., Phone, computer
- **Transmitter**
  - Converts data into transmittable signals. E.g., encode bit stream into electromagnetic signals.
- **Transmission System**
  - Carries data. E.g., transmission line, or a complex network
- **Receiver**
  - Converts received signal into data readable to des. device.
- **Destination**
  - Takes incoming data

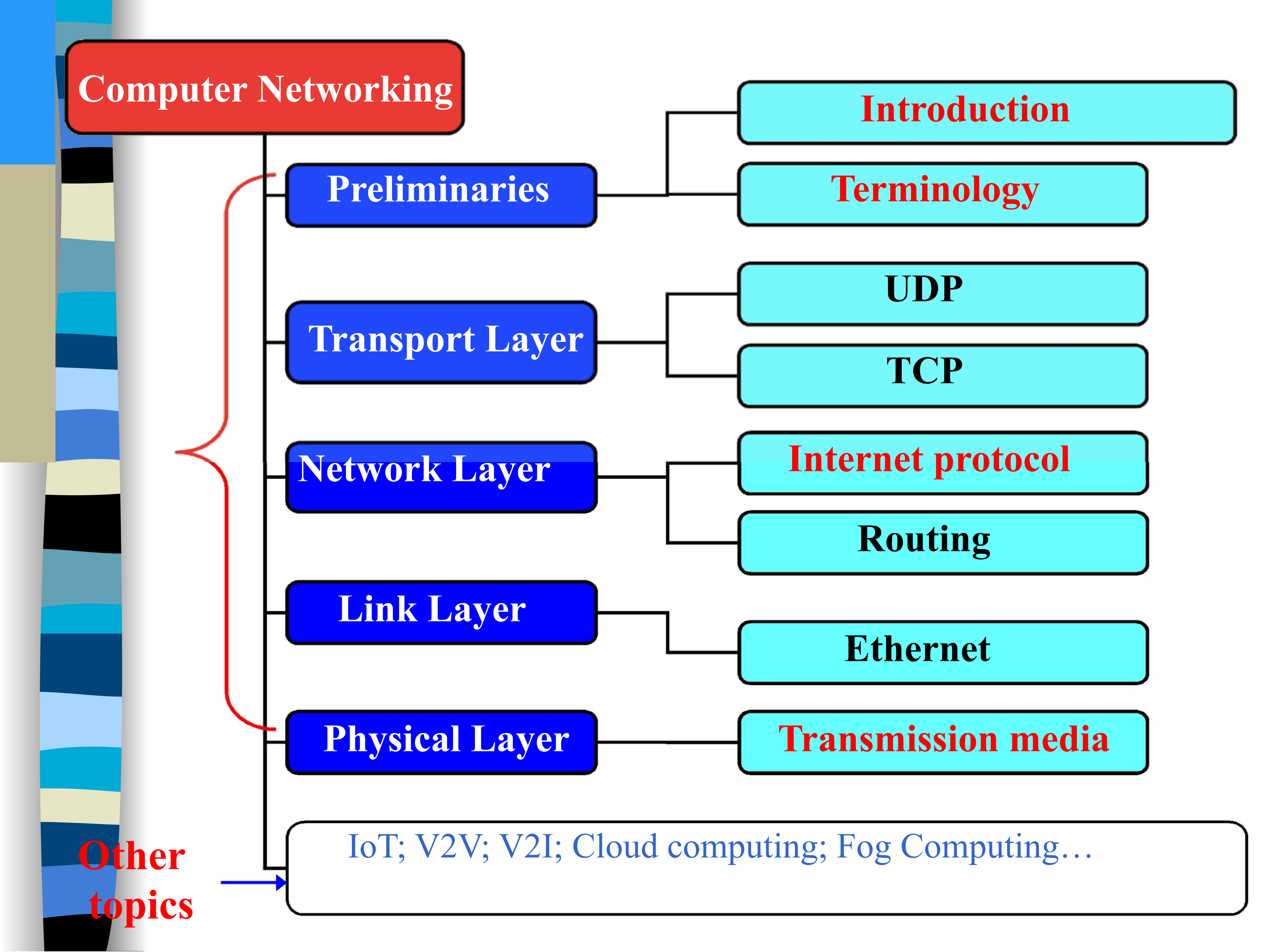
Simplified Data Communications Model



Networking

- Point-to-point communication not usually practical
  - Devices are too far apart
  - Large set of devices would need impractical number of connections
- Solution is a communications network





Computer Networking
Preliminaries
Introduction
Terminology
Transport Layer
UDP
TCP
Network Layer
Internet protocol
Routing
Link Layer
Ethernet
Physical Layer
Transmission media
IoT; V2V; V2I; Cloud computing; Fog Computing…
Other topics

Networks

- It is estimated that by 2016 there will be over 20 billion fixed and mobile networked devices
  - This affects traffic volume in a number of ways:
    - It enables a user to be continuously consuming network capacity
    - Capacity can be consumed on multiple devices simultaneously
    - Different broadband devices enable different applications which may have greater traffic generation capability

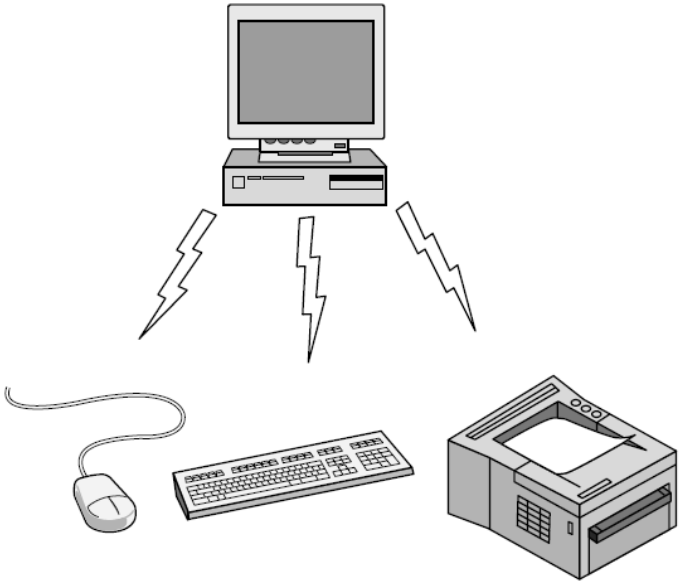
Network Hardware

- Networks can be classified by their scale:

Scale	**Type**
Vicinity	*PAN (Personal Area Network)* **»**
Building	*LAN (Local Area Network)* **»**
City	*MAN (Metropolitan Area Network)* **»**
Country	*WAN (Wide Area Network)* **»**
Planet	*The Internet (network of all networks)*

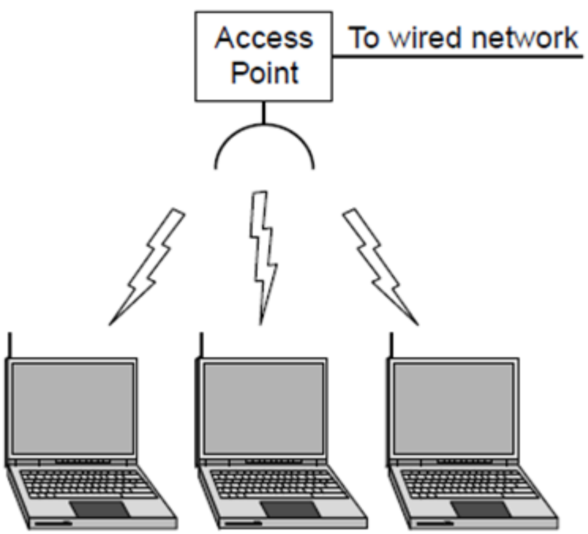
Personal Area Network

- Connect devices over the range of a person
- Example of a Bluetooth (wireless) PAN:

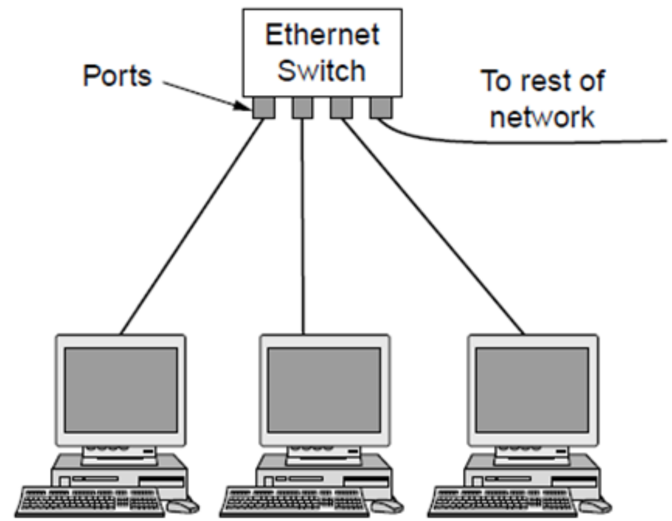


Local Area Networks

- Connect devices in a home or office building
- Called enterprise network in a company

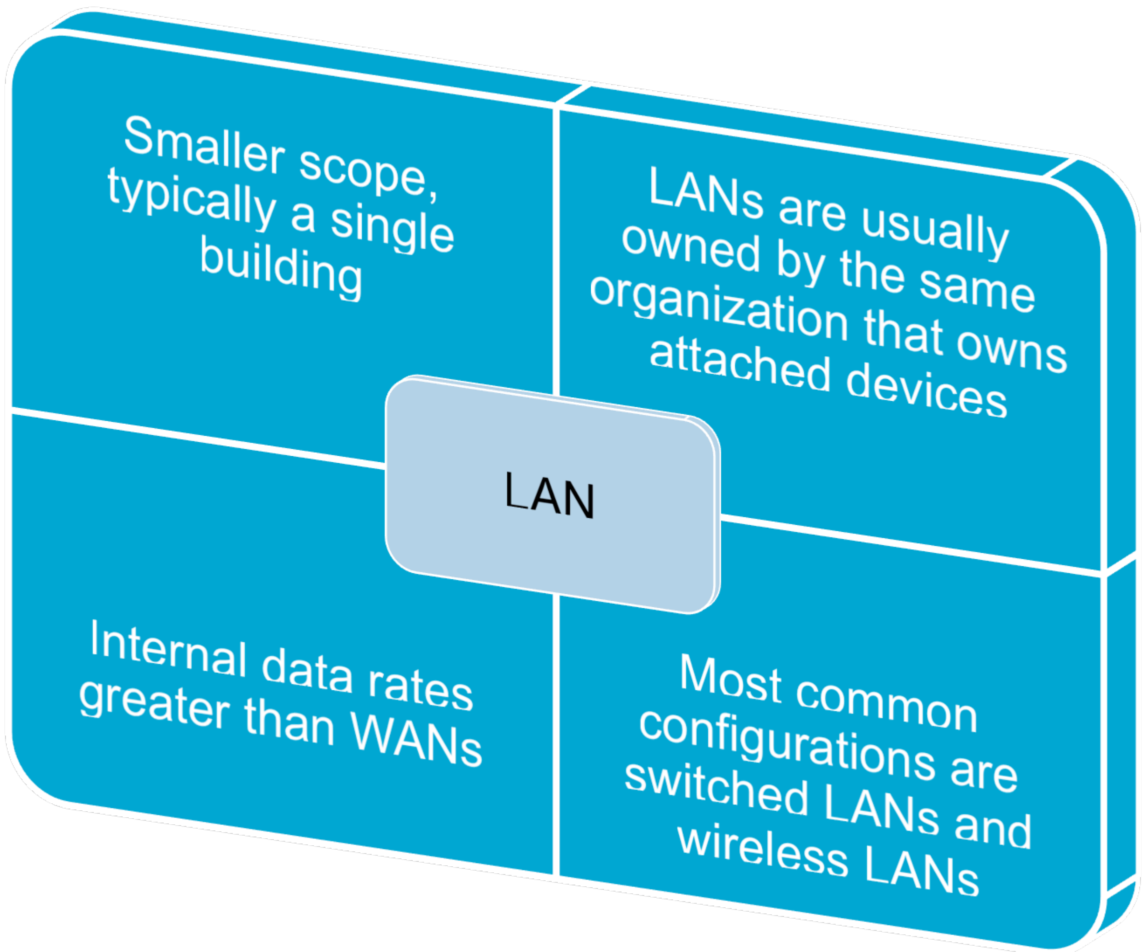


Wireless LAN with 802.11



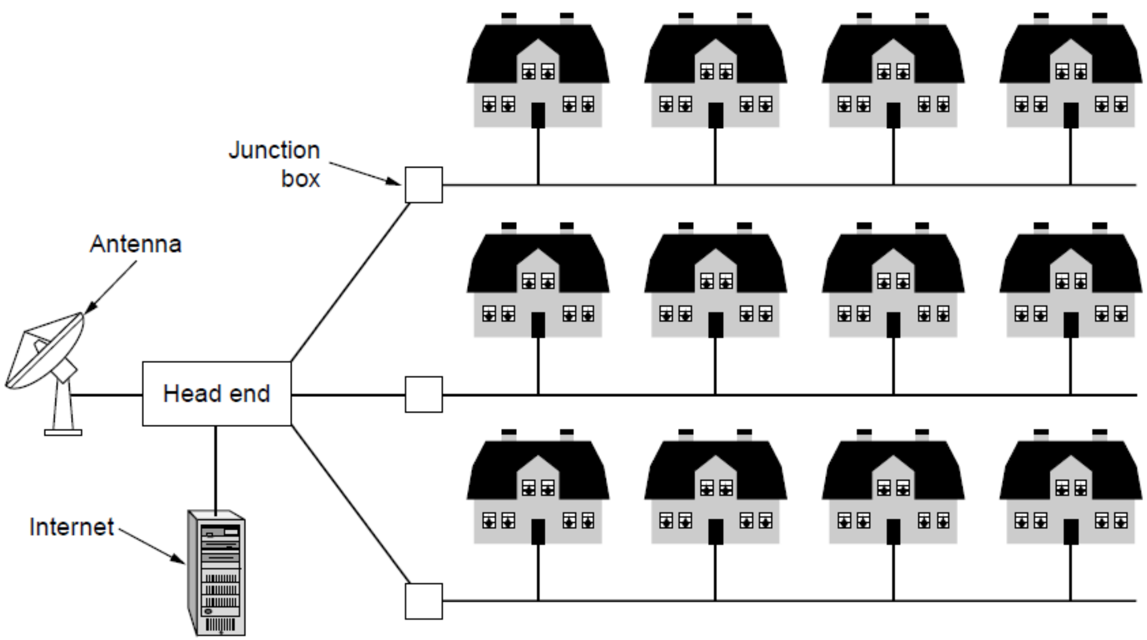
Wired LAN with switched Ethernet

Local Area Networks (LAN)



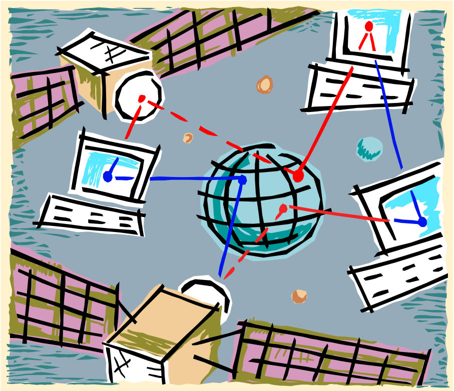
Metropolitan Area Networks

- Connect devices over a metropolitan area
- Example MAN based on cable TV:



Wide Area Networks (WANs)

- Span a large geographical area
- Require the crossing of public right-of-ways
- Rely in part on common carrier circuits
- Typically consist of a number of interconnected switching nodes



Wide Area Networks

Alternative technologies used include:

- Circuit switching
- Packet switching
- Frame relay
- Asynchronous Transfer Mode (ATM)

