CSCE 463/612 Networks and Distributed Processing Fall 2020

Introduction

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Updates

- Recv loop reminder
  - timeout.tv_usec must be initialized to zero
  - NULL-terminate buf before searching with strchr or strstr

```
while (true) {
  FD_SET (...);
  if ((ret = select (0, &fd, ..., &timeout)) > 0)
  {
    // new data available; now read the next segment
    int bytes = recv (sock, buf + curPos, allocatedSize – curPos, ...);
    if (errors)
          // print WSAGetLastError() & return false;
    if (connection closed)
    {
          buf[curPos] = NULL;
          return true; // normal completion
    }
    curPos += bytes;          // adjust where the next recv goes
    if (allocatedSize – curPos < THRESHOLD)
          // realloc() buf to double its size
  }
  else if (timeout)
          // report timeout & return false;
  else
          // print WSAGetLastError() & return false;
}
```

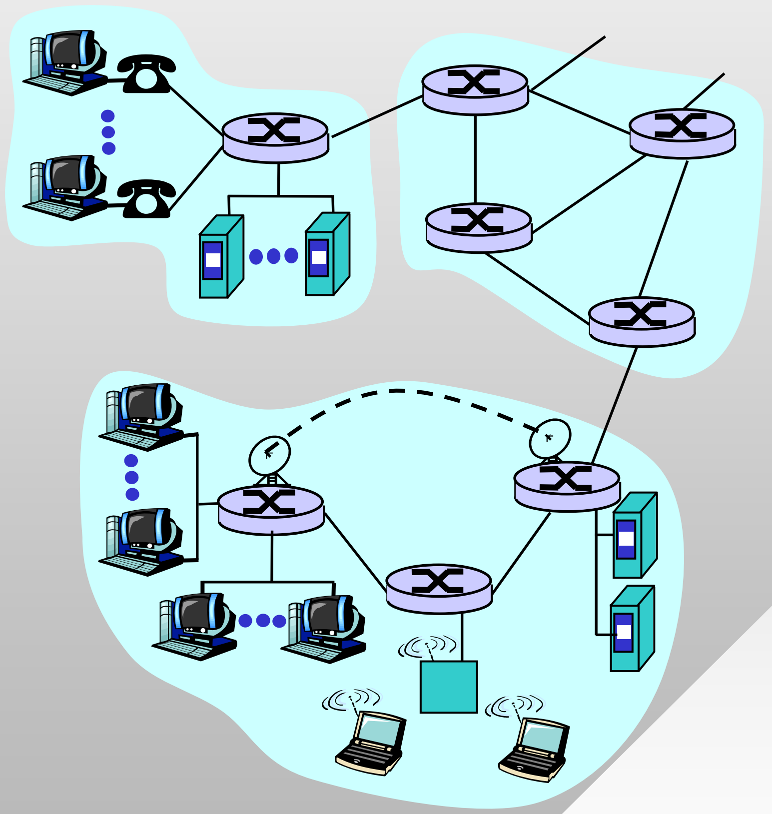
commonly forgotten

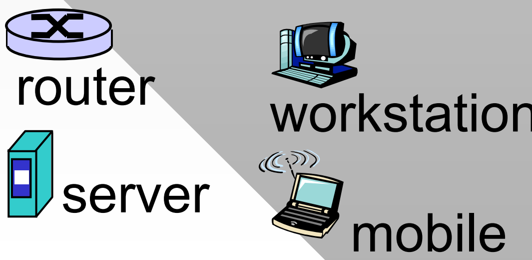
Chapter 1: Roadmap

1.1 What *is* the Internet?
1.2 Network edge
1.3 Network core
1.4 Network access and physical media
1.5 Internet structure and ISPs
1.6 Delay & loss in packet-switched networks
1.7 Protocol layers, service models
1.8 History

