DATA COMMUNICATOIN NETWORKING

Instructor: Ouldooz Baghban Karimi

Textbook & Slides: Computer Networking: A Top-Down Approach
Kurose, Ross

Course Overview

- **Basics of Computer Networks**
  - Internet & Protocol Stack
  - Application Layer
  - Transport Layer
  - Network Layer
  - Data Link Layer

- **Advanced Topics**
  - Case Studies of Computer Networks
  - Internet Applications
  - Network Management
  - Network Security

Grading

- **Four Assignments: 20%**
- **Five Quizzes: 10%**
- **Midterm** (Oct 12)**: 20%**
- **Final** (Dec 5)**: 50%**

Resources

Course textbook:

- Computer Networking, A top-down approach
  Kurose & Ross, Sixth Edition

Other recommended textbooks:

- Computer Networks: A Systems Approach
  Paterson & Davie, Fifth Edition

- TCP/IP Illustrated, Vol.1: The protocols
  Stevens

- Unix Network Programming, Vol.1: The Sockets Networking API
  Stevens

Office Hours

- **Ouldooz Baghban Karimi:**
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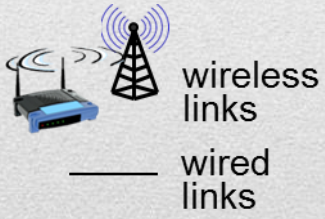
Internet

- **Exciting Place**
  - Two billion users, five billion devices (2011)
  - Infrastructure that provides services to numerous 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
- **Tense Place**
  - Cyber Attacks, Blocking,…
- **Internet: "network of networks"**
  - Access/core network
  - Interconnected Internet Service Providers (ISP)
- **Protocols**
  - TCP, IP, HTTP, 802.11,…
    - IETF (Internet Engineering Task Force)
    - RFC (Request For Comments)

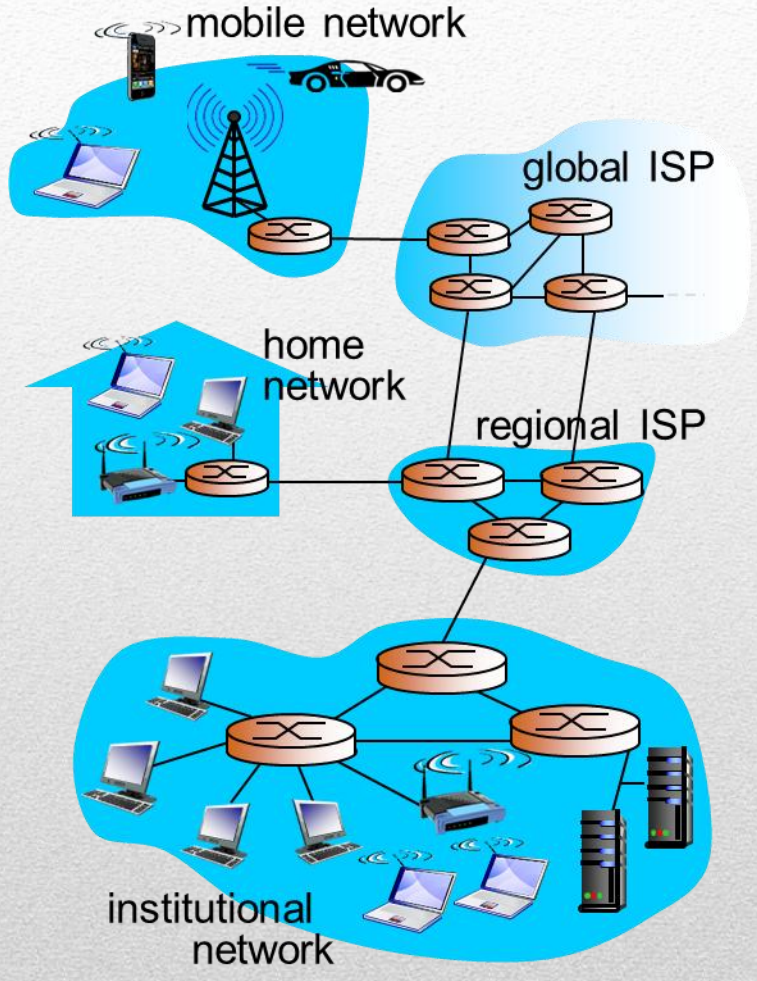
Internet

- Millions of connected computing devices:
  - hosts = end systems
  - running network apps



- Communication links
  - fiber, copper, radio, satellite
  - transmission rate: bandwidth

