Last Year's COMS 4119 Computer Networking Socket Programming

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Socket Programming

- What is a socket?
- Using sockets
  - Types (Protocols)
  - Associated functions
  - Styles

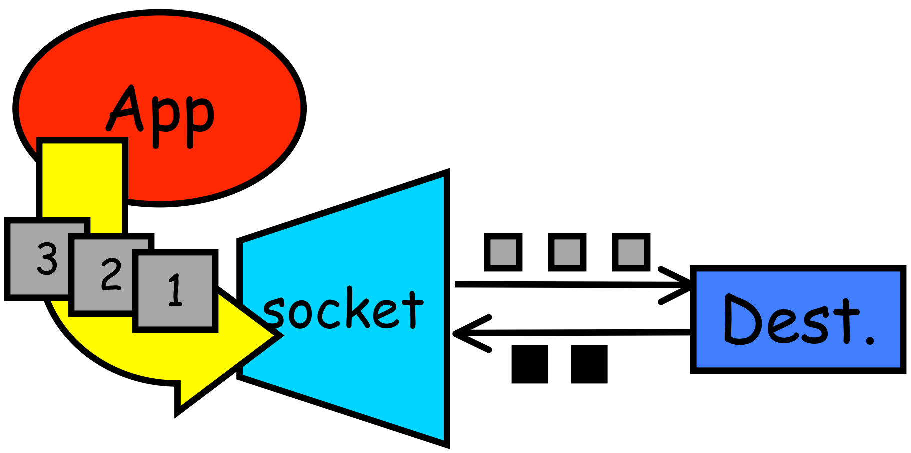
  - We will look at using sockets in C
  - For Java, see Chapter 2.6-2.8 (optional)
    - Note: Java sockets are conceptually quite similar

What is a socket?

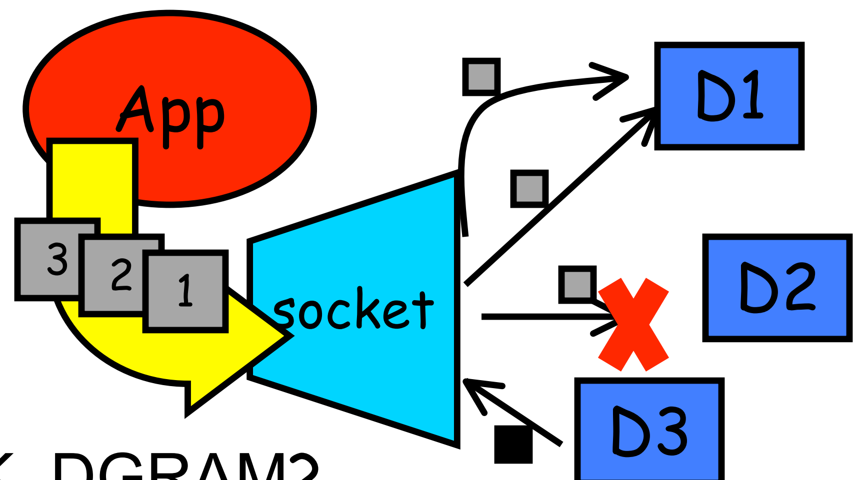
- An interface between application and network
  - The application creates a socket
  - The socket *type* dictates the style of communication
    - reliable vs. best effort
    - connection-oriented vs. connectionless
- Once configured the application can
  - pass data to the socket for network transmission
  - receive data from the socket (transmitted through the network by some other host)

Two essential types of sockets

- SOCK_STREAM
  - a.k.a. TCP
  - reliable delivery
  - in-order guaranteed
  - connection-oriented
  - bidirectional



- SOCK_DGRAM
  - a.k.a. UDP
  - unreliable delivery
  - no order guarantees
  - no notion of "connection" – app indicates dest. for each packet
  - can send or receive