The Internet: "Nuts and Bolts" View

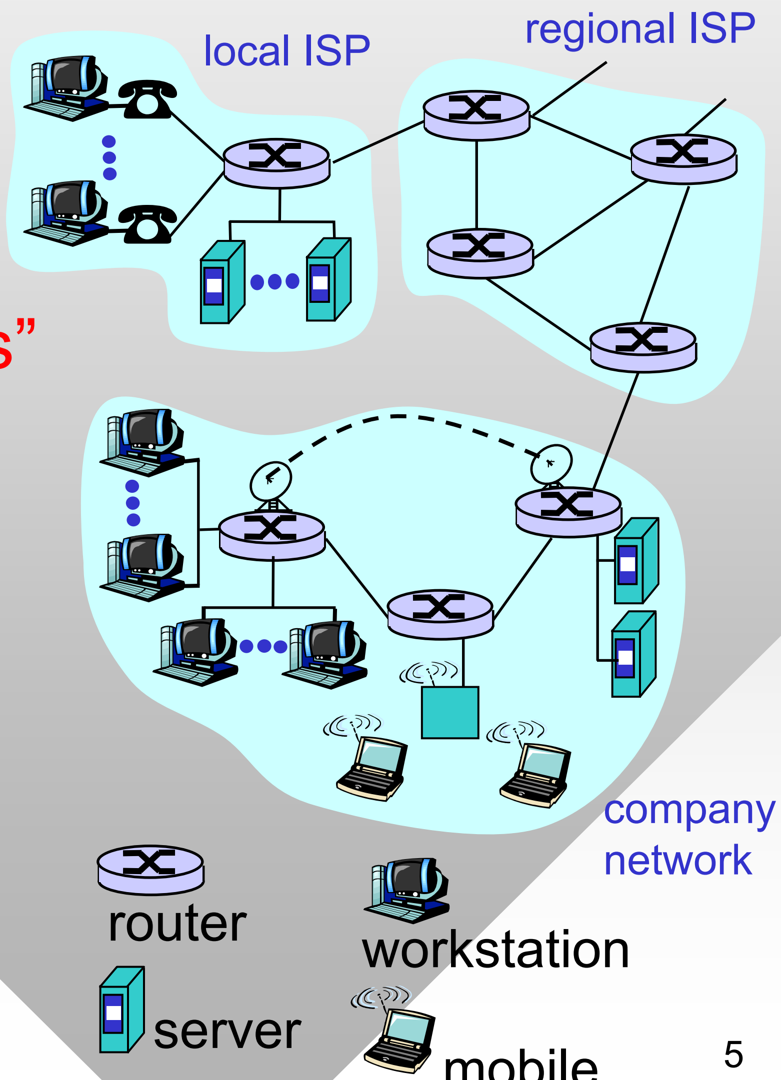
- 1) Hosts (end systems)
  - Computing devices (servers, desktops, phones, laptops)
  - Run network apps
- 2) Routers
  - Forward packets (chunks of data) to destinations
- 3) Communication links
  - Connect hosts & routers
  - Fiber, copper, radio, satellite
  - Transmission rate = bandwidth





The Internet: "Nuts and Bolts" View

- 4) Protocols
  - Control sending/receiving of messages (e.g., TCP, IP, HTTP, FTP, SMTP)
- *Internet:* "network of networks"
  - Loosely hierarchical
- Who rules the Internet?
  - No single authority, mostly decentralized
- Internet standards
  - IETF: Internet Engineering Task Force
  - RFC: Request for comments