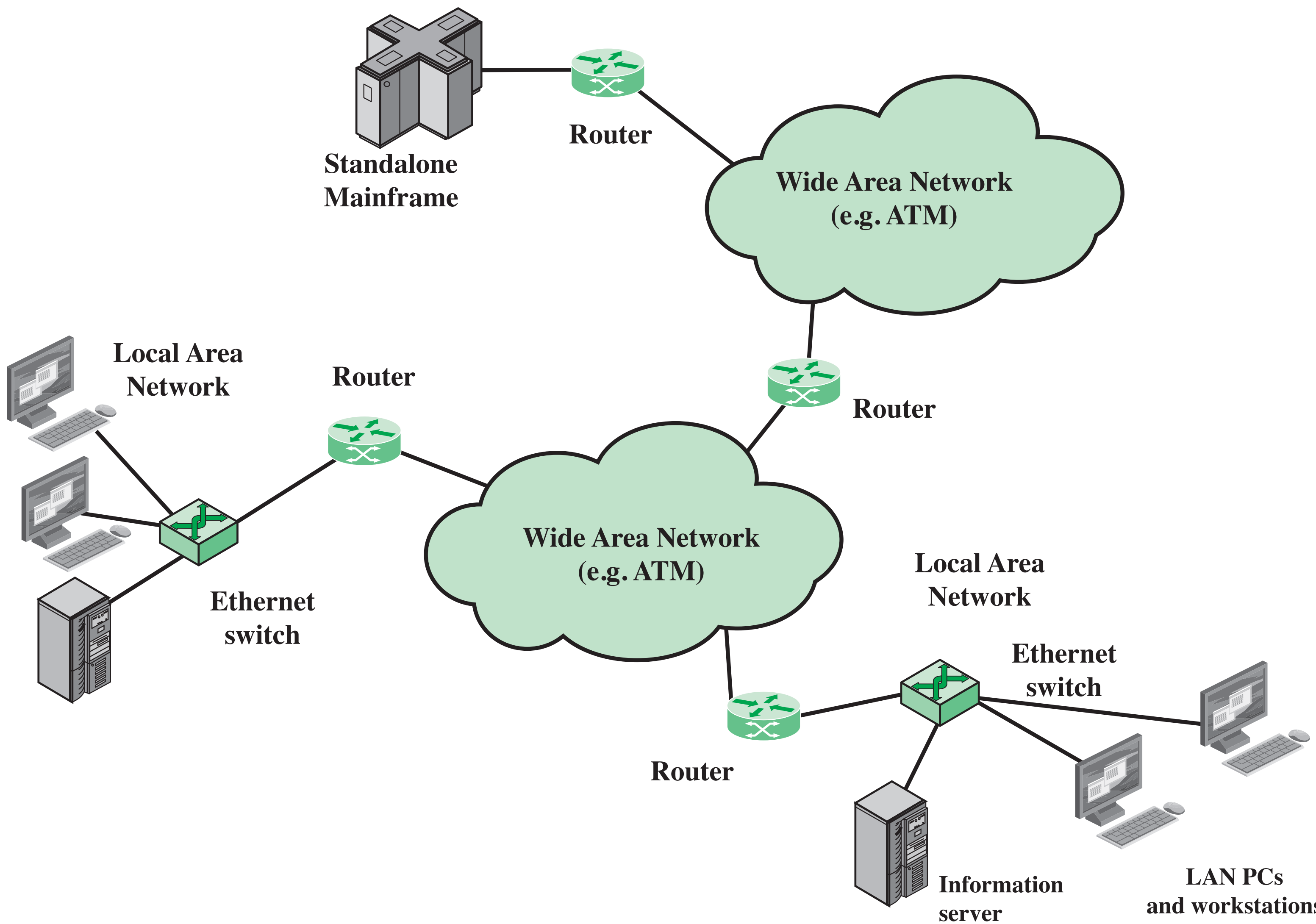


Figure 1.5 Key Elements of the Internet

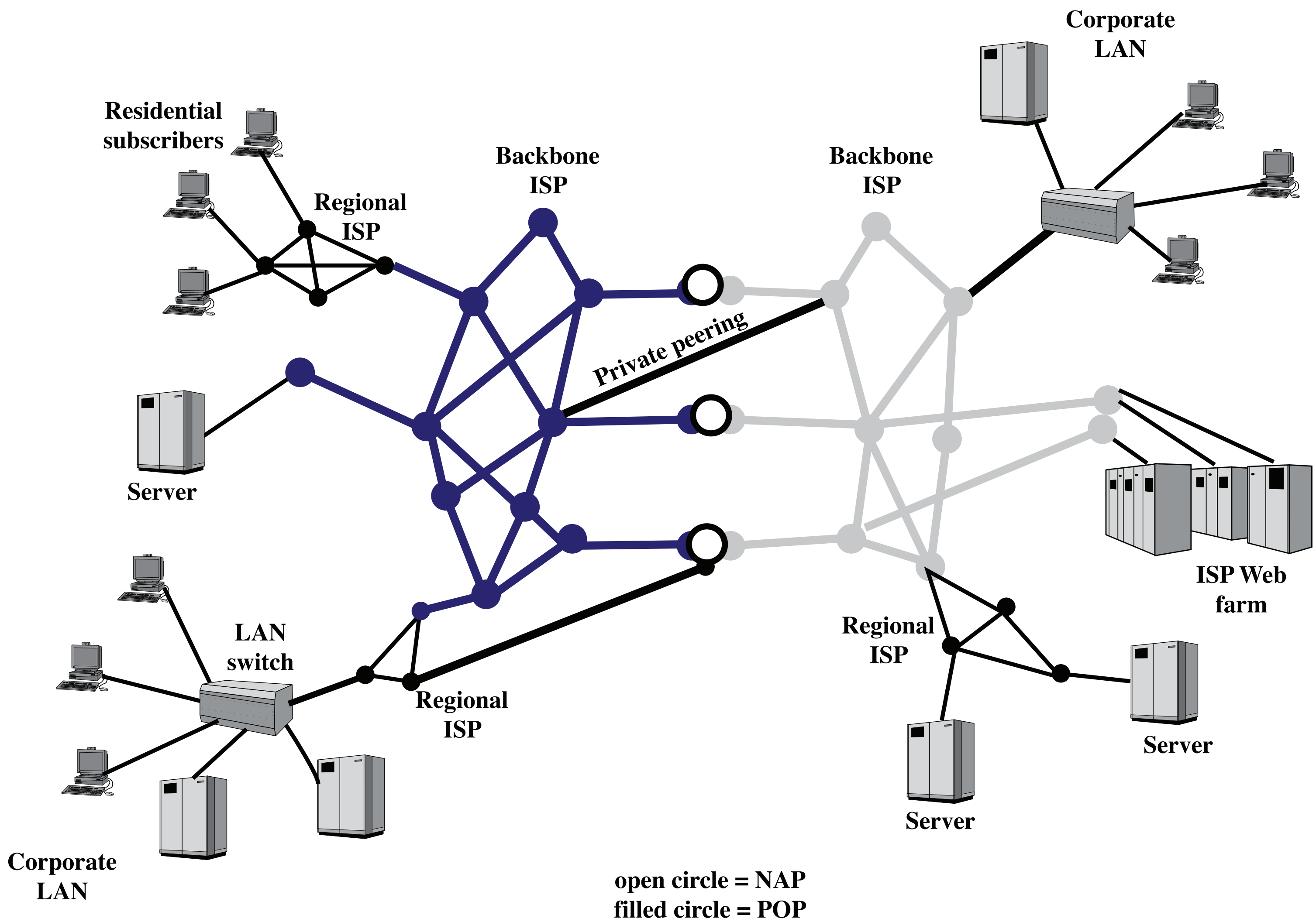


Figure 1.6 Simplified View of Portion of Internet

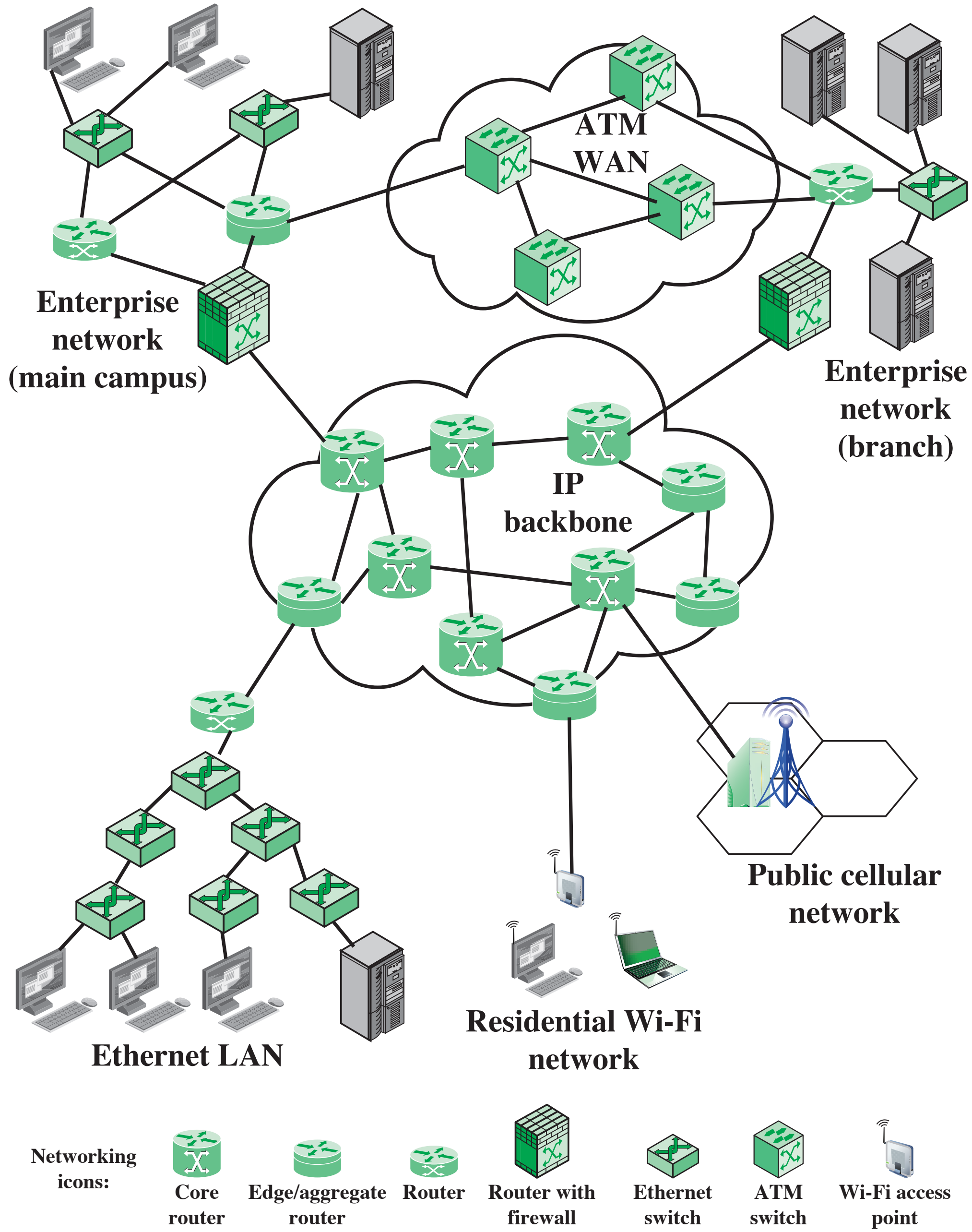
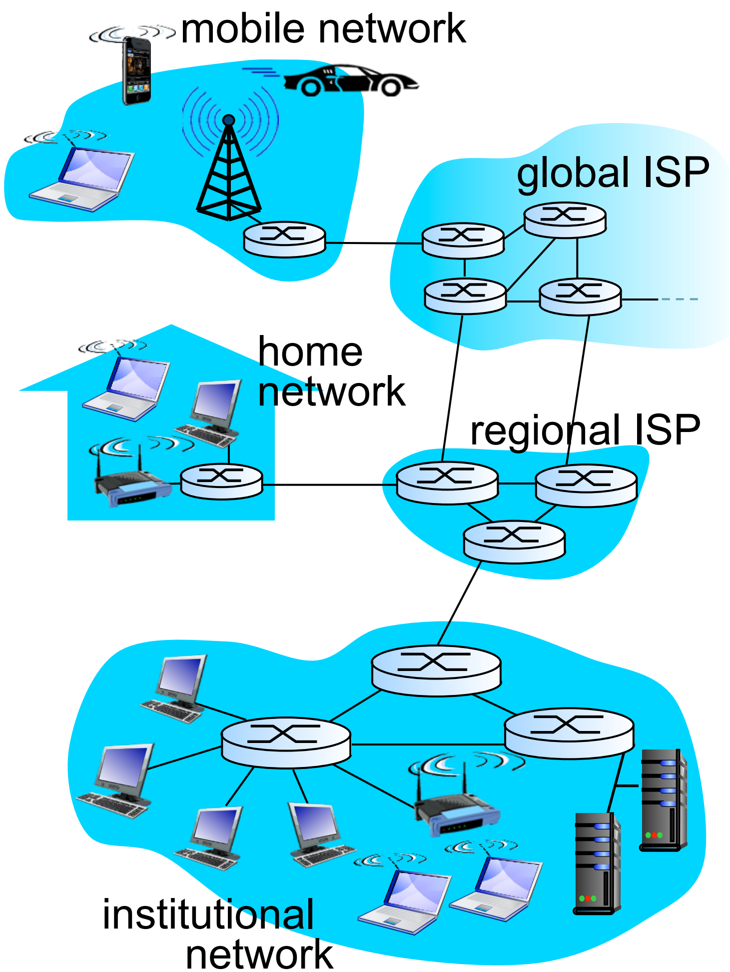


Figure 1.7 A Networking Configuration

A closer look at network structure:

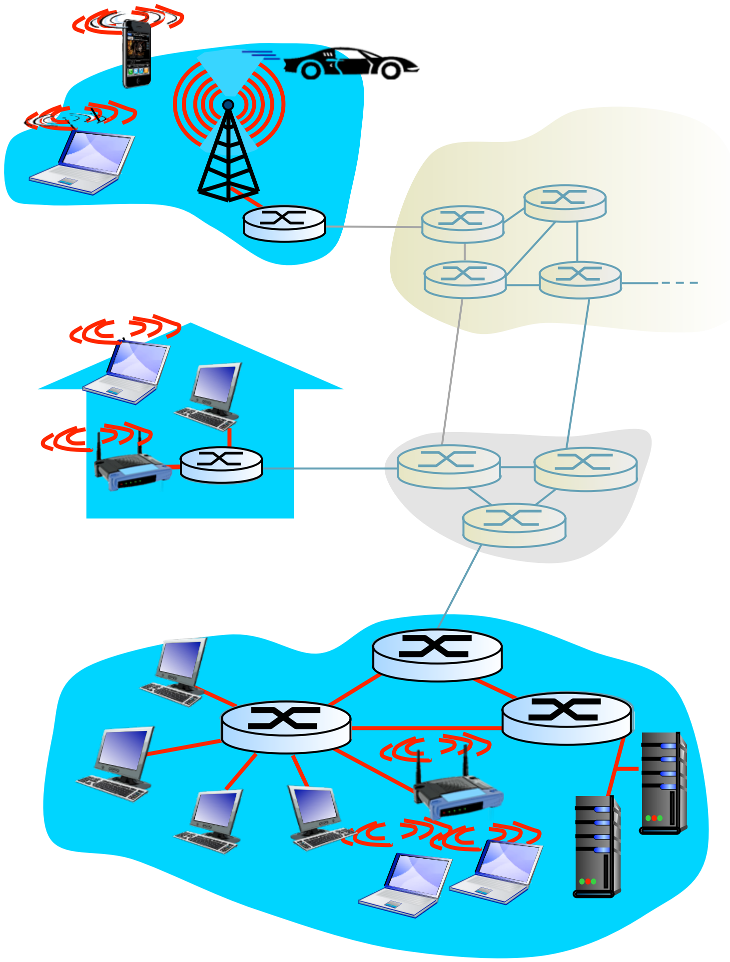
- *network edge:*
  - hosts: clients and servers
  - servers often in data centers
- *access networks, physical media:* wired, wireless communication links
- *network core:*
  - interconnected routers
  - network of networks



Access networks and physical media

Q: How to connect end systems to edge router?

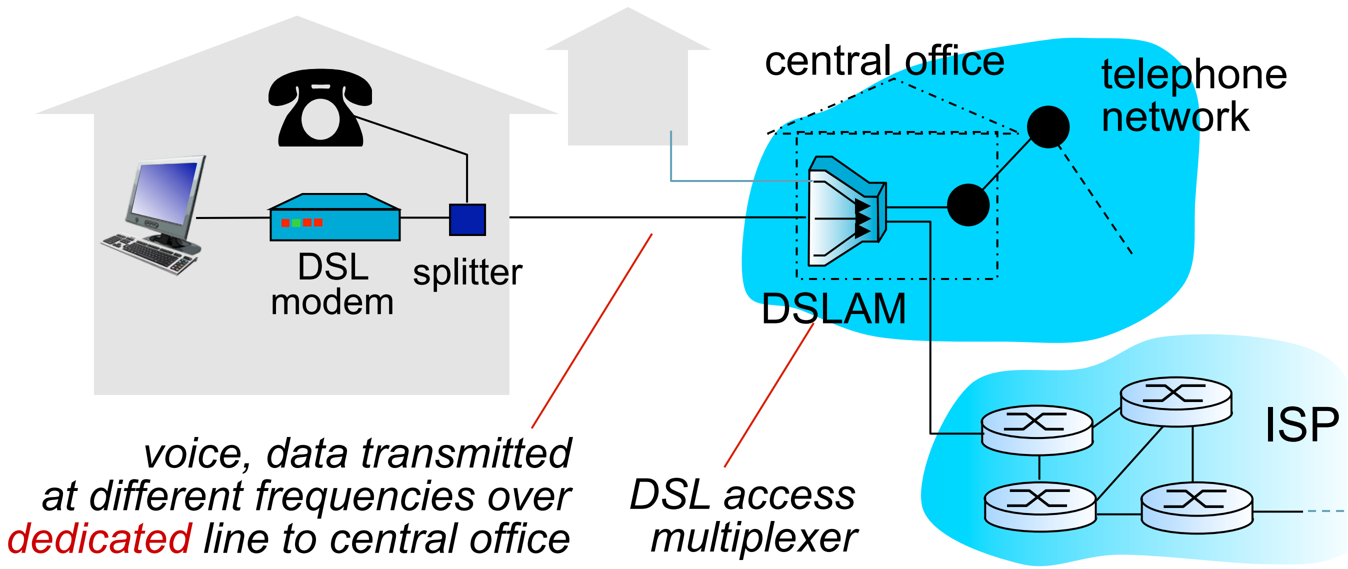
- residential access nets
- institutional access networks (school, company)
- mobile access networks



keep in mind:

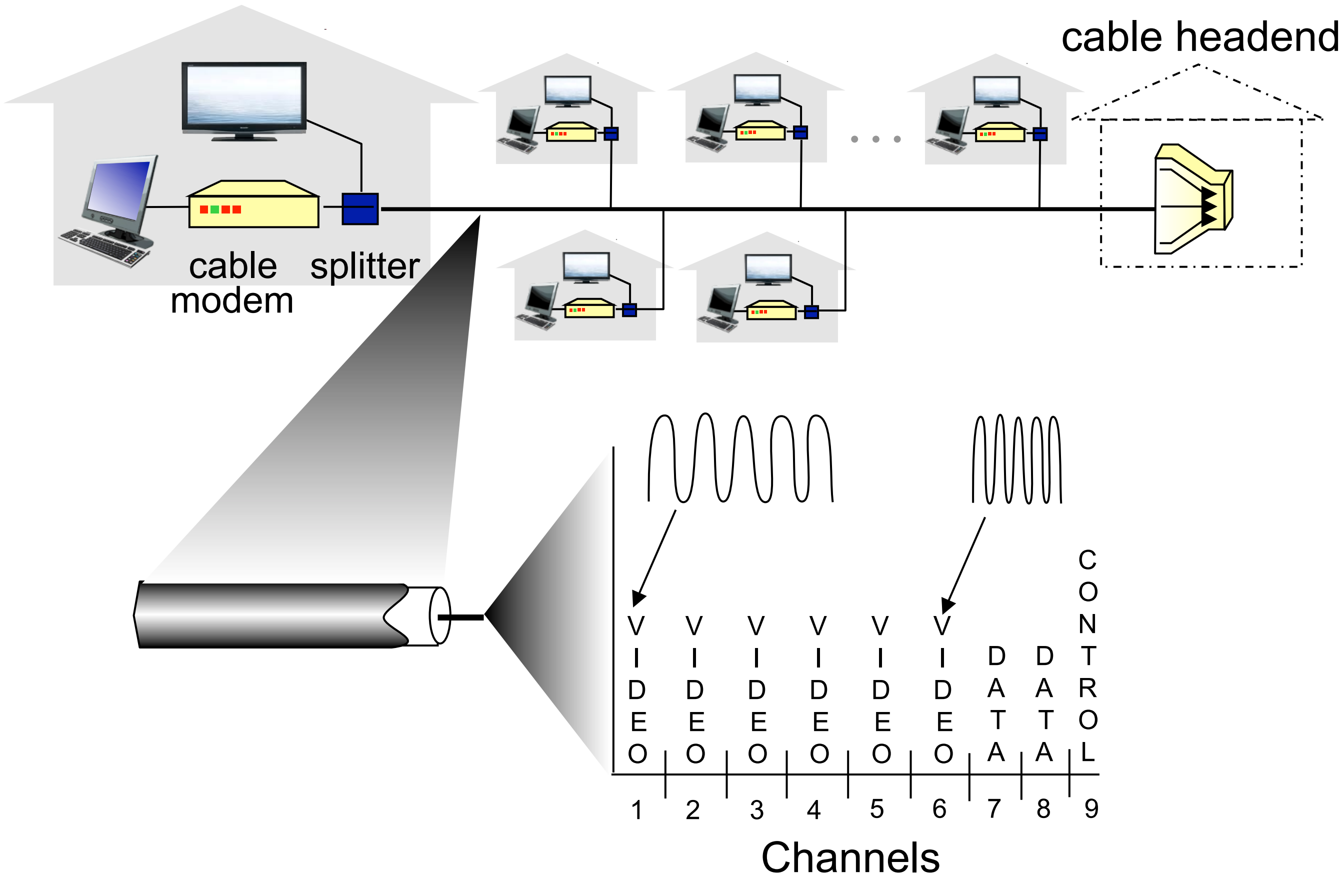
- bandwidth (bits per second) of access network?
- shared or dedicated?

Access net: digital subscriber line (DSL)



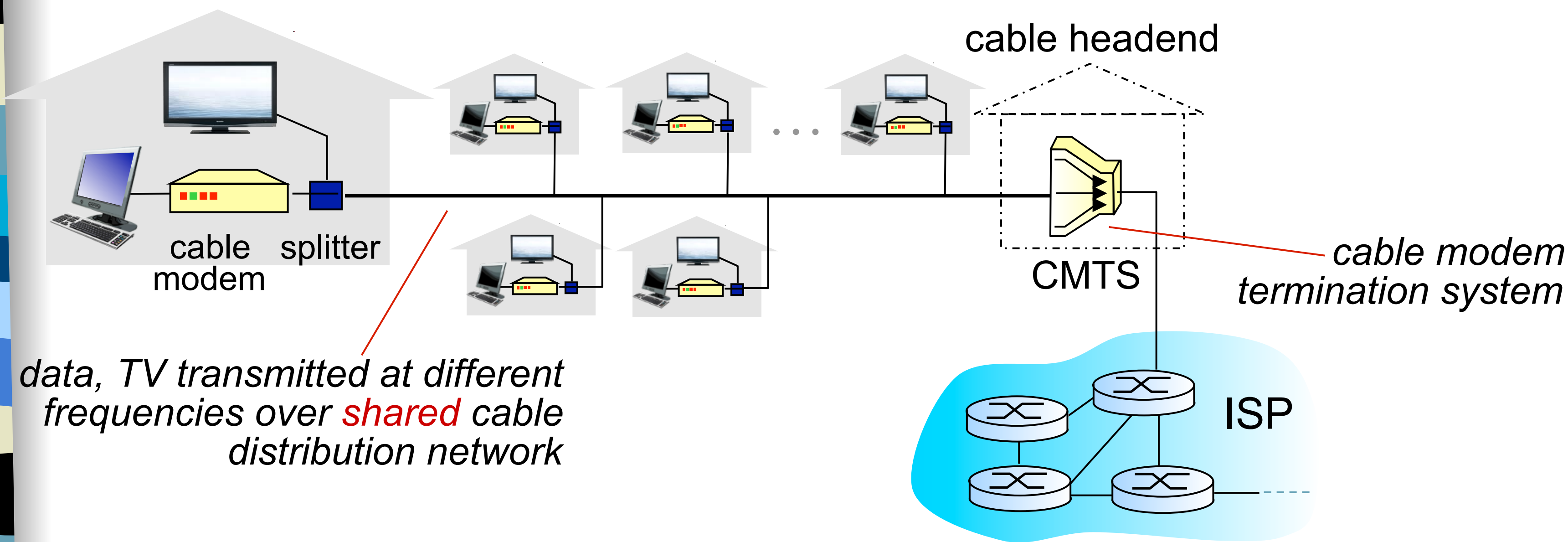
- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

Access net: cable network



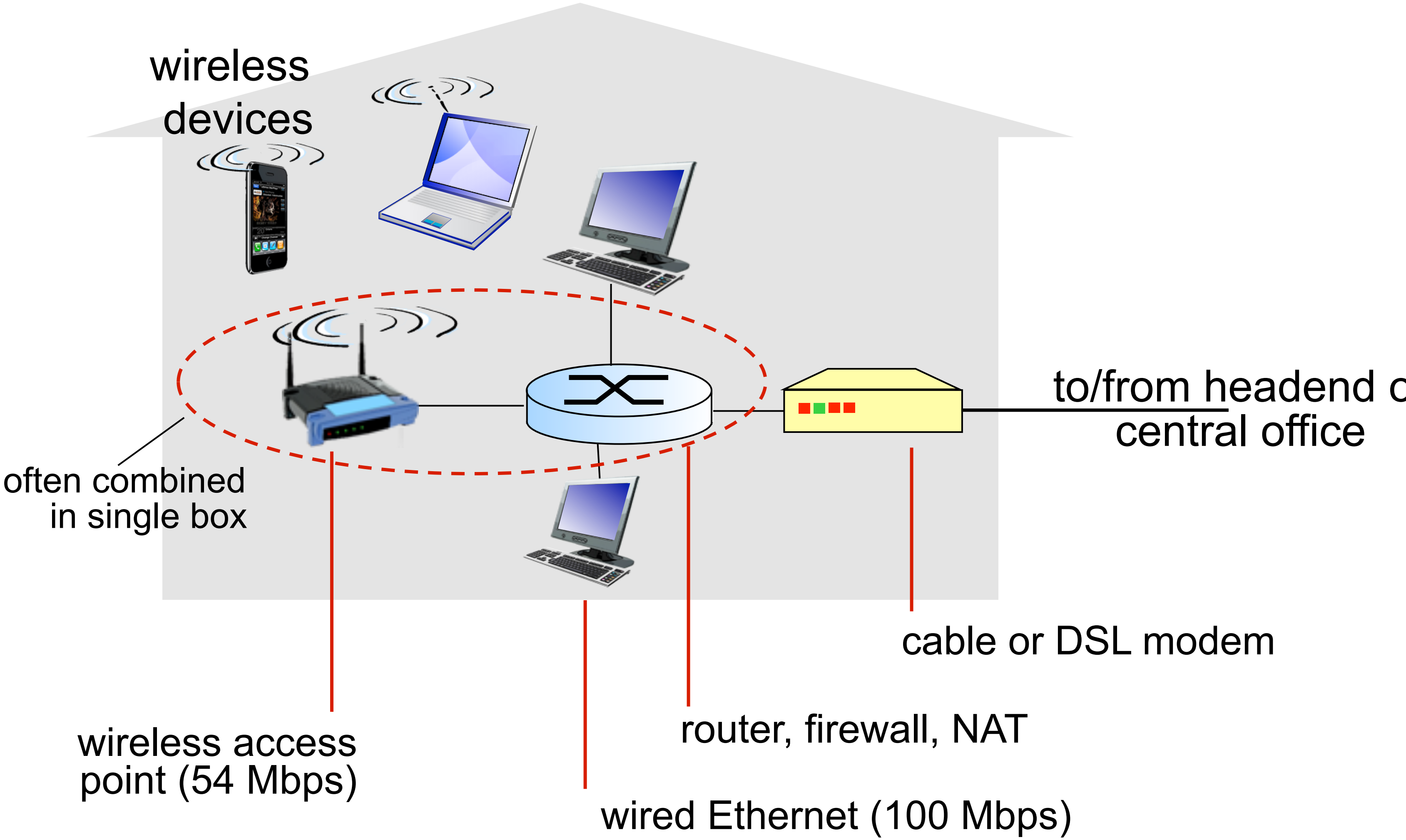
frequency division multiplexing: different channels transmitted in different frequency bands

Access net: cable network

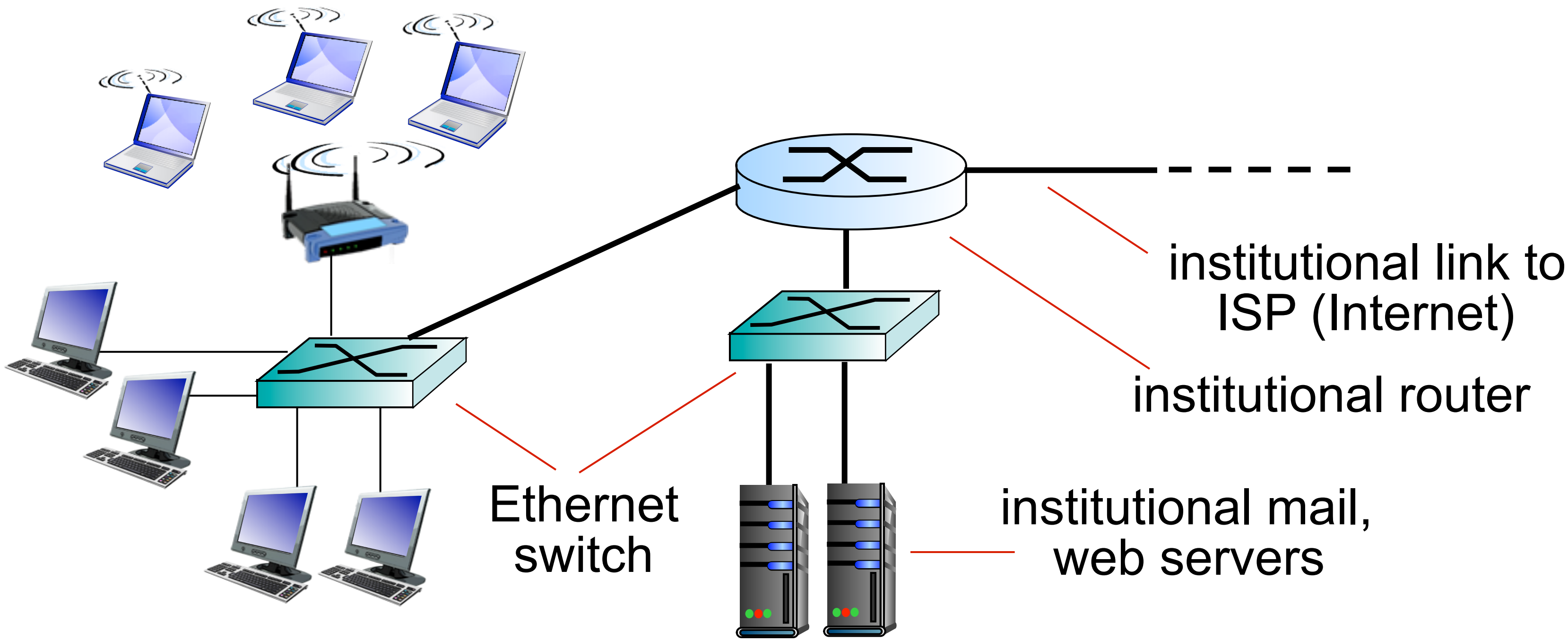


- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

Access net: home network



Enterprise access networks (Ethernet)



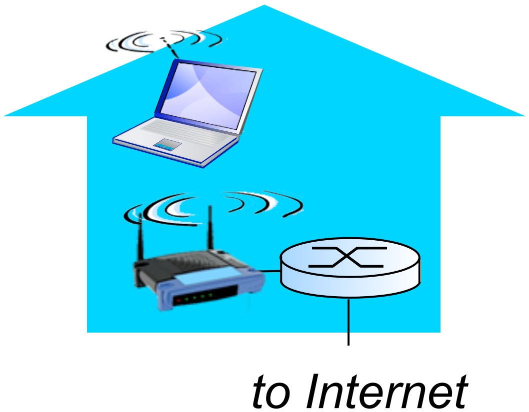
- typically used in companies, universities, etc
  - 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
  - today, end systems typically connect into Ethernet switch

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

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

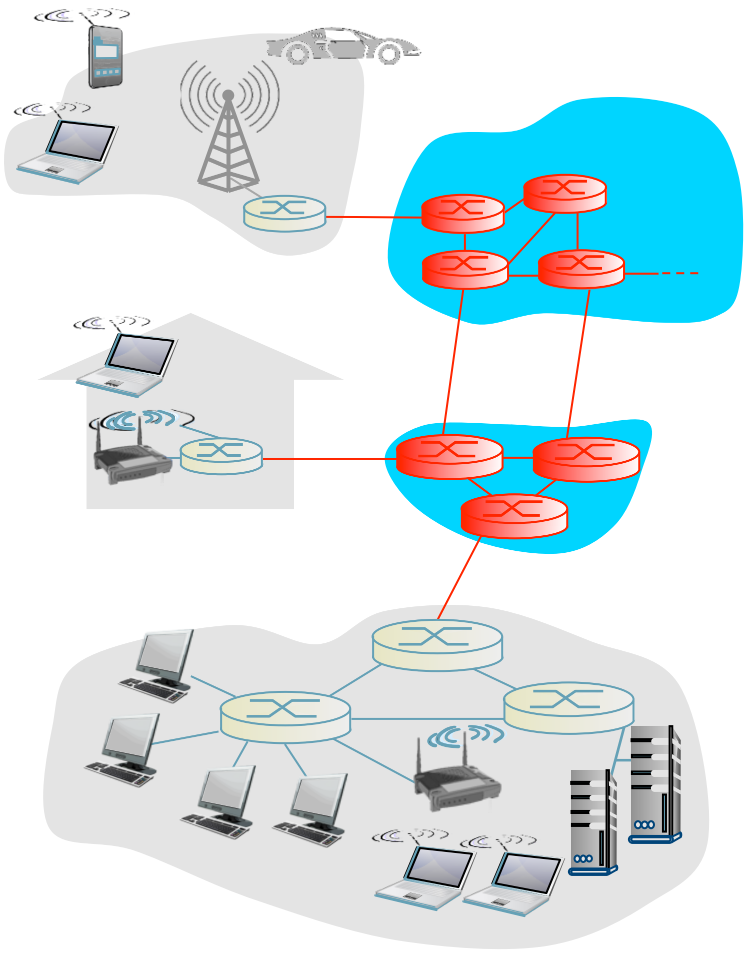
1.5 protocol layers, service models

1.6 networks under attack: security

1.7 history

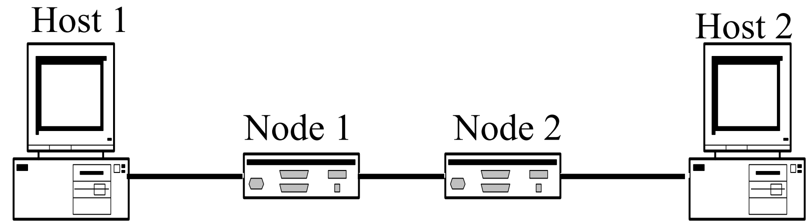
The network core

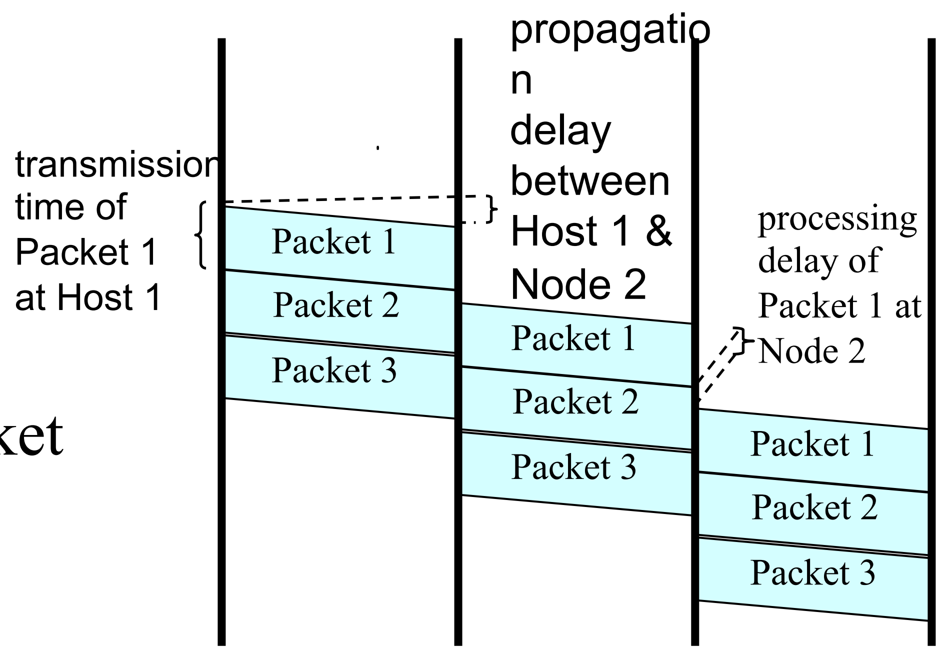
- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