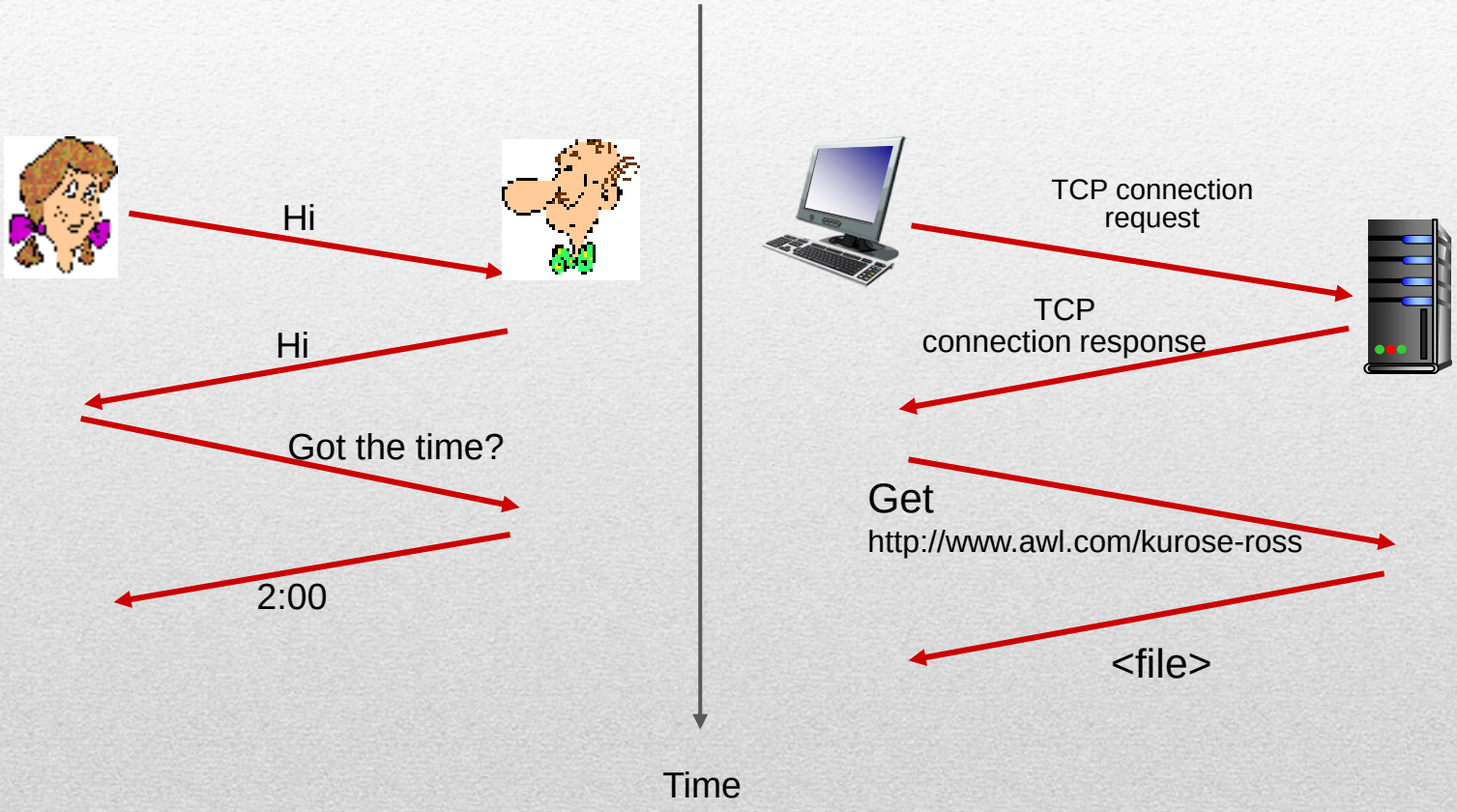
- Packet switches: forward packets (chunks of data)
  - routers and switches



Protocol

- **Human protocols**
  - Specific messages sent
  - Specific actions taken when messages received, or other events
- **Network Protocols**
  - Machines rather than humans
  - All communication activity in Internet governed by protocols

Protocol

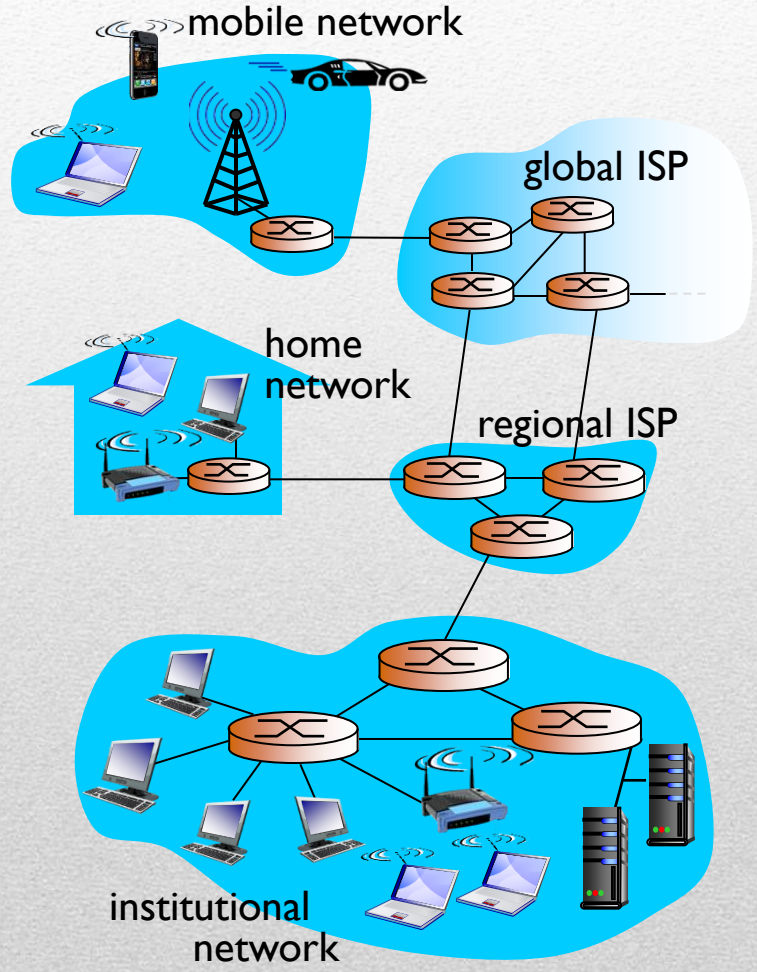

Hi
Hi
Got the time?
2:00
TCP connection request
TCP connection response
Get
http://www.awl.com/kurose-ross
<file>
Time

Protocol

protocols define format, order of messages sent and received among network entities, and actions taken on message transmission, receipt