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 take place

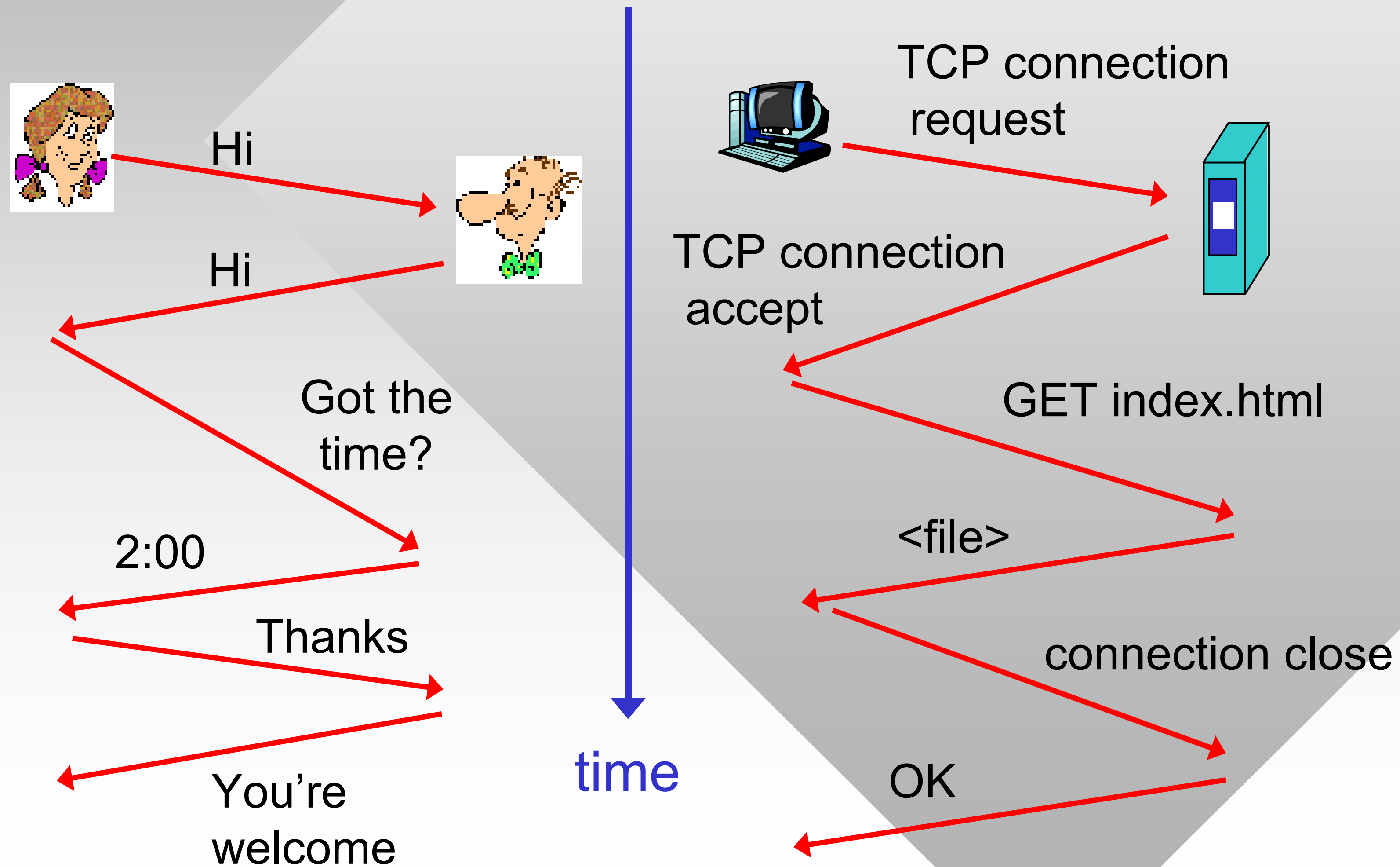
Network protocols:

- Machines rather than humans
- All communication activity in the Internet governed by protocols

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

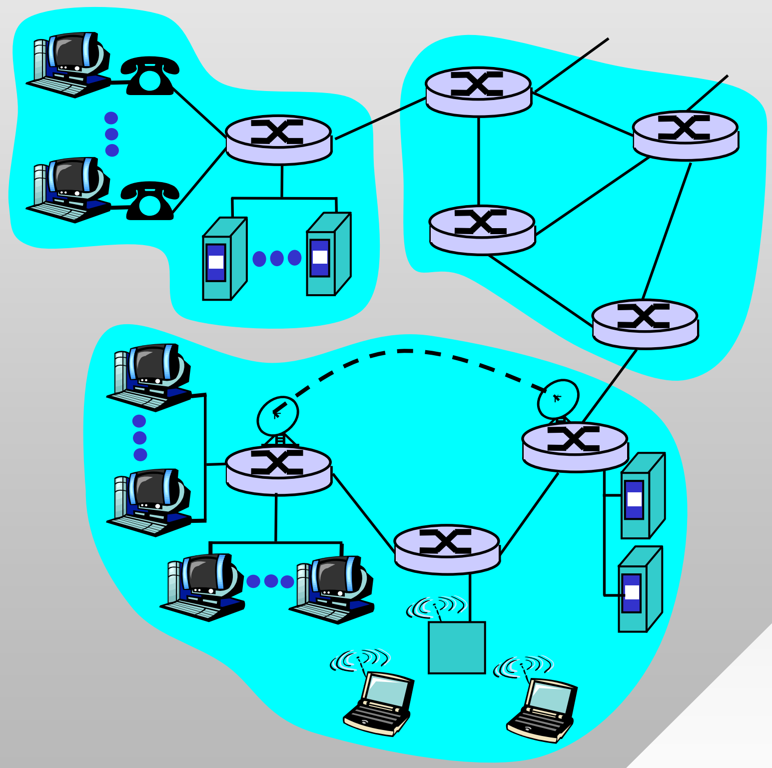
What's a Protocol?