Packet Switching

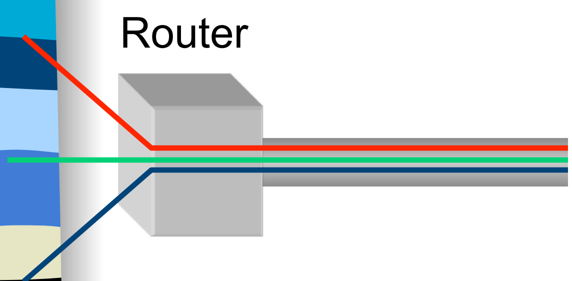
- Used in the Internet
- Data is sent in **Packets** (header contains control info, e.g., source and destination addresses)

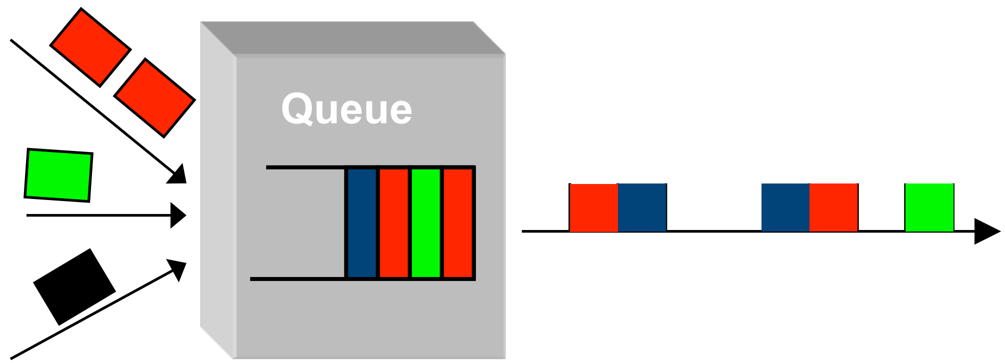




- Per-packet routing
- At each node the entire packet is received, stored, and then forwarded (**store-and-forward networks**)
- No capacity is allocated

Packet Switching: Multiplexing/ Demultiplexing





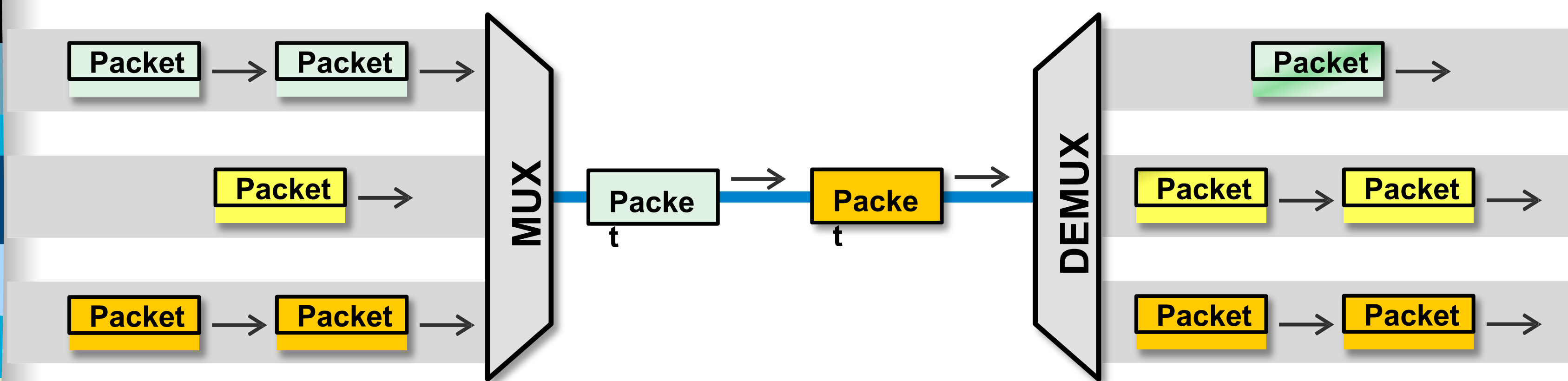
- Multiplex using a queue
  - Routers need memory/buffer
- Demultiplex using information in packet header
  - Header has destination
  - Router has a routing table that contains information about which link to use to reach a destination

Multiplexing, Demultiplexing

In multiplexing, data from multiple input lines (physical or logical connections) is aggregated and sent out a single output line.

On the receiver side, a demultiplexer performs the reverse operation by breaking up the data stream into the original input data streams.

Mux / Demux pairs are typically used to save transmission lines or resources for logical connections on end systems.

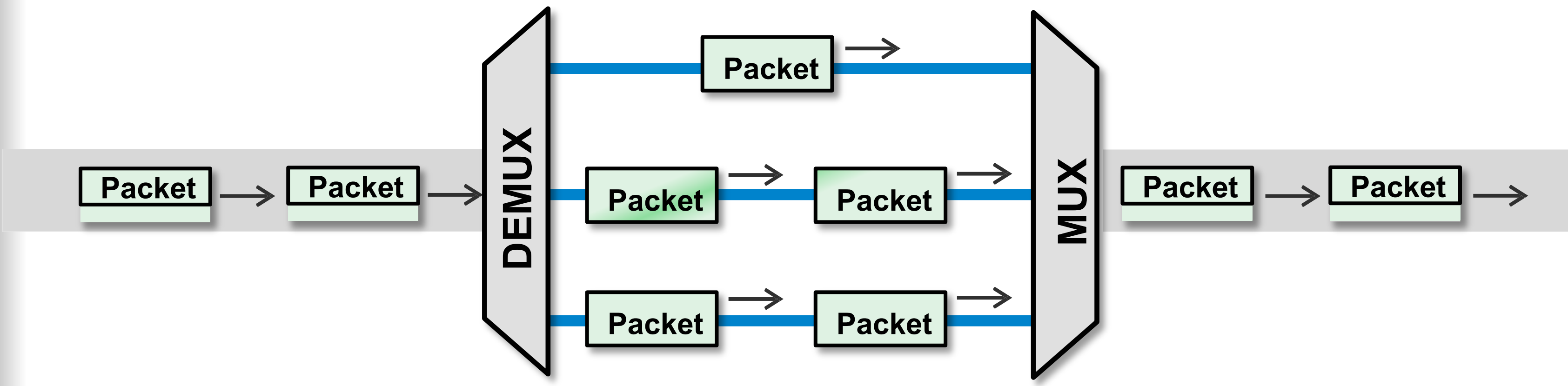


Inverse Multiplexing

Inverse multiplexing is used to distribute traffic over multiple lines, e.g. for load distribution over a number of physical lines.

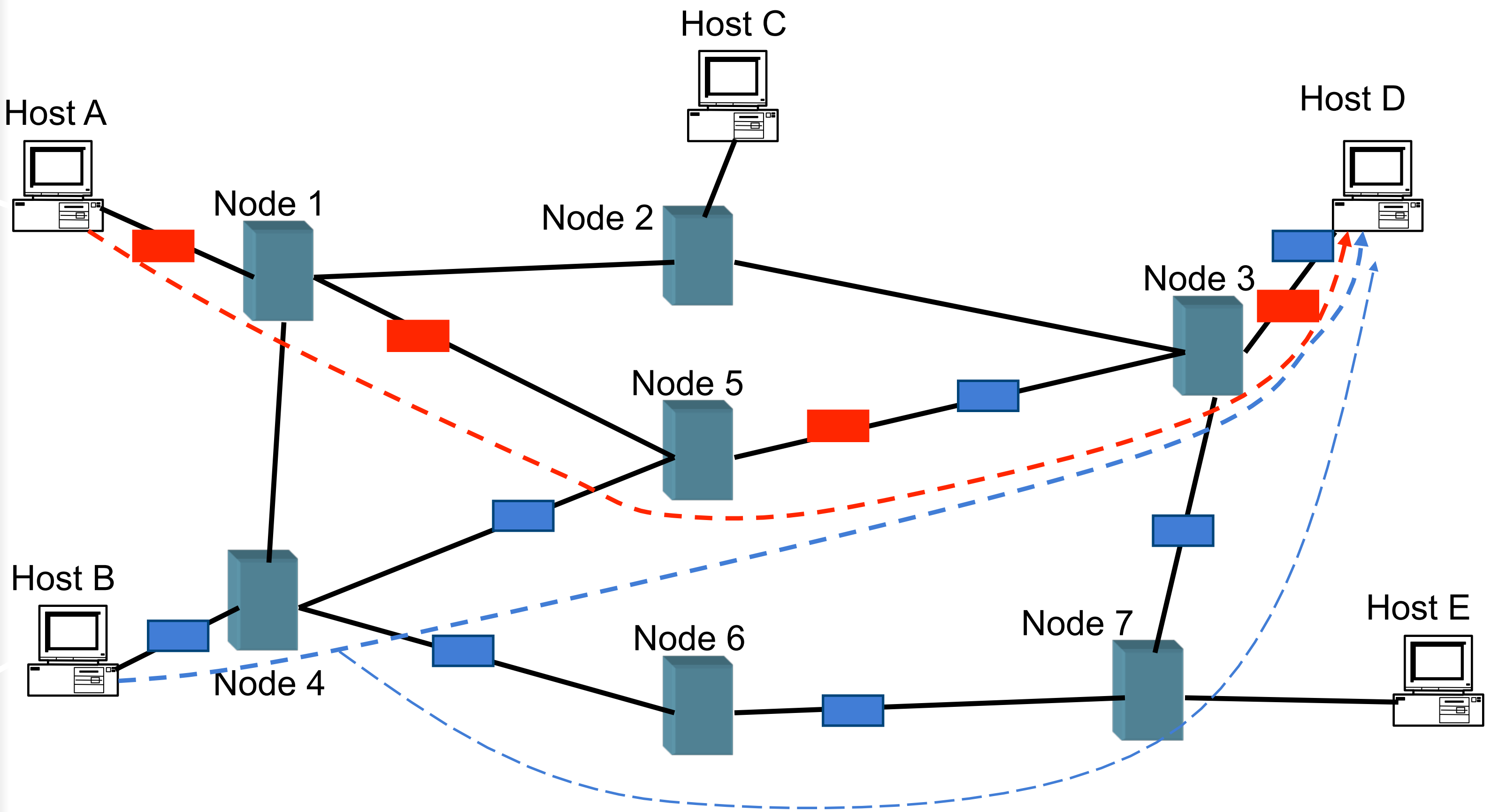
Since some protocols are sensitive to reordering of packets (e.g. VoIP), inverse multiplexing must make sure that the receiver demultiplexes packets into the same order as they were received by the sender. This is typically achieved by adding some additional header to the packets carrying sequencing information.

An additional benefit of inverse multiplexing may be some form of redundancy. If one of the physical transmission lines fails, communication is still possible over the remaining transmission lines.



Packet switching also show reordering

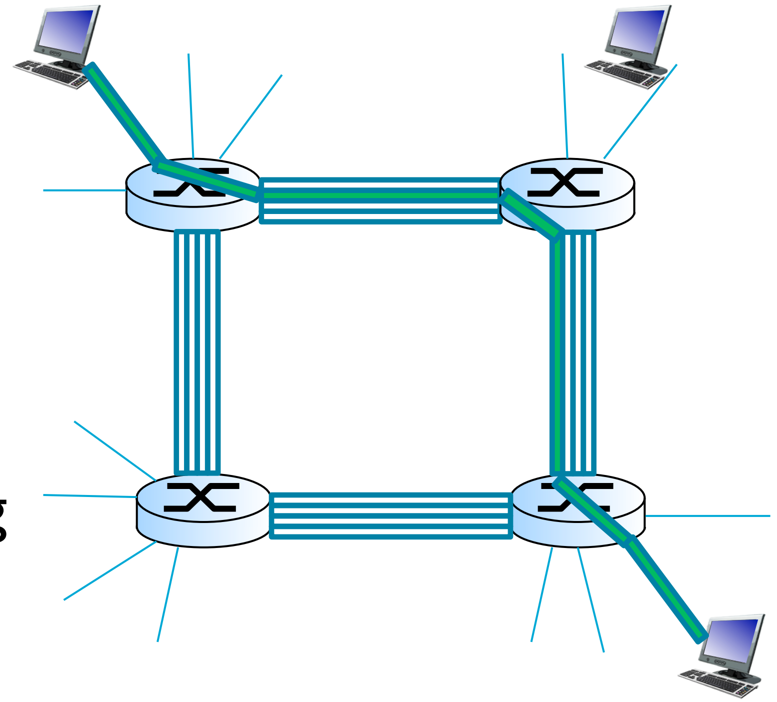
Packets in a flow may not follow the same path (depends on routing as we will see later) → packets may be reordered



Alternative core: circuit switching

end-end resources allocated to, reserved for "call" between source & dest:

- In diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- Commonly used in traditional telephone networks

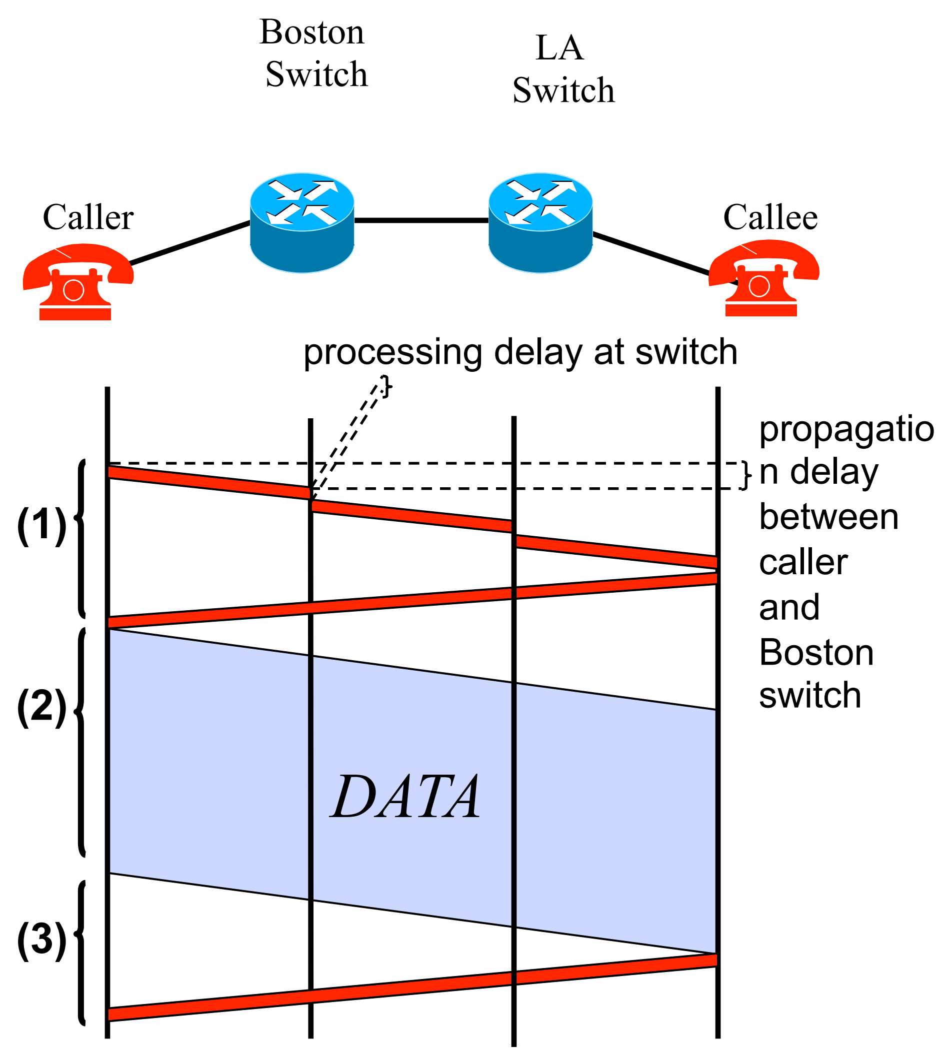


Circuit Switching

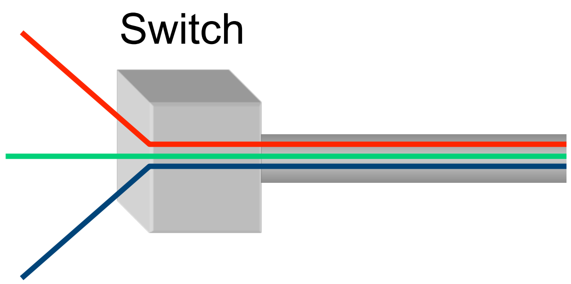
- It's the method used by the telephone network
- A call has three phases:

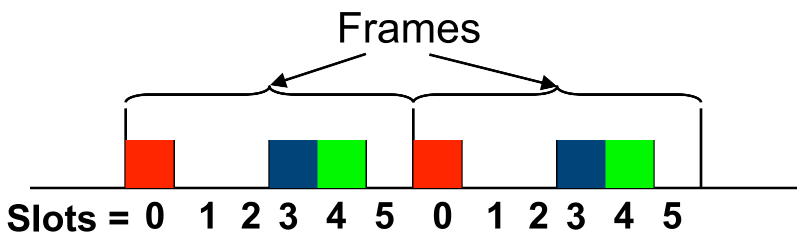
1. Establish circuit from end-to-end ("dialing"),
2. Communicate,
3. Close circuit ("tear down").

