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

```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;
                curPos += bytes; // adjust where the next recv goes
                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:

Hi

Got the time?

2:00

Hi

TCP connection request

TCP connection accept

GET index.html

<file>

connection close

You’re welcome

Thanks

OK

time
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: 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 interleaved)
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

```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 \( s = s + 1 \)

```c
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
```