A human protocol and a computer network protocol:



Closer Look at Network Structure

- Network edge:
  - Applications and hosts
- Network core:
  - Routers
  - Links
- How large is the edge?
  - Billions of hosts, trillions of web pages, zettabytes of information
- Large ISPs form the Internet backbone
  - Terabits per second router speed



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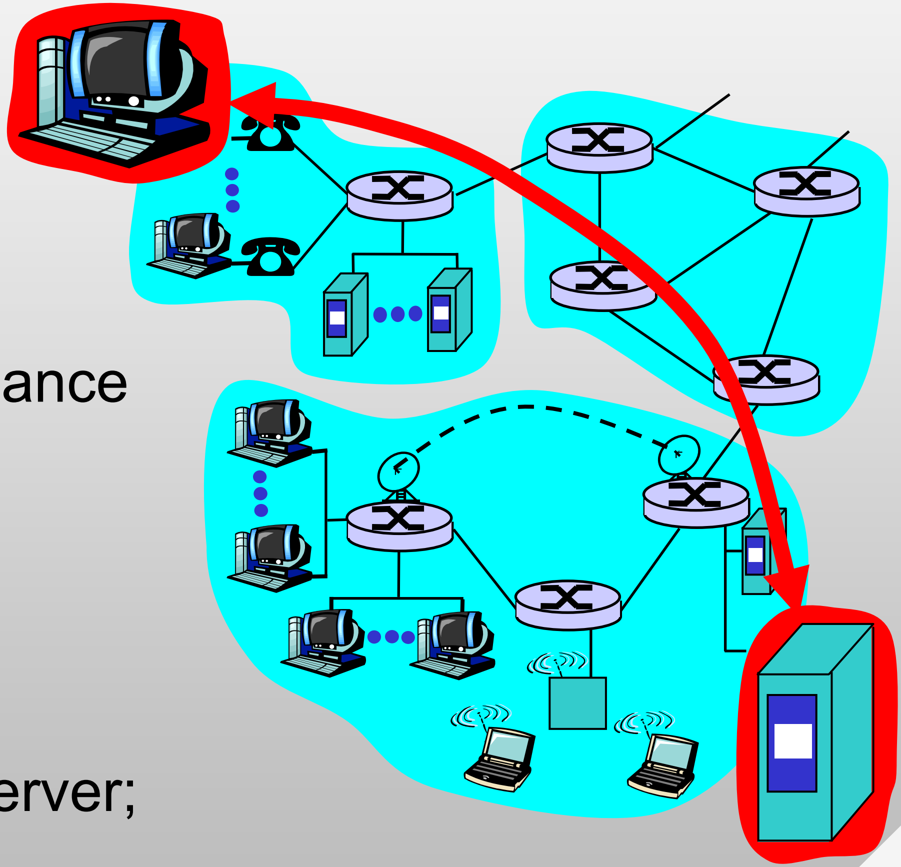
Network Edge



- The edge:
  - Responsible for almost all data supply/demand
  - Protocols impact performance
- Client/server model
  - Client host requests, receives service from always-on server
  - Example: web browser/server; email client/server
- Peer-to-peer (P2P) model:
  - Minimal use of dedicated servers; user hosts talk to each other
  - Example: Skype, BitTorrent