- If circuit not available: "busy signal"



Circuit Switching: Multiplexing/ Demultiplexing





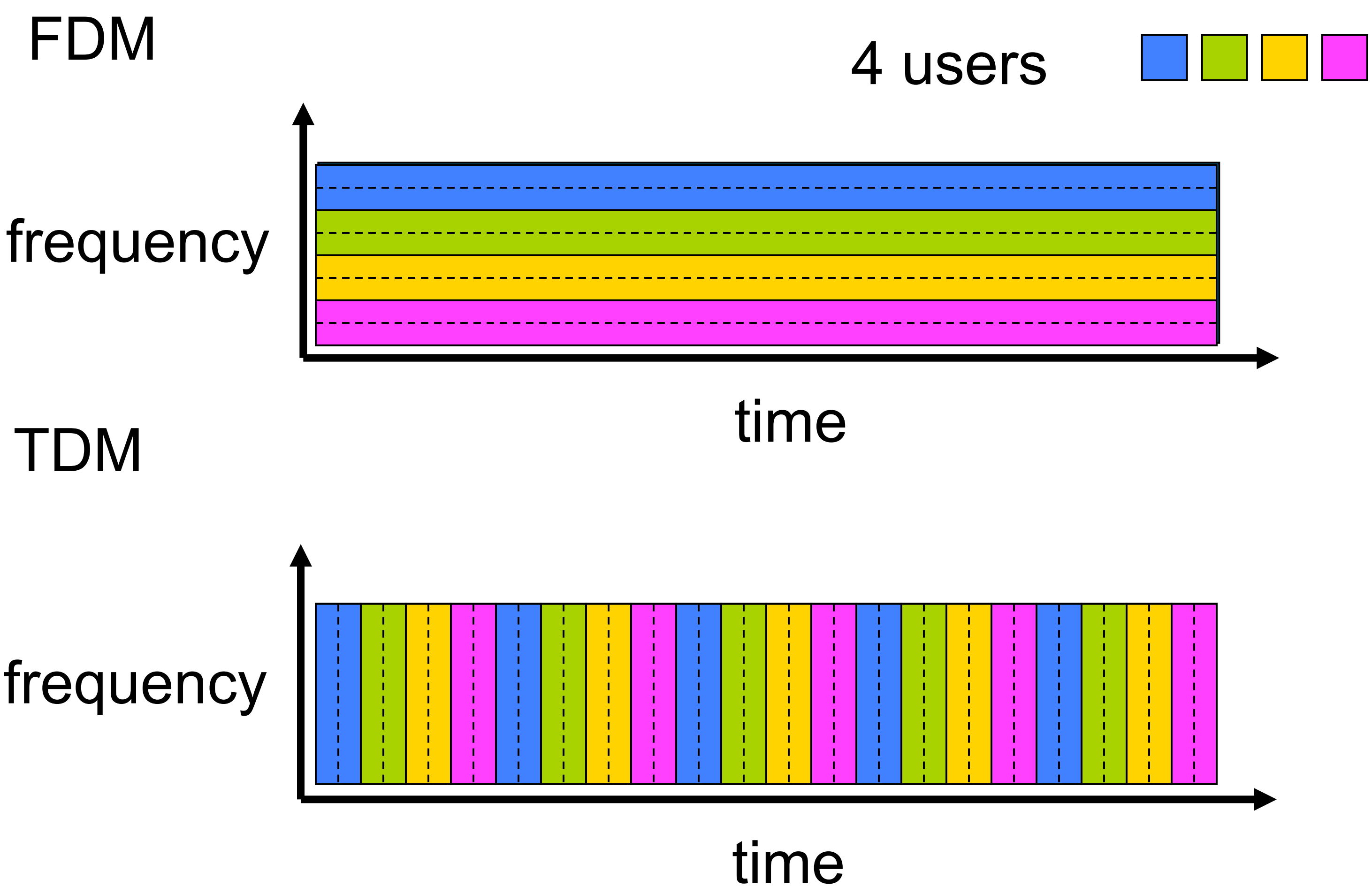
One way for sharing a circuit is TDM:

- Time divided into frames and frames divided into slots
- Relative slot position inside a frame determines which conversation the data belongs to
  - E.g., slot 0 belongs to the red conversation
- Need synchronization between sender and receiver

Circuit switching: FDM versus TDM

Example:

4 users

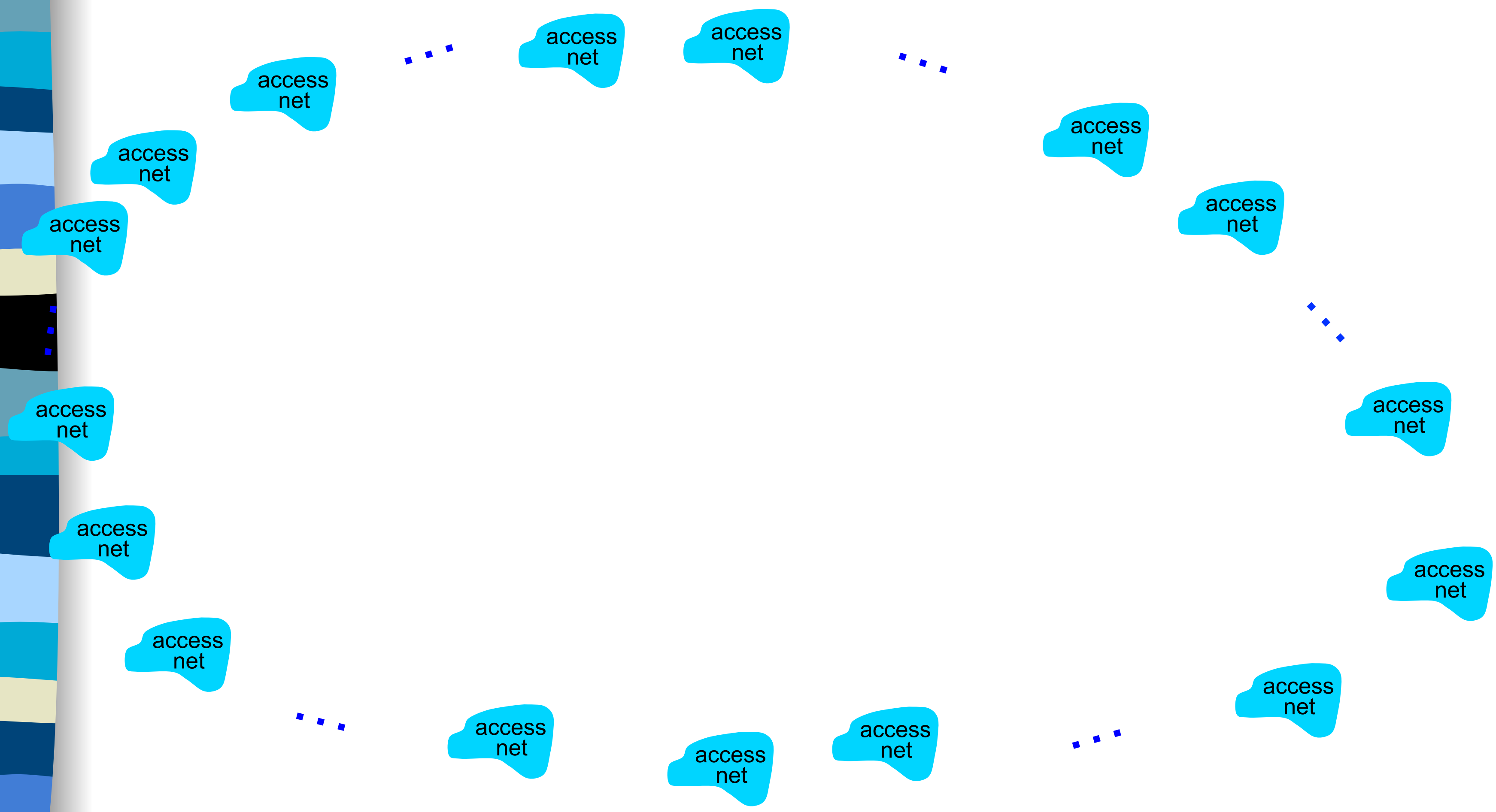


Internet structure: network of networks

- 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

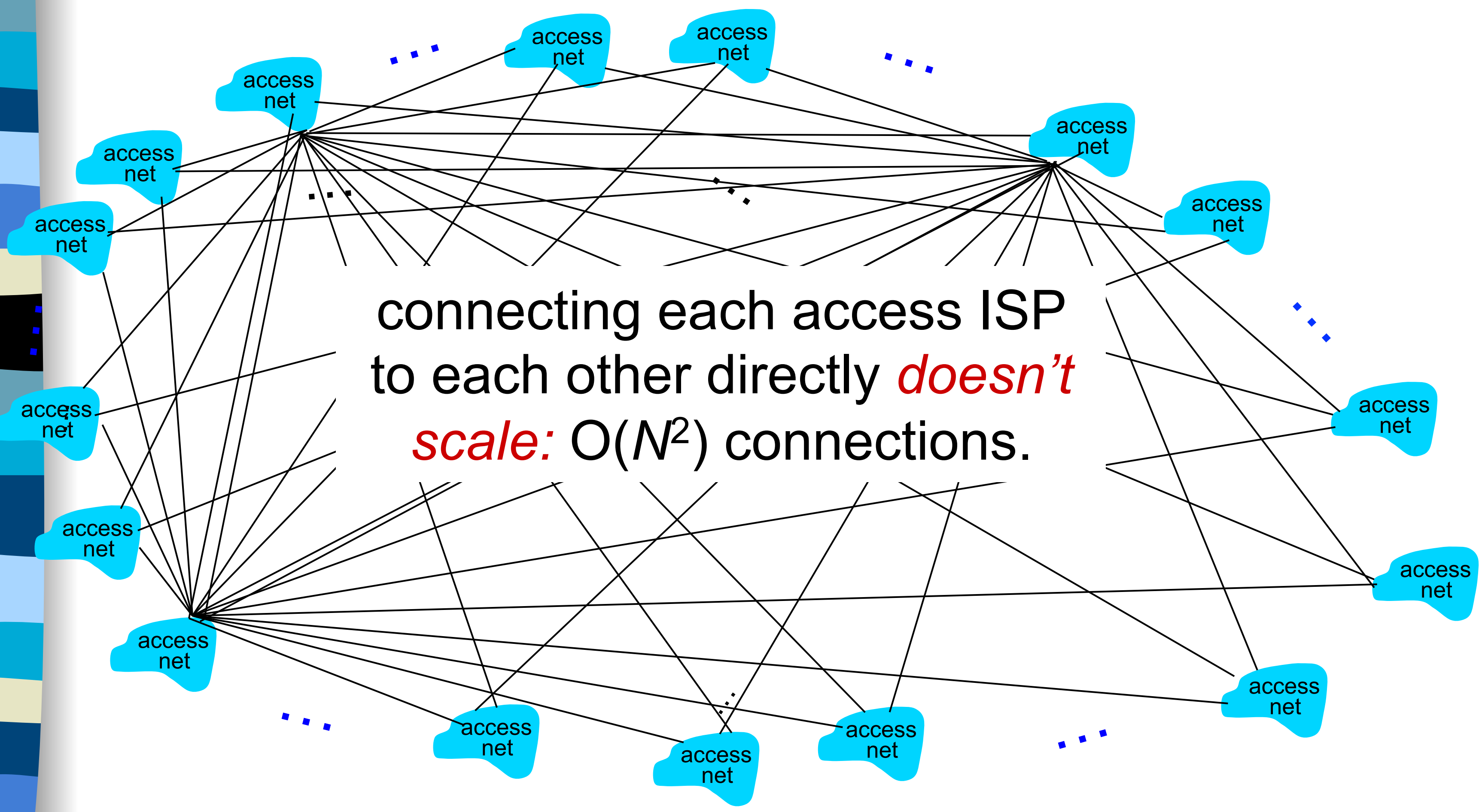
Internet structure: network of networks

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



Internet structure: network of networks

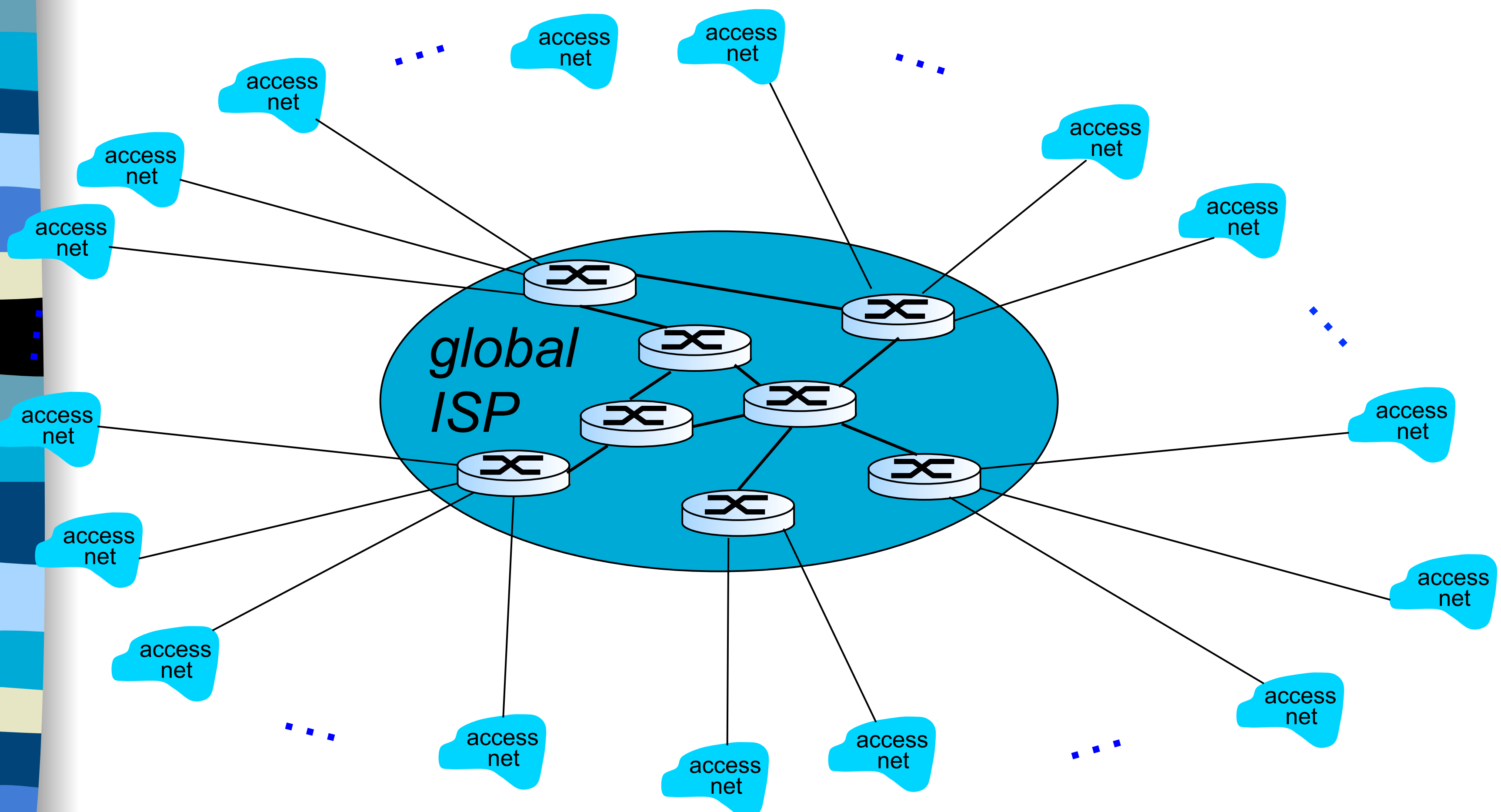
Option: connect each access ISP to every other access ISP?



connecting each access ISP to each other directly *doesn't scale:* O(N^2) connections.