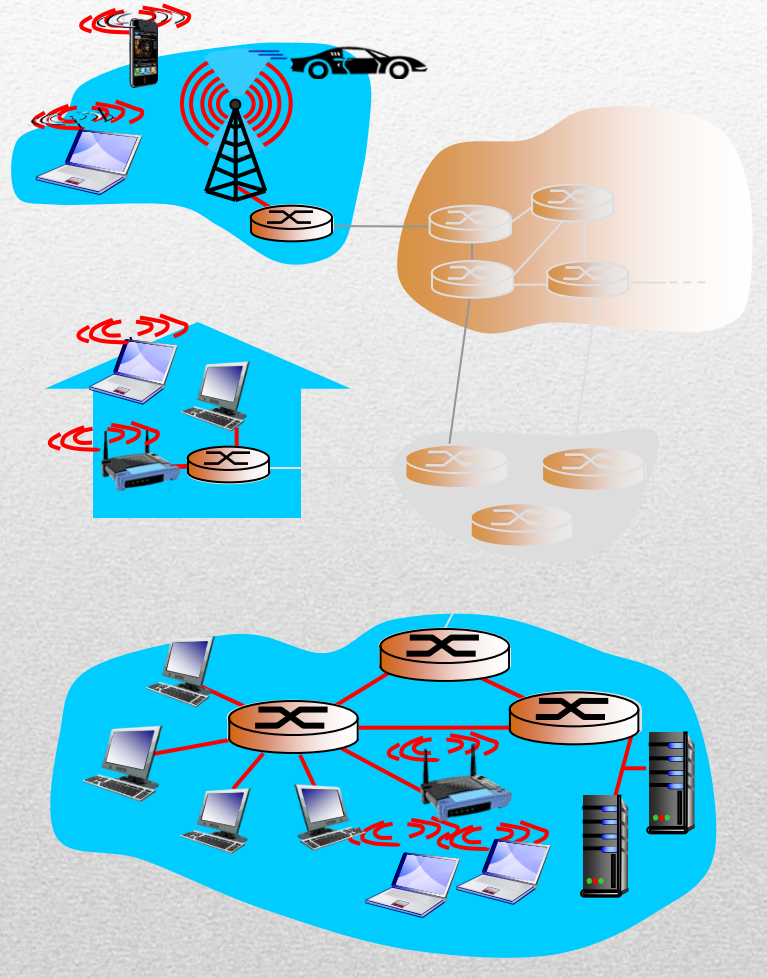
Network Edge

- **End Systems**
  - Clients
  - Servers
- **Access networks**
  - Wired
  - Wireless
- **Links**

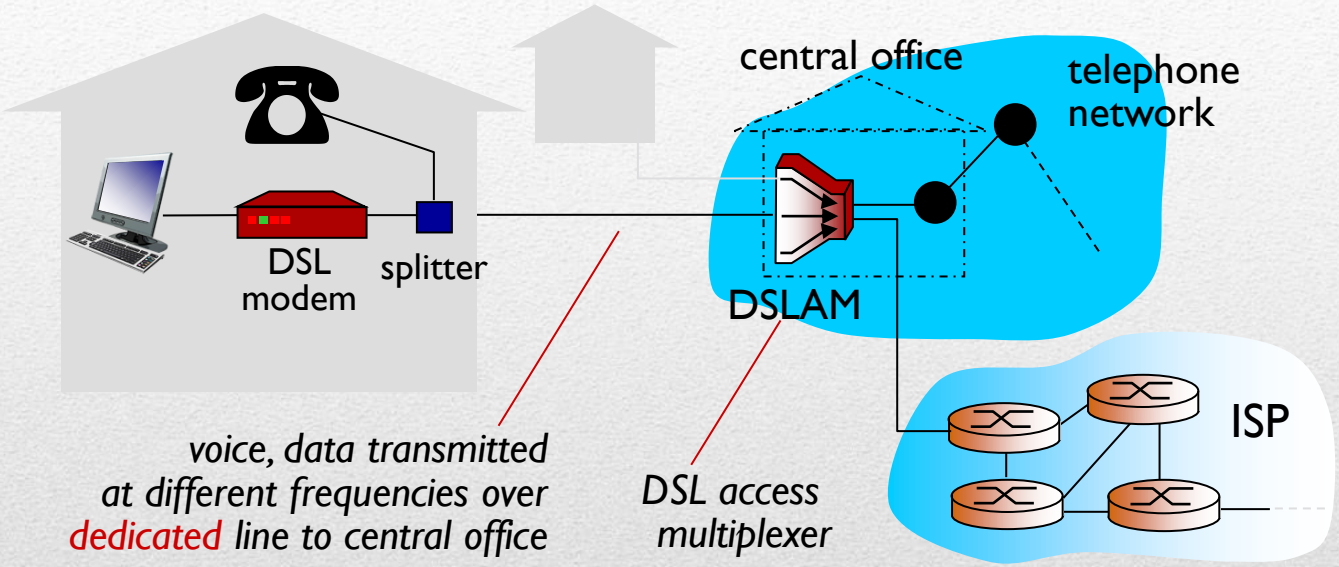


Access Networks

- **Connect end systems to edge router**
  - Residential access networks
    - DSL
    - Cable
  - Institutional access networks (Schools, Companies)
    - Wireless LAN
    - Ethernet
  - Mobile Access Networks