Network Edge: Reliable Service

- Goal: data transfer between sockets
- TCP – Transmission Control Protocol
  - Internet's reliable service
- Connection-oriented
  - *Handshaking:* send connection messages (prepare) for data transfer ahead of time
  - Set up *state* in two communicating hosts

TCP service [RFC 793]

- *Reliable, in-order* byte-stream data transfer
  - Packet loss handled through acknowledgements and retransmissions
- *Flow control:*
  - Sender won't overwhelm receiver
- *Congestion control:*
  - Senders reduce transmission rate when network becomes congested

Network Edge: Unreliable Service

- Goal: data transfer between sockets
  - Same as before!
- UDP – User Datagram Protocol [RFC 768]:
  - Connectionless
  - Unreliable data transfer
  - No flow control
  - No congestion control
- Less overhead and delay
  - TCP connection setup & termination is 7 packets
  - TCP retransmission delay is potentially unbounded

Apps using TCP:

- HTTP (Web), FTP (file transfer), SSH (remote login), SMTP (email)

Apps using UDP:

- DNS, SNMP
  - Short (single-packet) transfers
  - No need for congestion management
- Streaming media, online games, IP telephony
  - More sensitive to delay than packet loss

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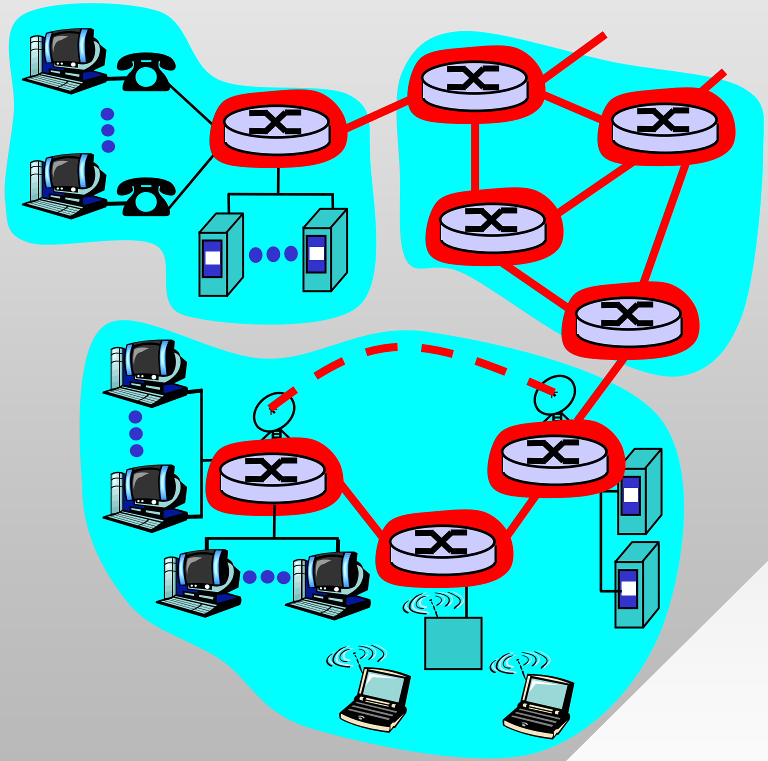
The Network Core