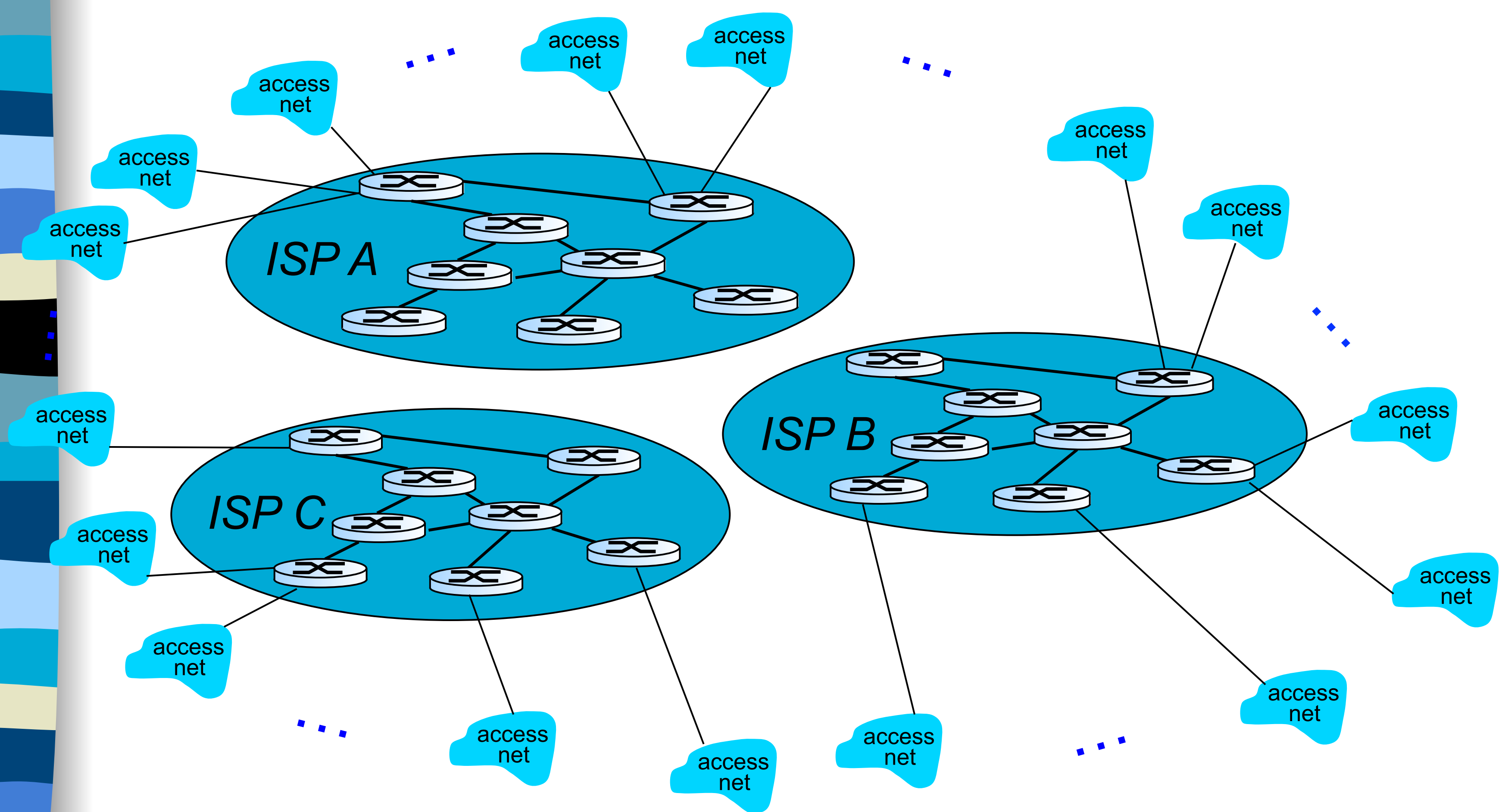
Internet structure: network of networks

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



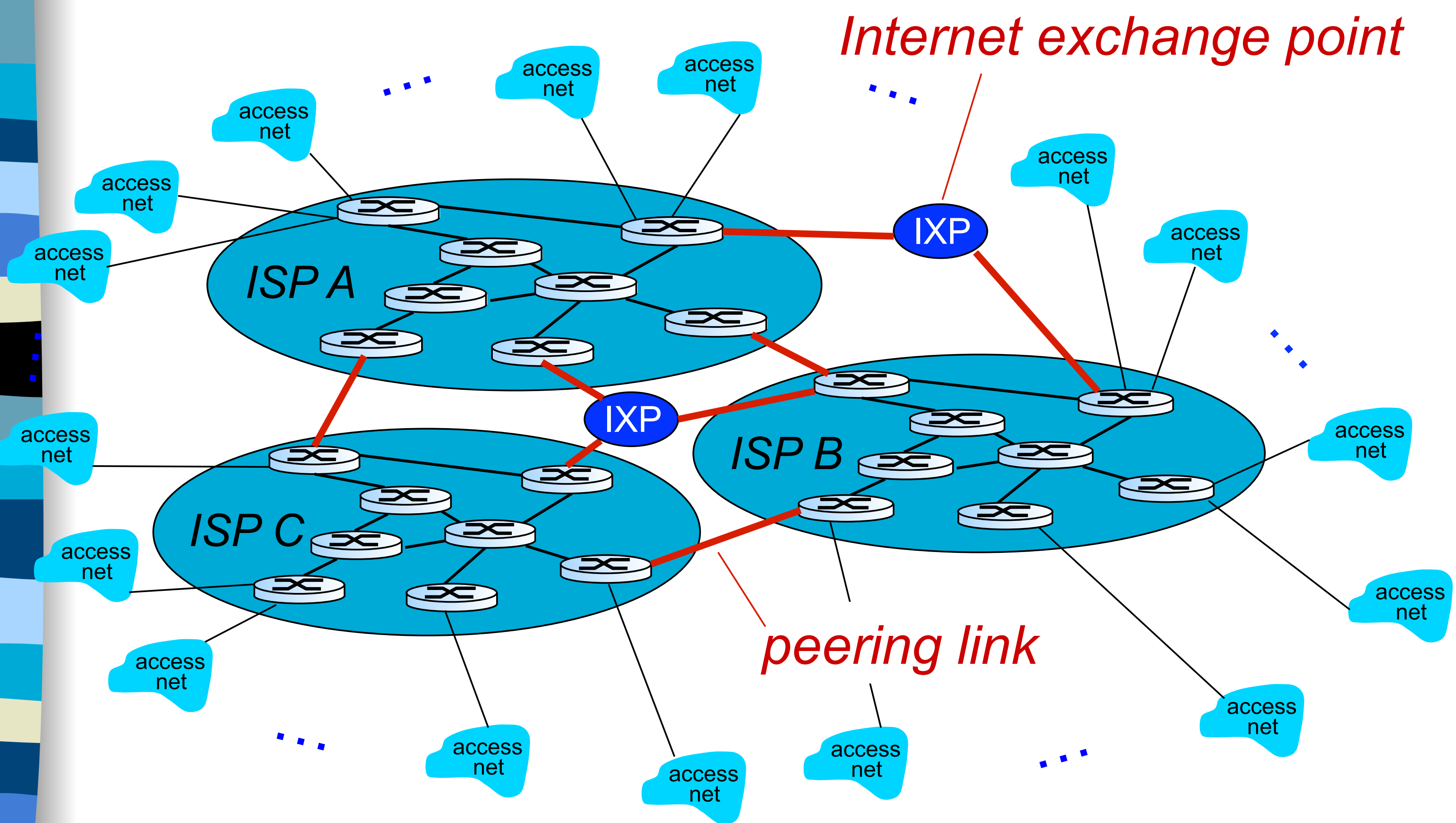
Internet structure: network of networks

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



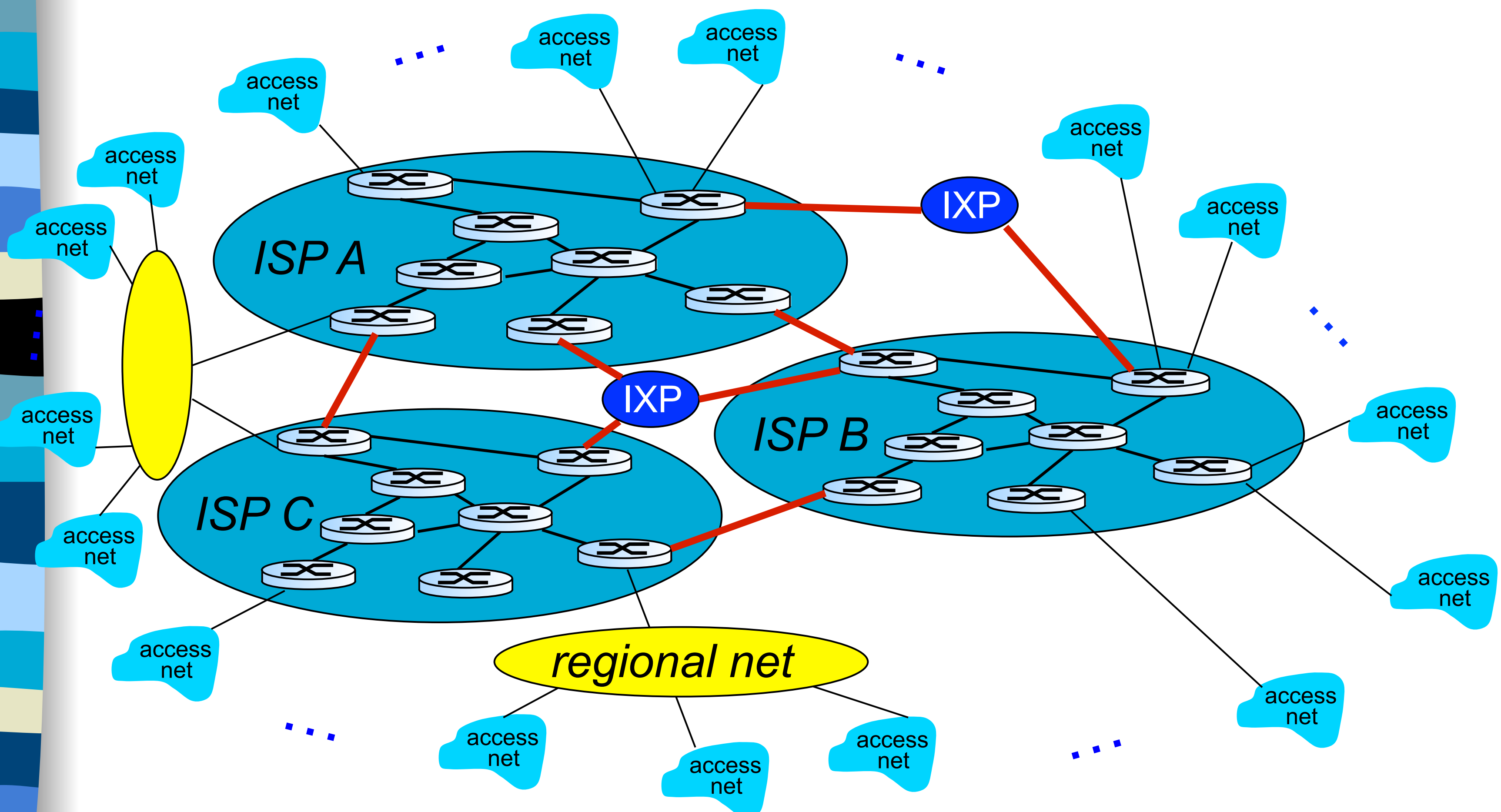
Internet structure: network of networks

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



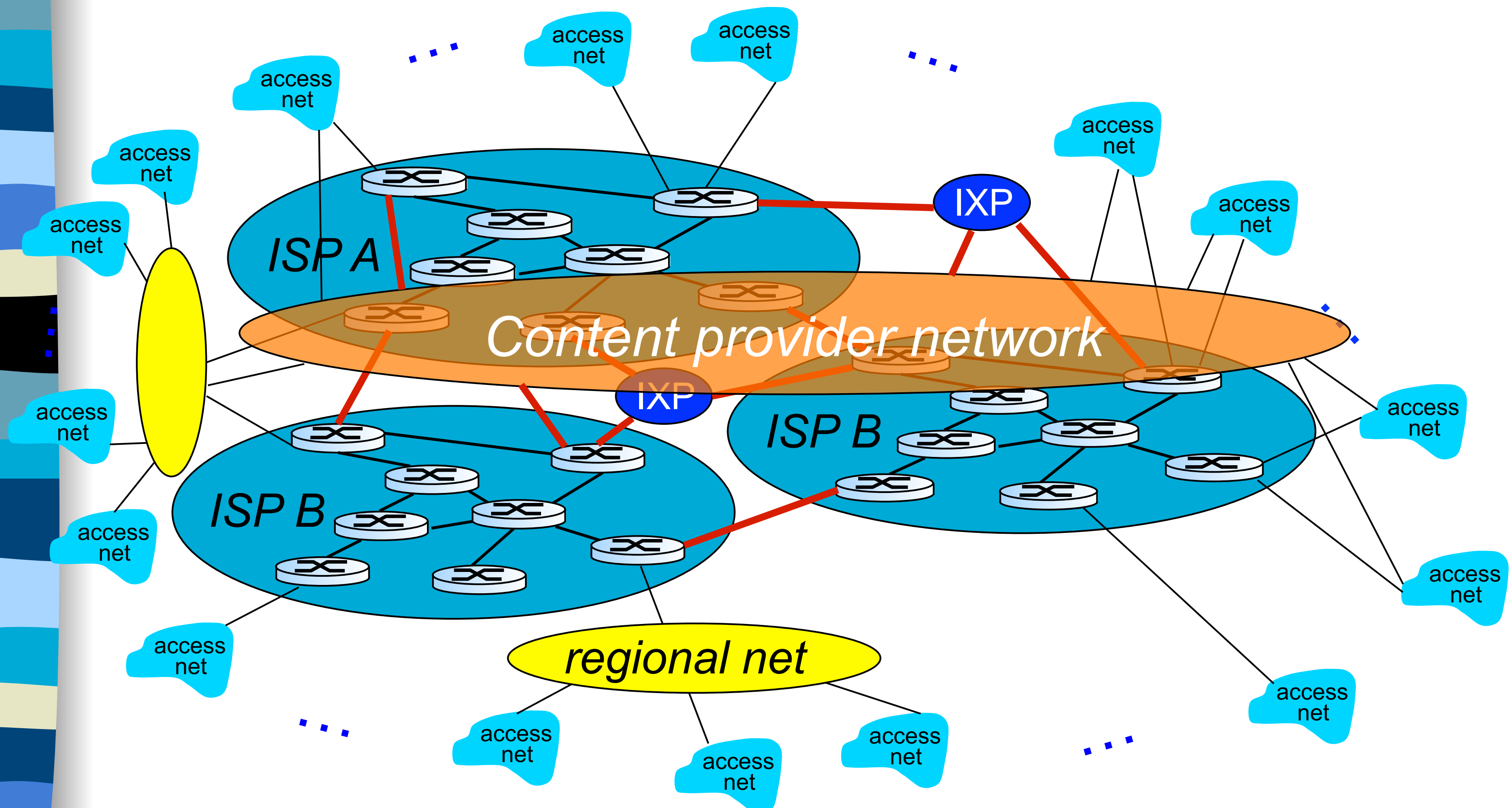
Internet structure: network of networks

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

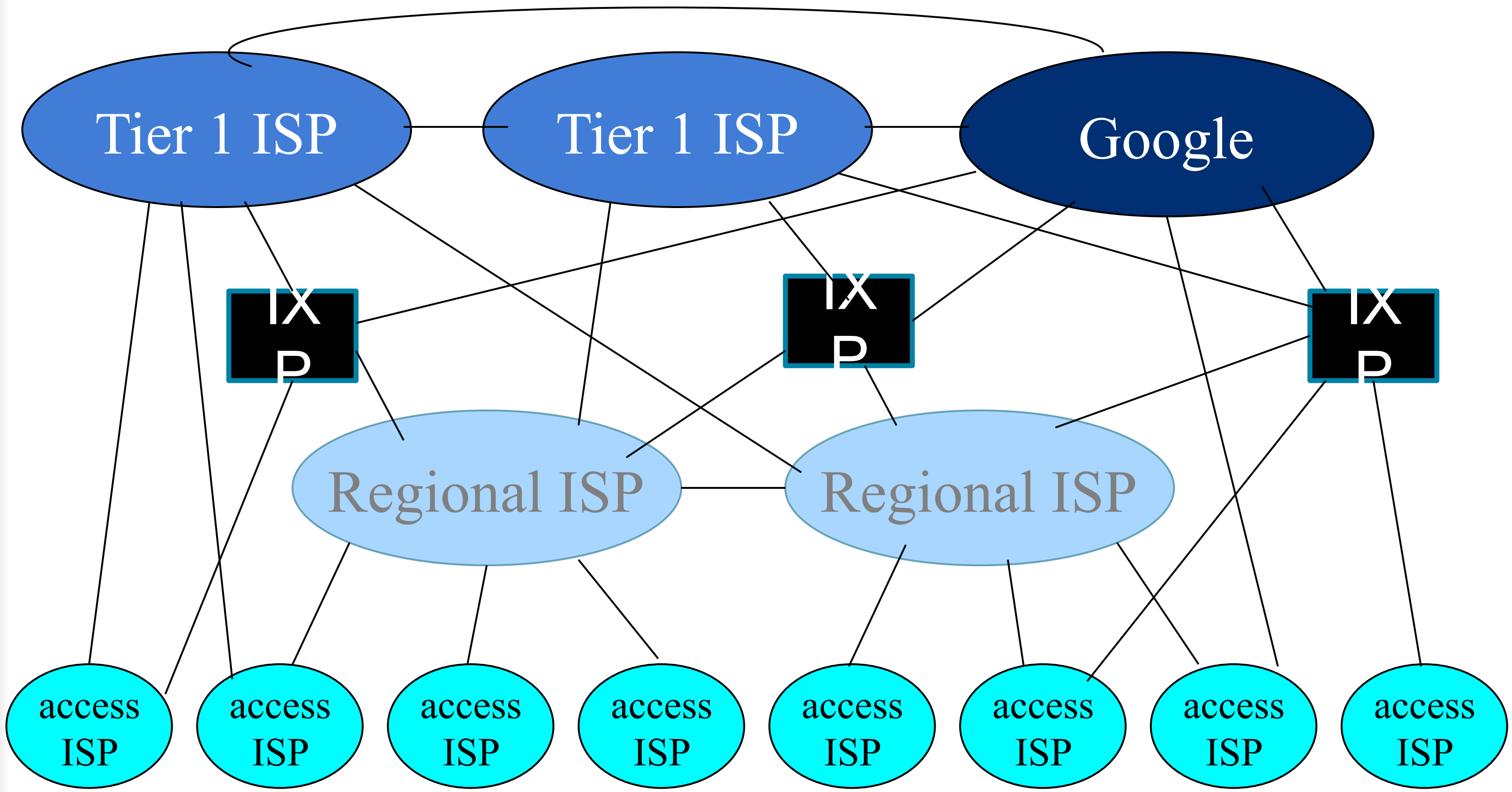


Internet structure: network of networks

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

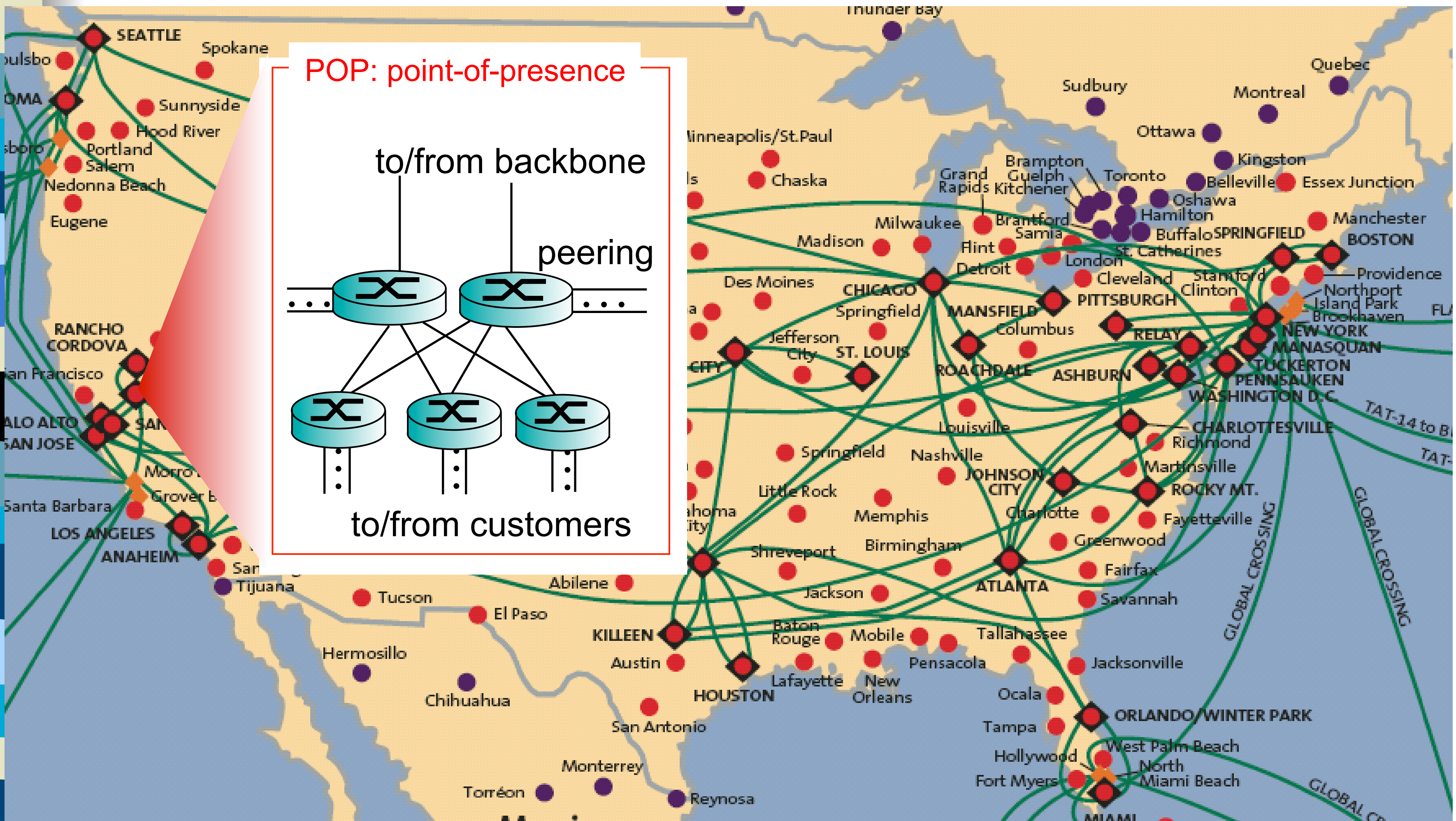