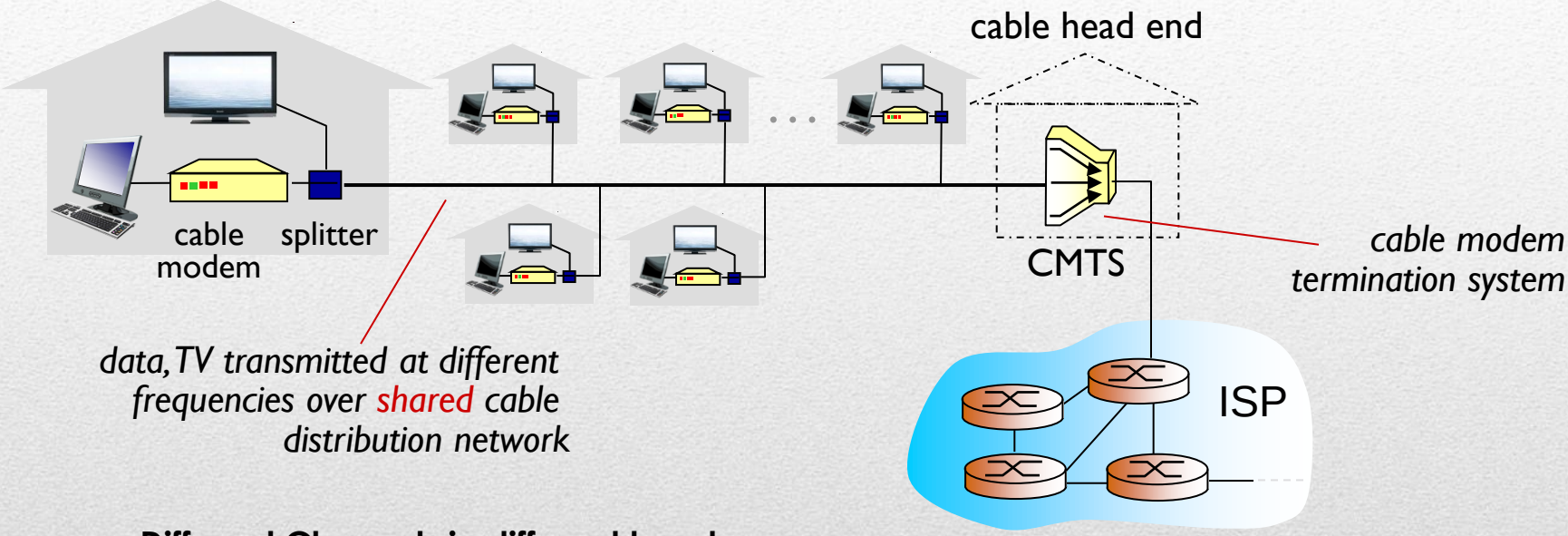


Digital Subscriber line (DSL)



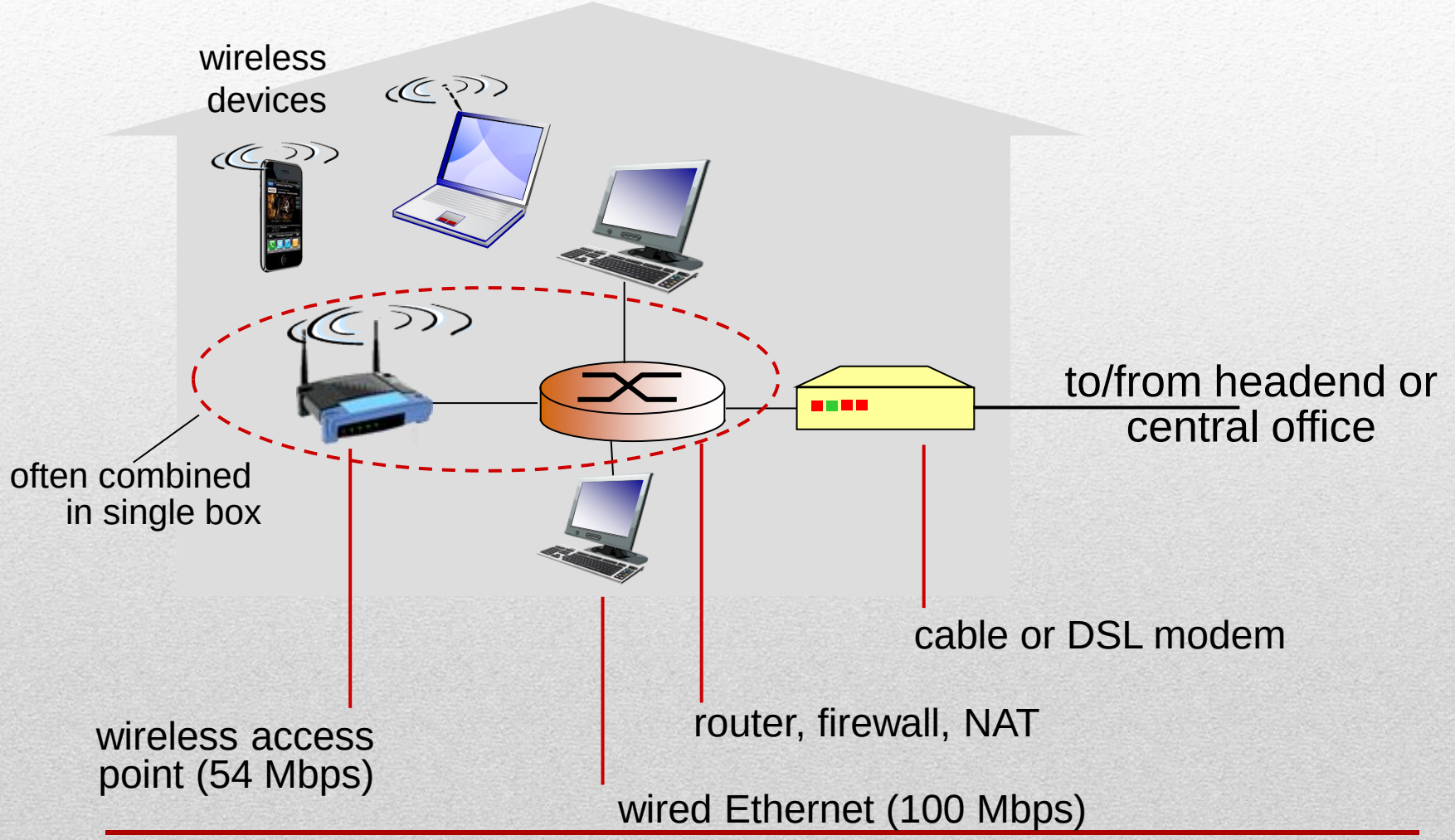
- **Use existing telephone line (twisted pair copper wire) to central office DSLAM**
  - Telephone company acts as ISP
  - Data over DSL phone line goes to Internet
  - Voice over DSL phone line goes to telephone line
- **Simultaneous data and voice**
  - Frequency division multiplexing : 0-4kHz phone, 4-50kHz upstream, 50kHz-1MHz downstream
  - <2.5 Mbps (Typically < 1Mbps) upstream & <24 Mbps (Typically < 10Mbps) downstream transmission rate
  - Short distance (5-10 miles)

