Introducti0n

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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`

```c
while (true) {
  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;
}
```
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:

- Human Protocol:
  - Person A: Hi
  - Person B: Hi
  - Person A: Got the time?
  - Person B: 2:00
  - Person A: Thanks
  - Person B: You’re welcome

- Computer Network Protocol:
  - TCP connection request
  - TCP connection accept
  - GET index.html
  - <file>
  - connection close
  - OK
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
- Less TCP retransmission delay
- TCP connection setup & termination is 7 packets

- TCP retransmission delay is potentially unbounded
- More sensitive to delay than packet loss

- Short (single-packet) transfers
- No need for congestion management

- Streaming media, online games, IP telephony

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

Apps using TCP:
- DNS, SNMP

Apps using UDP:
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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 $\Rightarrow$ 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 \( \frac{L}{R} \) 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 = \( 3\frac{L}{R} \)

**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

```c
CRITICAL_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
    // report error

// critical section...

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