Internet structure: network of networks



- 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

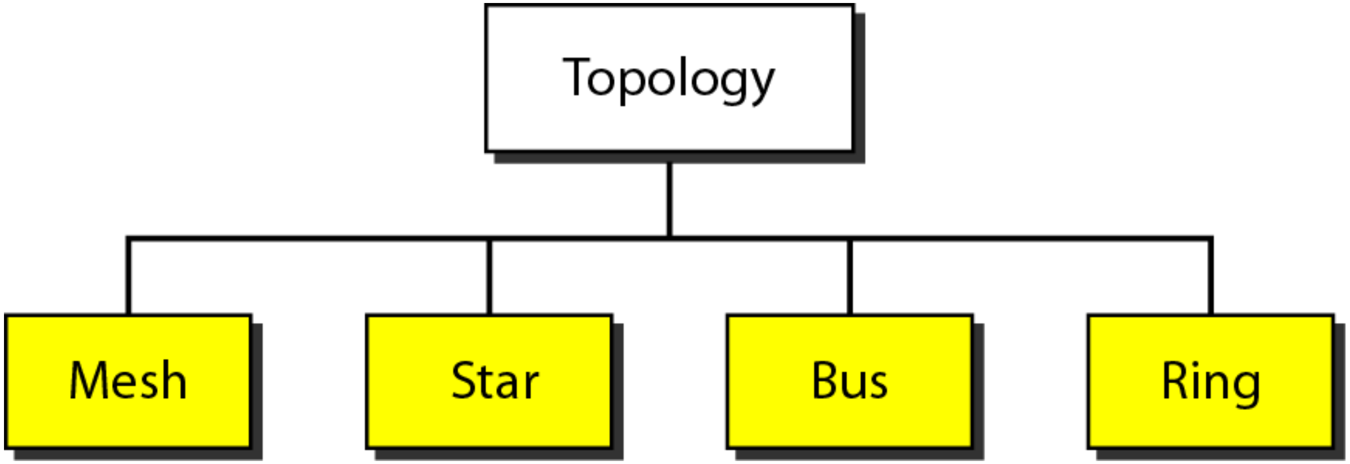


Network Topology

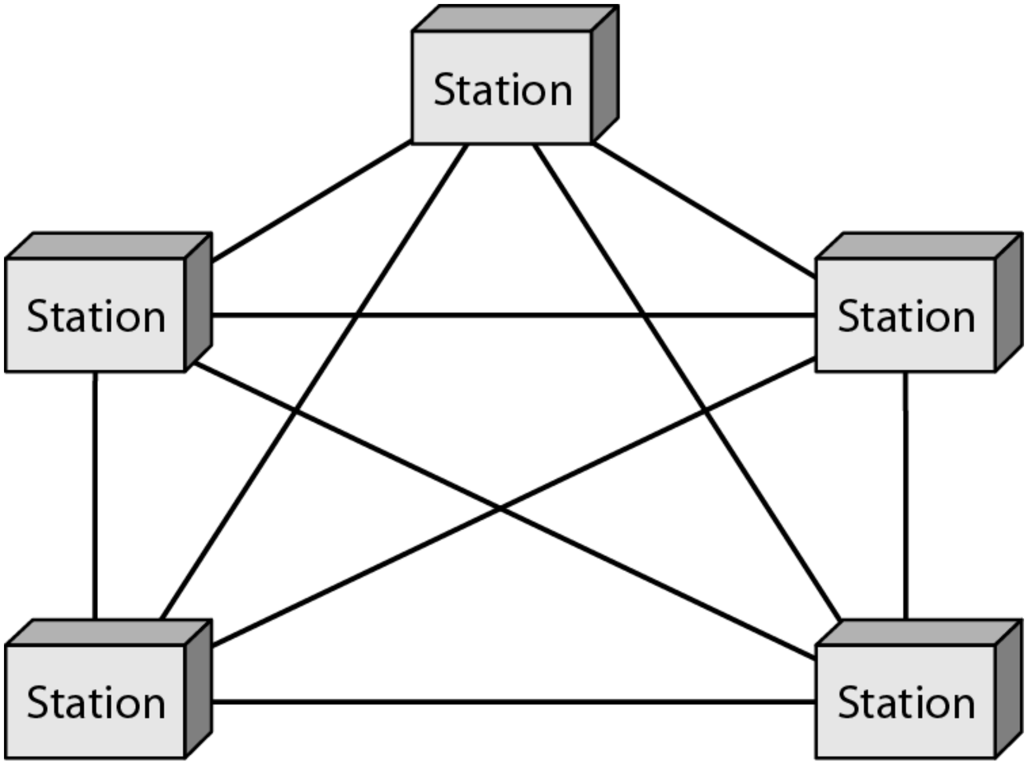
What is a Topology ?

- The physical topology of a network refers to the configuration of cables, computers and other peripherals.

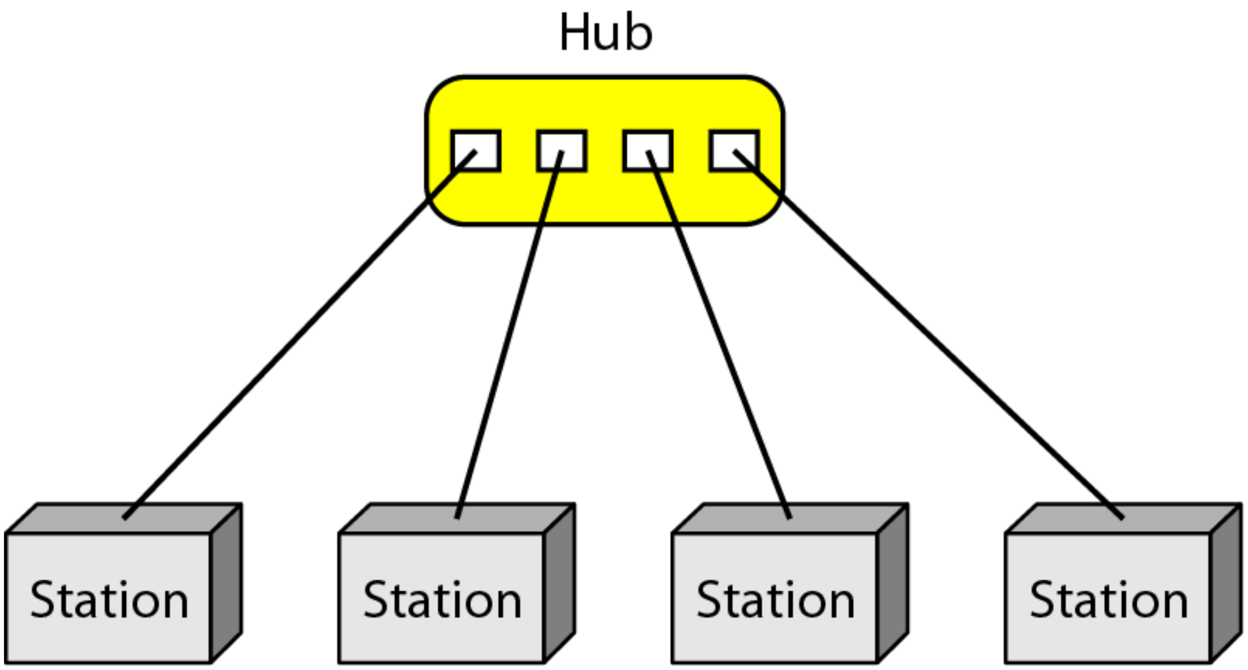
Categories of topology



A fully connected mesh topology (five devices)

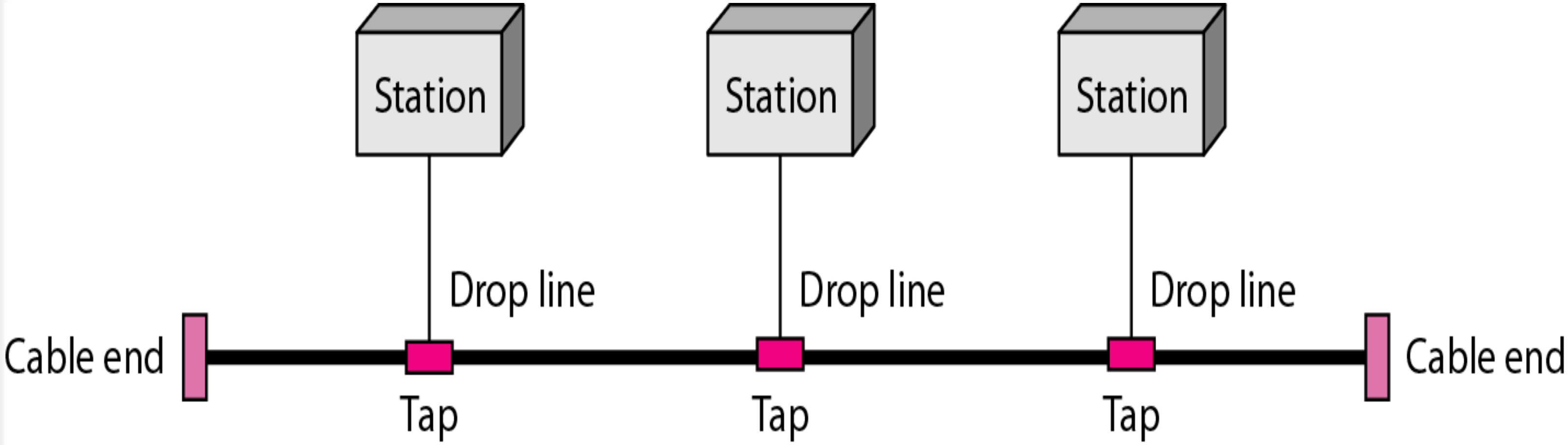


A star topology connecting four stations



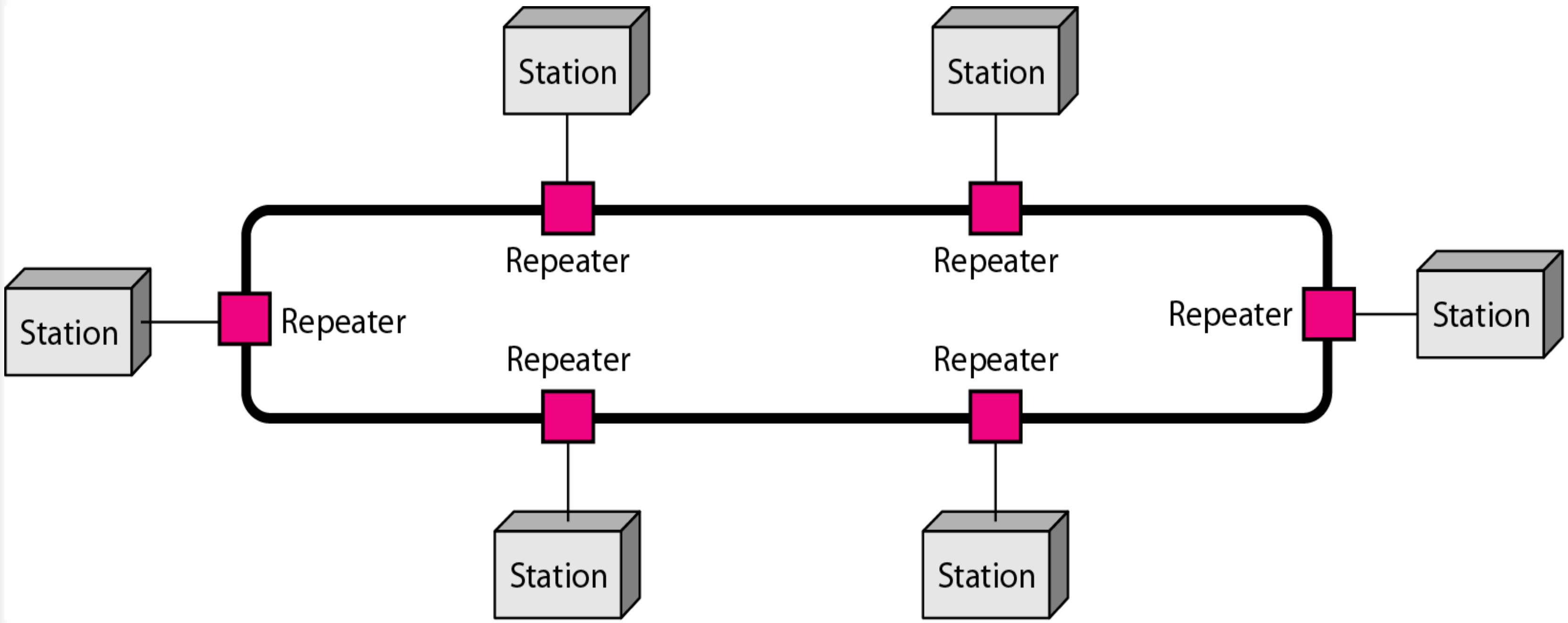
- All devices connect to a central device, called hub.
- All data transferred from one computer to another passes through hub.