Cable Network

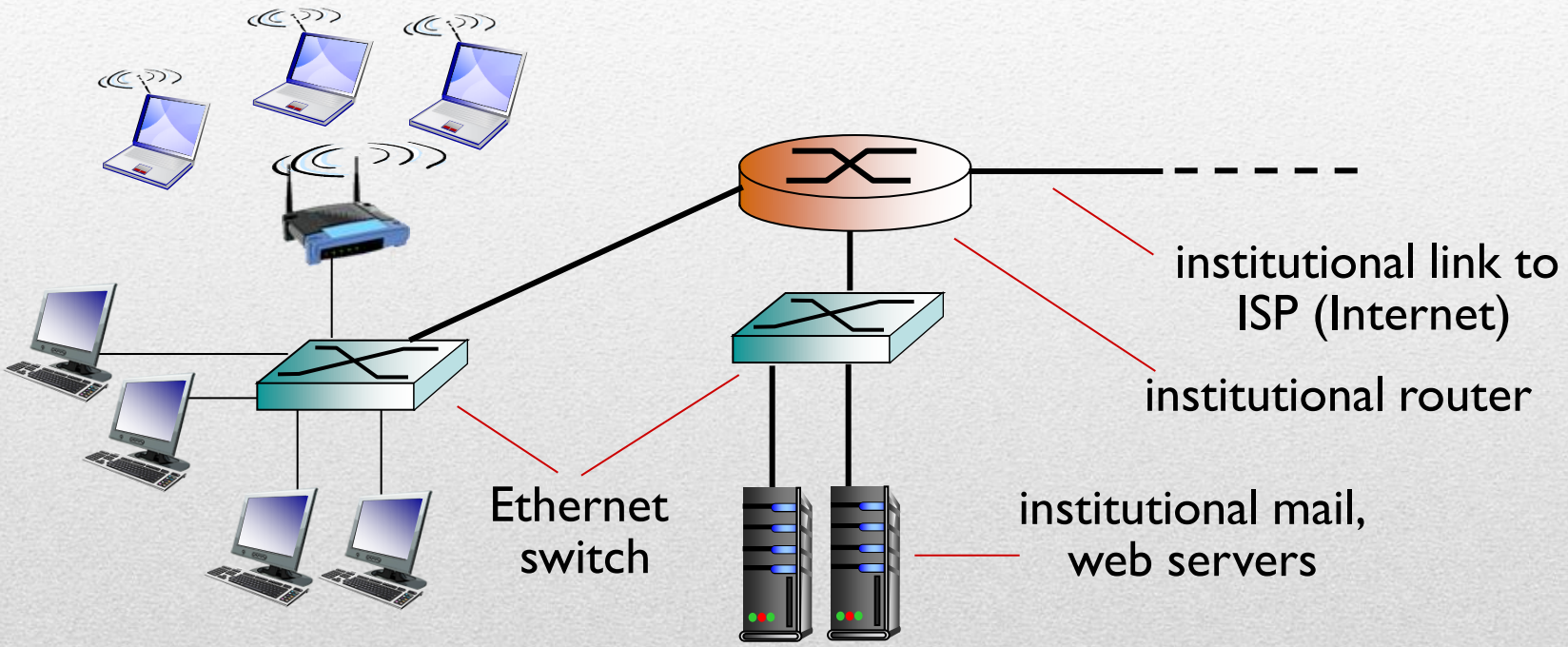


- **Different Channels in different bands**
- **HFC: Hybrid Fiber Coax**
  - 500-5000 homes share access,
    - Homes connect with a coax cable to fiber cable
    - Fiber attaches homes to ISP router
    - unlike DSL which has dedicated access to central office
  - Asymmetric
    - Up to 42.8 Mbps (typical 30 Mbps) downstream transmission rate
    - Up to 30.7 Mbps (typical 2Mbps) Upstream transmission rate

Home Network



Enterprise Access Networks (Ethernet)

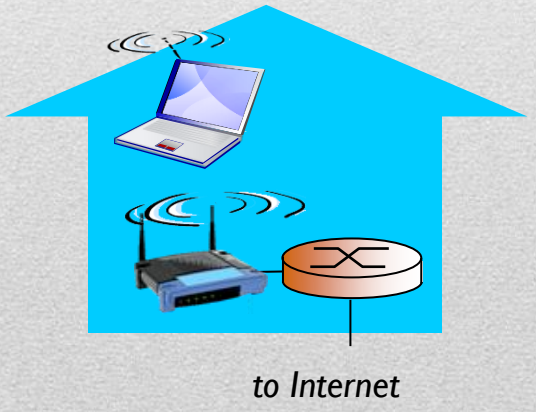


- Companies, Universities,…
- 10Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- Today end systems typically connect into Ethernet switch

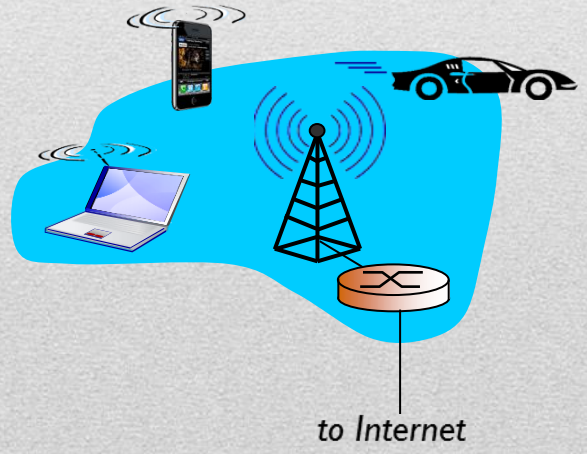
Wireless Access Networks

- Shared *wireless* access network connects end system to router
  - via base station (access point)

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

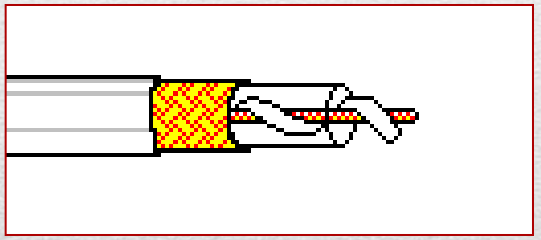


- Wide-area wireless access
  - Provided by cellular operator
  - between 1 and 10 Mbps
  - 3G, 4G, LTE