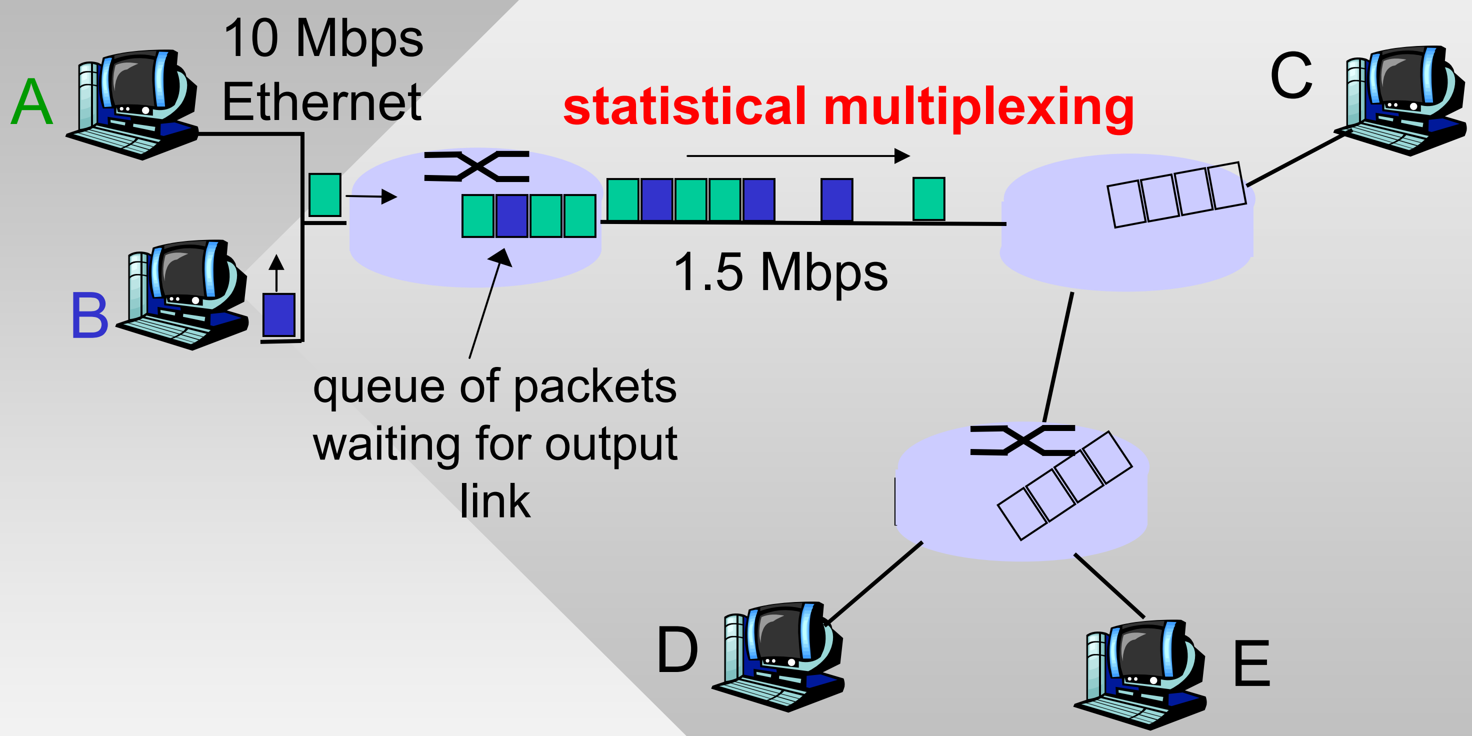
- Supports end-host communication
- Fundamental question: how is data transferred through the network?
  - Circuit switching: dedicated circuit per call (telephone network, origin 1800s)
  - Packet-switching: data sent in discrete “chunks” (1960s)
- Notation
  - Call = connection = flow



Network Core: Packet Switching

- End-end data stream divided into *packets*
  - Packets of users A and B *share* network resources
  - Each packet uses full link bandwidth
- Resource contention:
  - Aggregate resource demand can exceed amount available
  - Congestion: packets queue, wait for link use
- Store-and-forward:
  - Packets move one hop (router) at a time
  - Node receives complete packet before forwarding