A bus topology connecting three stations



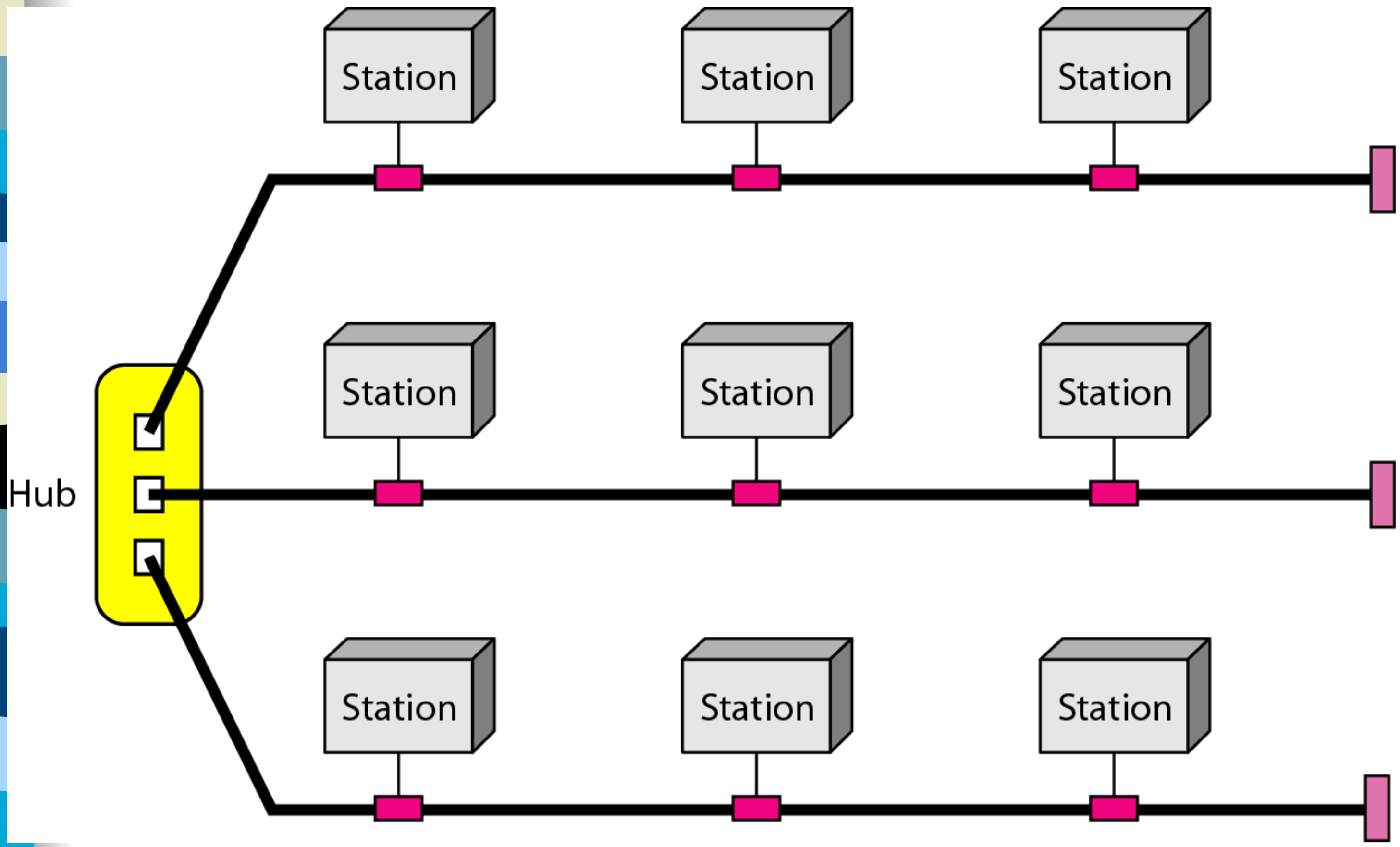
- All computers and devices connected to central cable or bus
- Consists of a main run of cable with a terminator at each end
- Popular on LANs because they are inexpensive and easy to install

A ring topology connecting six stations



- Cable forms closed ring or loop, with all computers and devices arranged along ring
- Data travels from device to device around entire ring, in one direction
- Primarily is used for LANs, but also is used in WANs

A hybrid topology: a star backbone with three bus networks



Network Software

- Protocol layers »
- Design issues for the layers »
- Connection-oriented vs. connectionless service »
- Service primitives »
- Relationship of services to protocols »

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

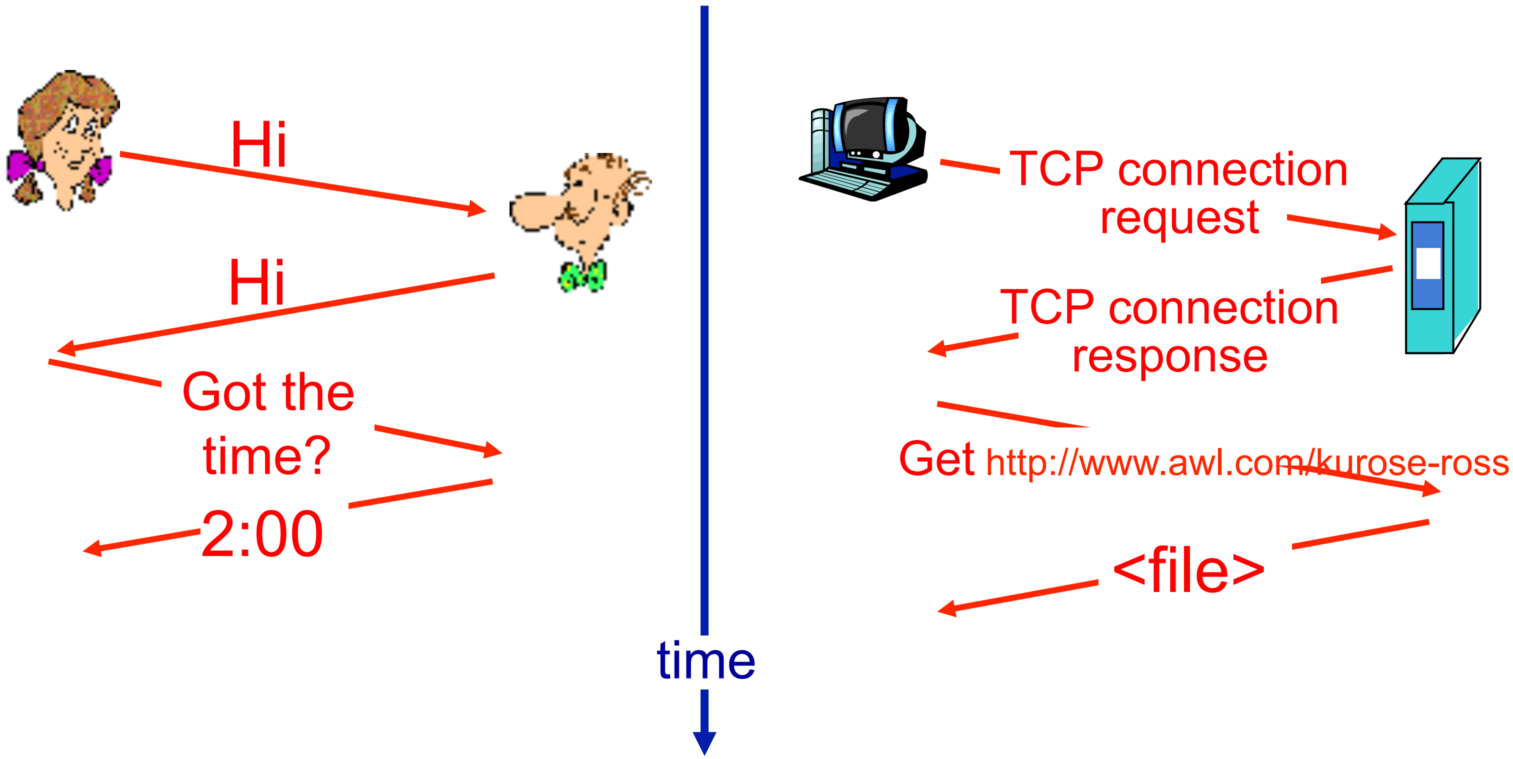
network protocols:

- 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

What's a protocol?

A human protocol and a computer network protocol:



Protocol Layers (1)

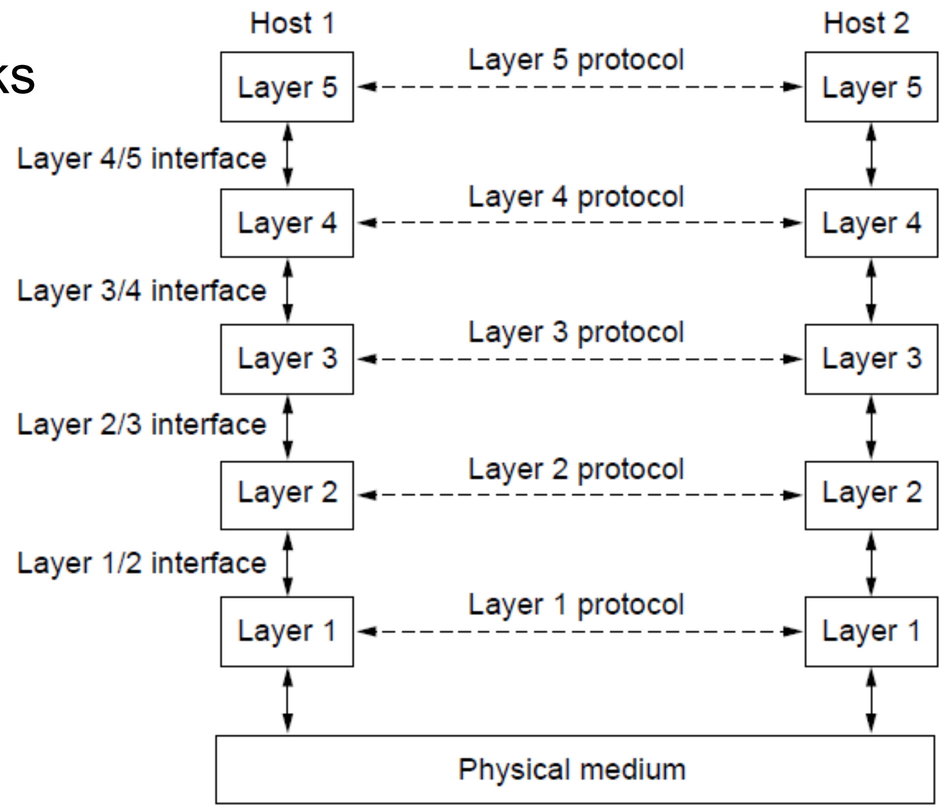
- Protocol layering is the main structuring method used to divide up network functionality.

• Each protocol instance talks virtually to its <u>peer</u>

• Each layer communicates only by using the one below

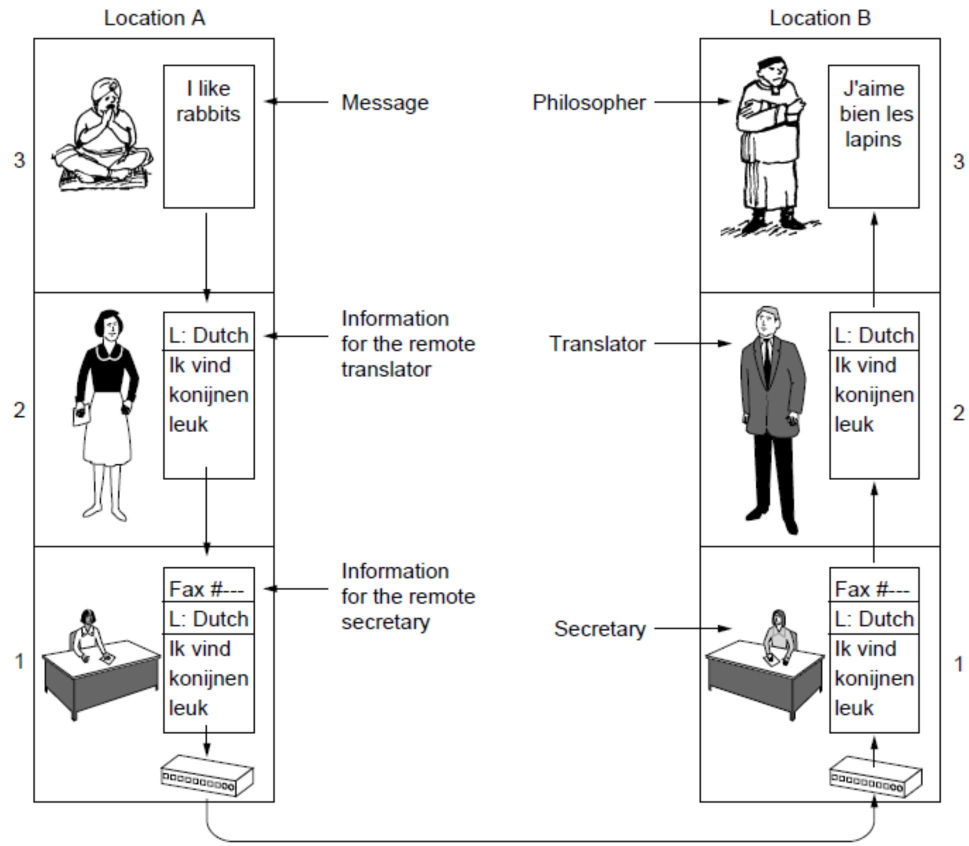
• Lower layer <u>services</u> are accessed by an <u>interface</u>

• At bottom, messages are carried by the medium



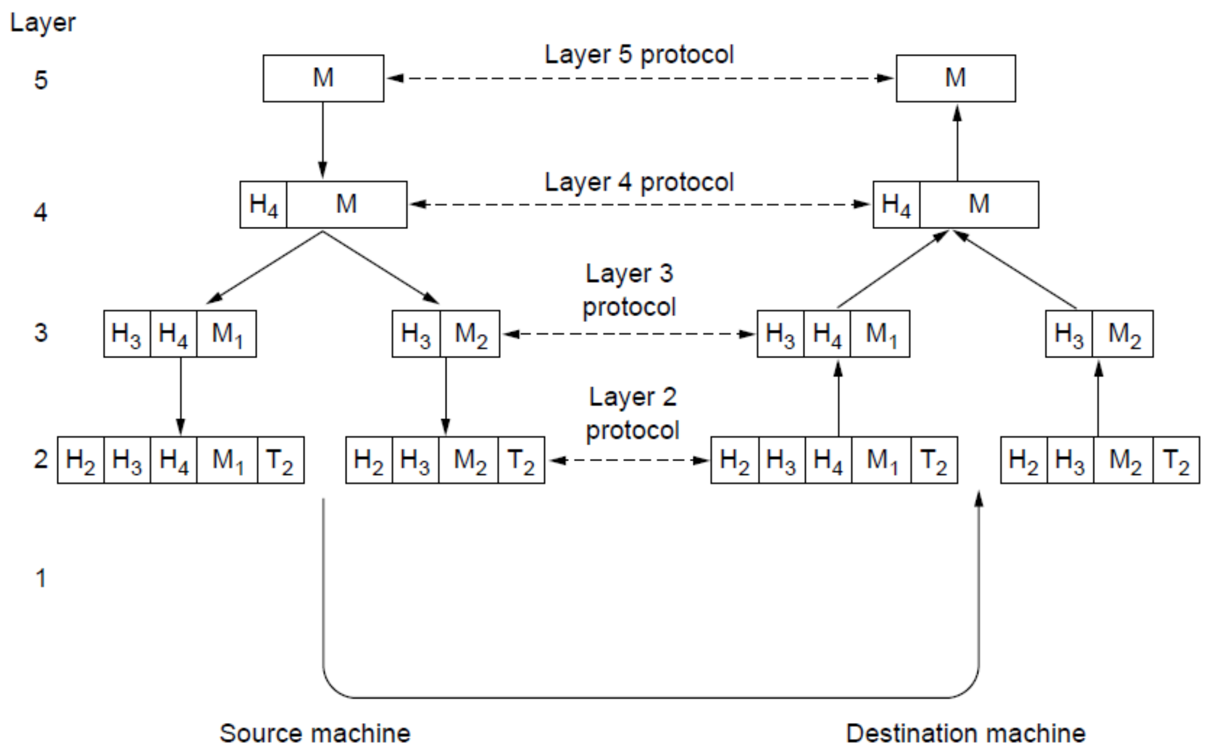
Protocol Layers (2)

- Example: the philosopher-translator-secretary architecture
- Each protocol at different layers serves a different purpose



Protocol Layers (3)

- Each lower layer adds its own header (with control information) to the message to transmit and removes it on receive



- Layers may also split and join messages, etc.

Data Transfer Rate

Data transfer rate defines the amount of information transferred per unit of time.

Examples of data transfer rate units are:

Data Transfer Rate Units	
Bit per second	**See decimal or ISO units in table below**
Baud rate	**Number of symbols per second**
Packet rate	**Number of frames or packets per second**

Decimal Units		ISO Units (ISO 80000-13)	
Prefix	**Bit / s**	**Prefix**	**Bit / s**
kbit/s	10^3	**Kibit/s**	2^{10}
Mbit/s	10^6	**Mibit/s**	2^{20}
Gbit/s	10^9	**Gibit/s**	2^{30}
Tbit/s	10^{12}	**Tibit/s**	2^{40}