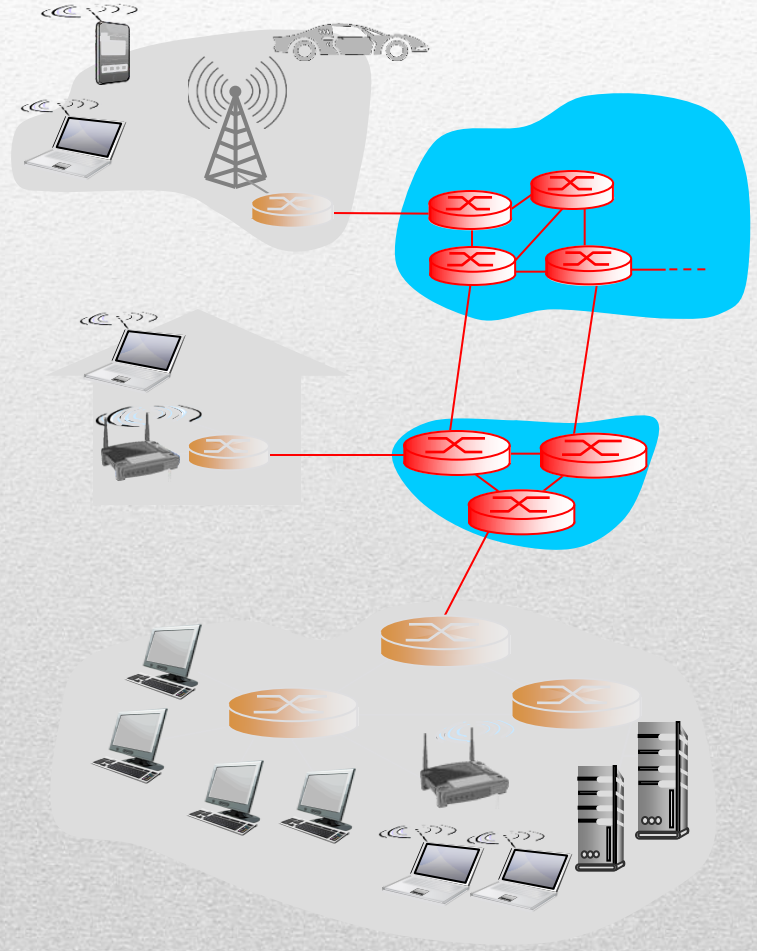
Links

- **Wired**
  - Twisted-pair copper wire
    - Two insulated copper wires
    - 10Mbps – 10 Gbps
  - Coaxial cable
    - Shared medium
  - Fiber Optics
    - Light pulses – each one bit
    - 100's Gbps: n x 51.8Mbps
- **Wireless**
  - Terrestrial Radio Channels
    - PAN, LAN, WAN
  - Satellite Radio Channels
    - Geostationary
    - Low Earth Orbiting
      - Might be used for internet access in future



Network Core

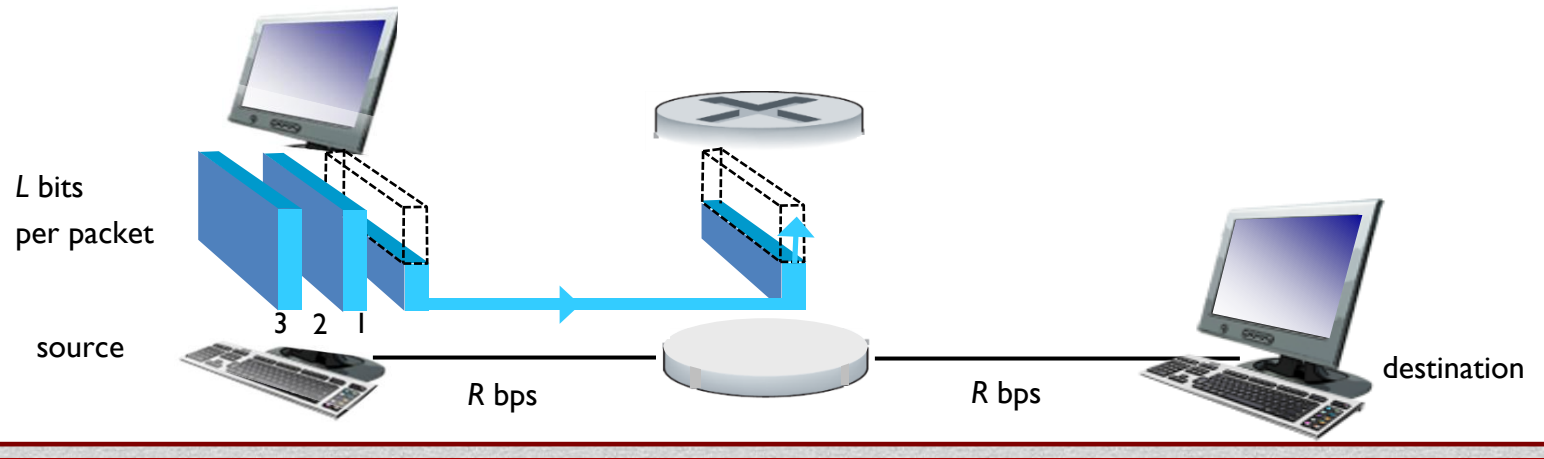
- **Mesh of Connected Routers**
- **Packet Switching**
  - Hosts break application-layer messages into packets
  - Forward packets from one router to the next across links on path from source to destination
  - Each packet transmitted at full link capacity