Packet Switching: Statistical Multiplexing

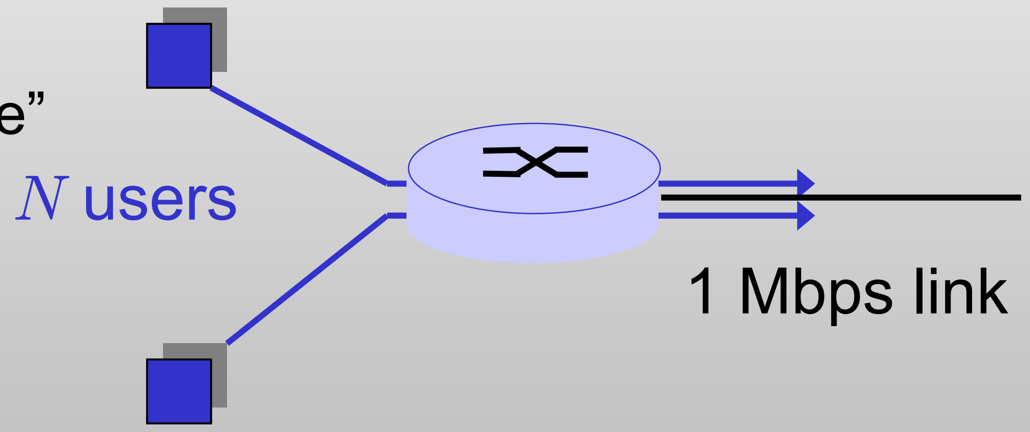


- Sequence of A's and B's packets does not have a fixed pattern ➔ ***statistical multiplexing***

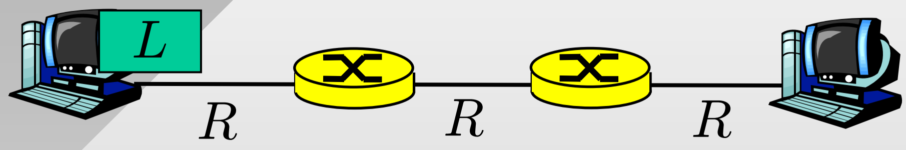
Packet Switching vs. Circuit Switching

Packet switching allows more users than circuit switching

- 1 Mbps link
- Each user:
  - 100 Kbps when “active”
  - Active 10% of time
- Circuit-switching:
  - Supports 10 users
- Packet switching:
  - With 35 users, probability that more than 10 are active is 0.0424%; with 50 users – 0.94%
  - Max 100 users (if perfectly unsynchronized)



Packet Switching: Store-and-Forward



- Takes L/R seconds to transmit (push out) packet of L bits on to link of R bps
- Entire packet must arrive at router before it can be transmitted on next link: *store and forward*
- Path delay $= 3L/R$

Example:

- $L = 7.5$ Mbits
- $R = 1.5$ Mbps
- End-to-end delay $=$ 15 sec

Multi-Threading

- Threads execute concurrently as part of a process
- Benefits:
  - Allows for parallelism in a multiprocessor/multicore system
  - If a blocking call is made in one thread, other threads can continue executing
- Issues:
  - Memory is shared between threads, concurrent access requires proper synchronization
  - Order of execution of threads is non-deterministic
- Homework note: pass shared parameters to threads using a dedicated class instead of using global variables (see 463-sample.zip on course site)

Multi-Threading 2

- Reasons for using multiple threads in hw #1
  - Web servers respond slowly (1-10 seconds/request)
  - While a thread is suspended waiting for connect() and recv(), other threads should be allowed to work
- Multiple threads achieve significant speed-up
  - You could run thousands of threads, but limit your testing to 10 until you know it works correctly
- Common synchronization mechanisms
  - Mutex (mutual exclusion): allows only one thread access to critical section; others must wait
  - Semaphore: allows up to N concurrent threads
  - Event: binary (i.e., ON or OFF) signal

Multi-Threading 3

- Mutex usage
  - Any data structure (e.g., queue) or resource (e.g., screen or disk) modified by parallel threads needs to be protected
  - If not, inconsistencies (data corruption) may result

```
CRITICIAL_SECTION cs;
InitializeCriticalSection (&cs);

EnterCriticalSection (&cs);   // lock
// critical section here ...
LeaveCriticalSection (&cs);   // unlock
```

- Events
  - CreateEvent, WaitForSingleObject, CloseHandle
- See MSDN for additional details

Multi-Threading 4

- A semaphore has a numerical value `s` attached to it
- Wait on semaphore (operation P)
  - If `s == 0`, the semaphore suspends the calling thread
  - If `s > 0`, the thread is allowed access and `s` is set to `s-1`
- Release semaphore (operation V)
  - If threads are waiting, unblock one of them and run it
  - Otherwise, increment `s = s + 1`

```
HANDLE sema = CreateSemaphore (...);
DWORD ret = WaitForSingleObject(sema, INFINITE);           // wait
if (ret != WAIT_OBJECT_0)
    // report error

// critical section...

if (ReleaseSemaphore (sema, ...) == FALSE)                 // release
    // report error
```