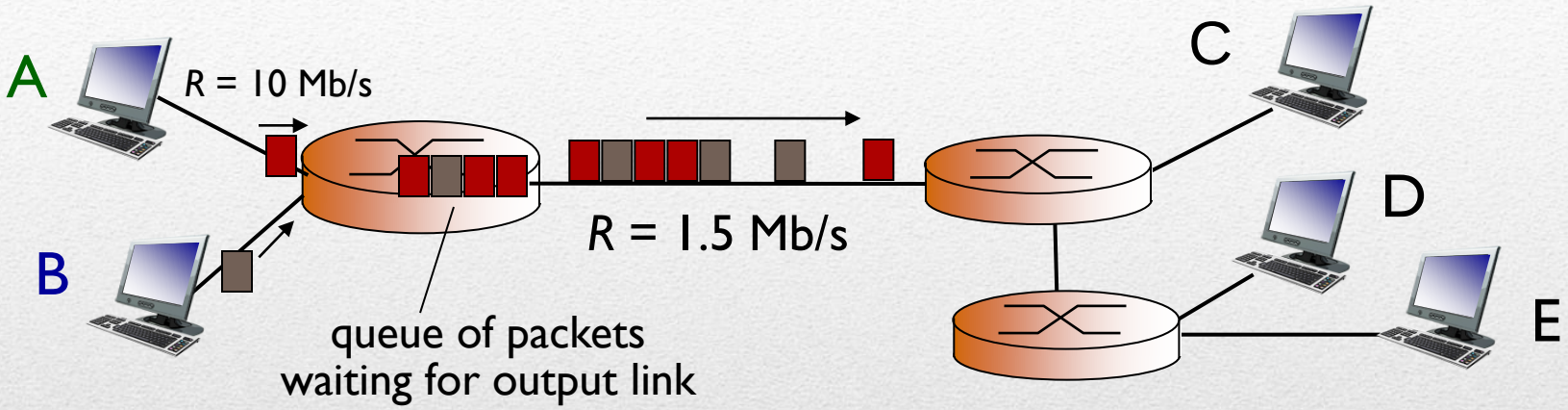
Packet Switching: Store & Forward

- **Store & Forward**
  - Entire packet should arrive at router before it can be transmitted on next link
- **Delay=L (Packet Length)/R (Transmission Rate, Capacity, Link Bandwidth)**
  - Takes L/R seconds to transmit L-bit packet into link at R bps
  - Example: L=7.5Mbits, R=1.5Mpbs, one hop transmission delay = 5ms

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



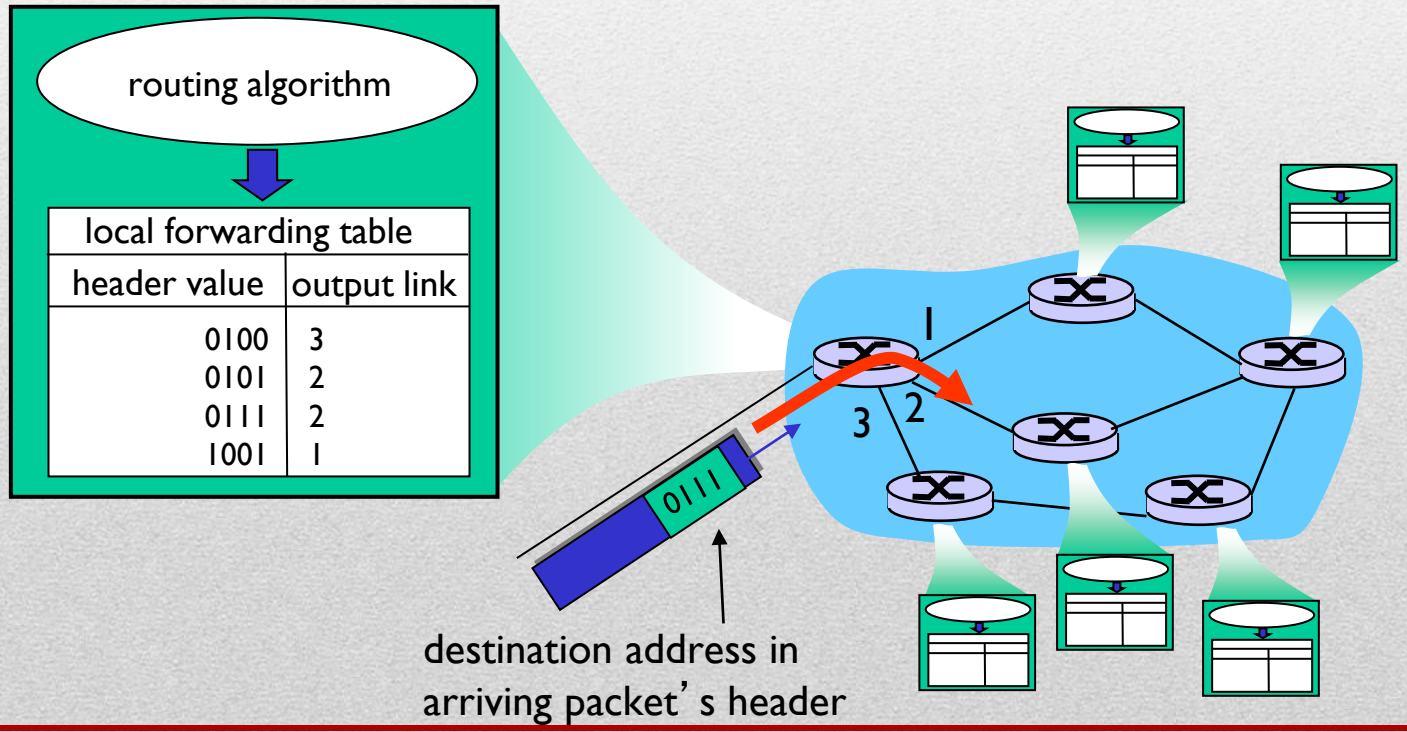
Packet Switching: Queue, Delay, Loss



- **Queuing & Loss**
  - If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
    - Packets will queue, wait to be transmitted on link
    - Packets can be dropped (lost) if memory (buffer) fills up

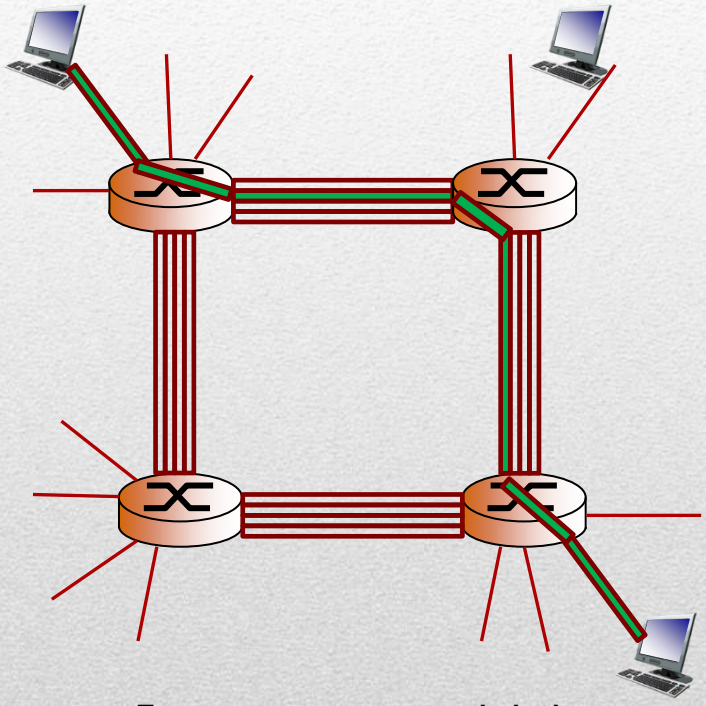
Network Core: Routing vs. Forwarding

- **Routing**
  - Determines source-destination route taken by packets
  - Routing Algorithms
- **Forwarding**
  - Move Packets from router's input to appropriate router output



Alternative Core: Circuit Switching

- **Reserved resources**
  - End to end resources allocated to, reserved for "call" between source and destination
  - No sharing of reserved dedicated resources → Less Users
- **Guaranteed Performance**
- **Idle circuit**
  - Circuit segment idle if not used by the call
- **Used in traditional telephone networks**



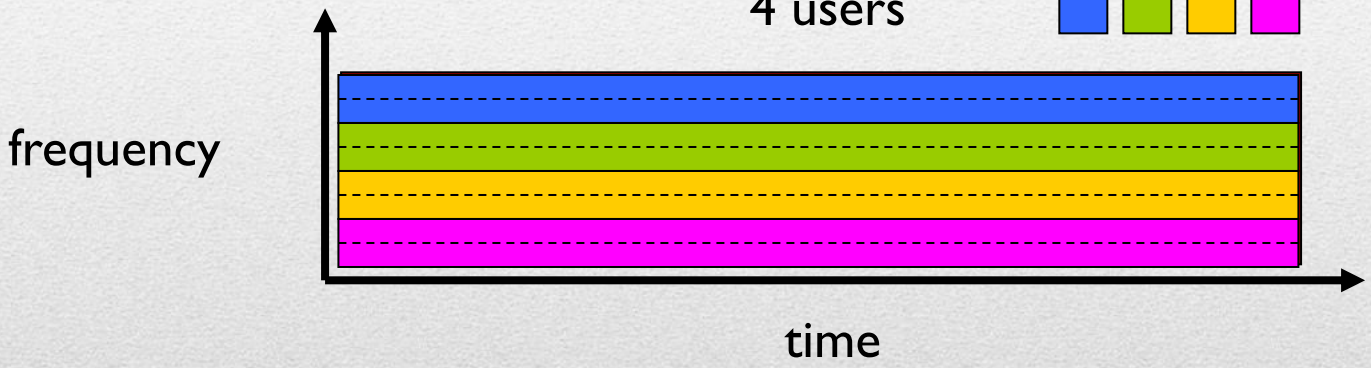
Four circuits on each link

Circuit Switching: TDM vs. FDM

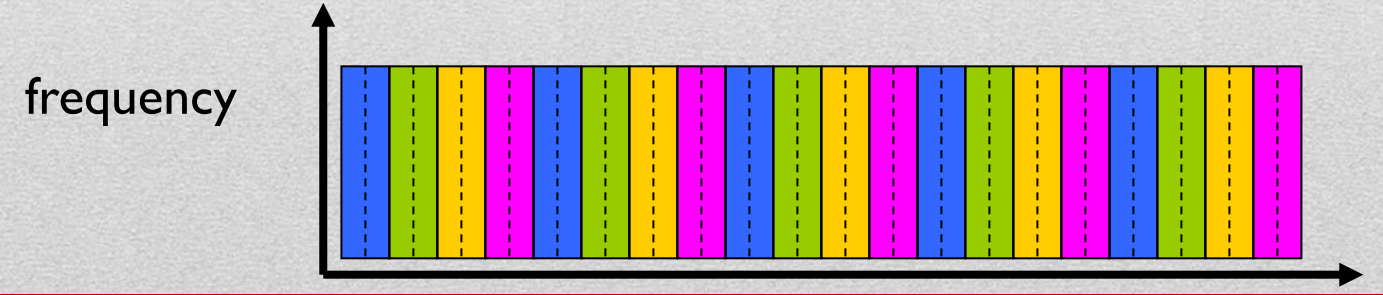
FDM

Example:

4 users

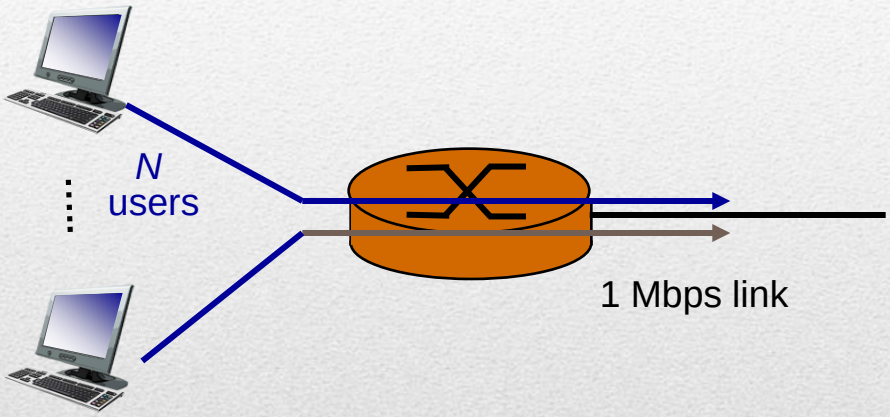


TDM



Packet switching vs. Circuit switching

- **Circuit Switching**
  - Share bandwidth among users
    - 10 users in the example



- **Packet Switching**
  - Sharing allows more users to use the network
    - 35 users in the example performs as good as circuit-switching – Why?
  - Great for Bursty Data
  - Simpler: No call set up

Example:

1Mbps Link

100kbps users when active

Users active 10% of the time

Packet switching vs. Circuit switching

- **Packet Switching Problems**
  - Excessive congestion possible
    - Delay
    - Loss
  - Reliable Data Transfer and Congestion Control protocols needed
- **How to provide circuit like behavior?**
  - Bandwidth guarantees needed for audio/video applications
  - Still an unsolved problem (We will discuss later)