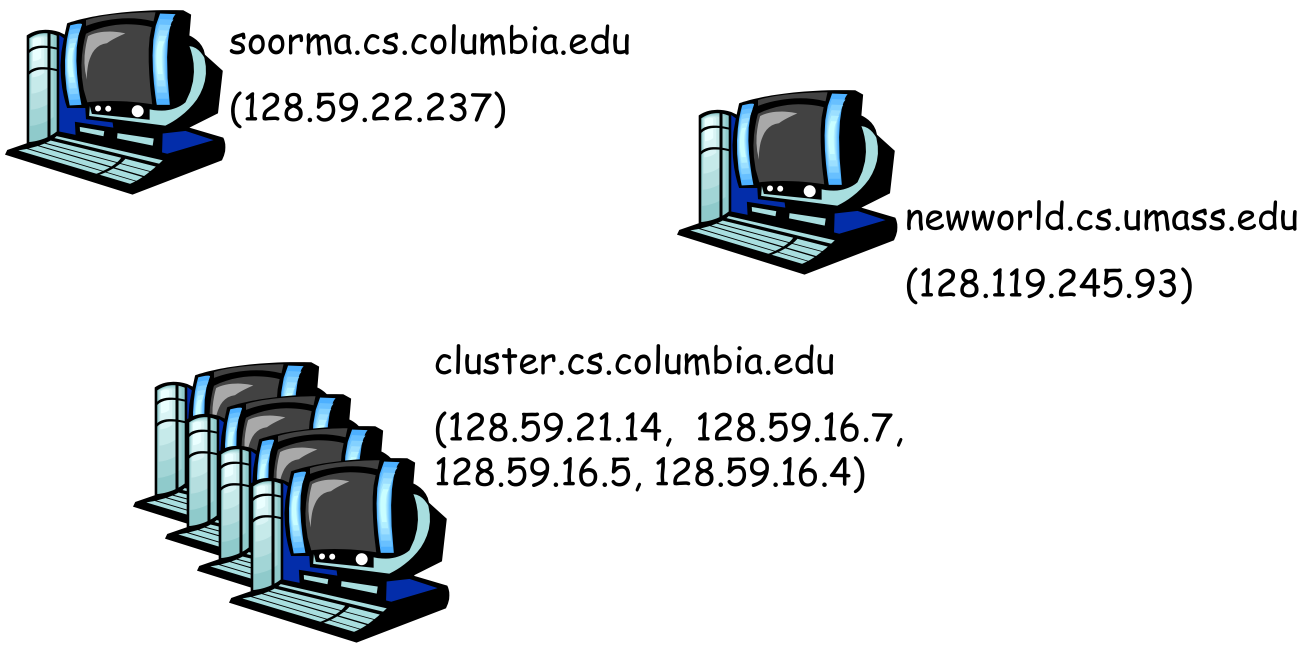


Q: why have type SOCK_DGRAM?

Socket Creation in C: socket

- int s = socket(domain, type, protocol);
  - s: socket descriptor, an integer (like a file-handle)
  - domain: integer, communication domain
    - e.g., PF_INET (IPv4 protocol) – typically used
  - type: communication type
    - SOCK_STREAM: reliable, 2-way, connection-based service
    - SOCK_DGRAM: unreliable, connectionless,
    - other values: need root permission, rarely used, or obsolete
  - protocol: specifies protocol (see file /etc/protocols for a list of options) - usually set to 0
- NOTE: socket call does not specify where data will be coming from, nor where it will be going to – it just creates the interface!

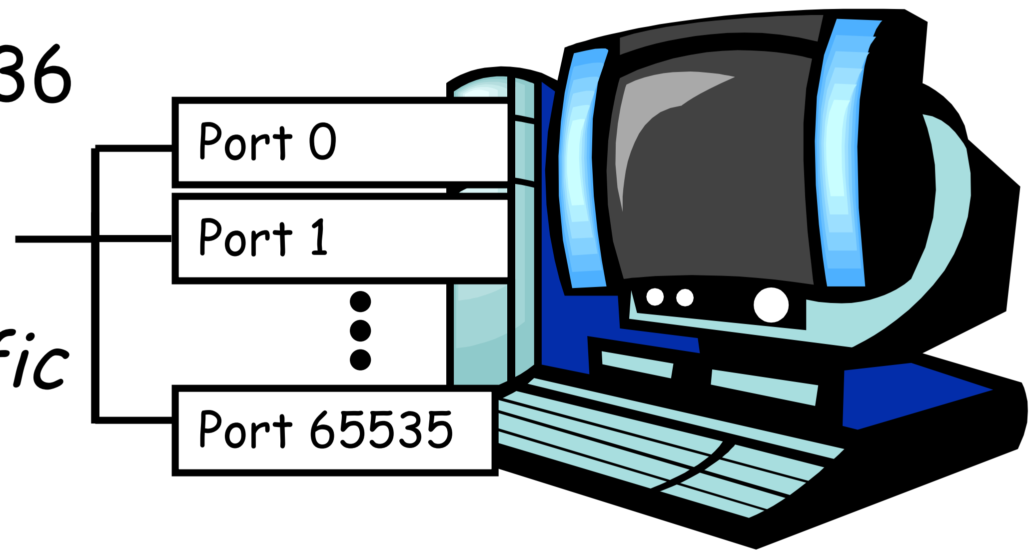
A Socket-eye view of the Internet



- Each host machine has an IP address
- When a packet arrives at a host

Ports

- Each host has 65,536 ports
- Some ports are *reserved for specific apps*
  - 20,21: FTP
  - 23: Telnet
  - 80: HTTP
  - see RFC 1700 (about 2000 ports are reserved)



- A socket provides an interface to send data to/from the network through a port

Addresses, Ports and Sockets

- Like apartments and mailboxes
  - You are the application
  - Your apartment building address is the address
  - Your mailbox is the port
  - The post-office is the network
  - The socket is the key that gives you access to the right mailbox (one difference: assume outgoing mail is placed by you in your mailbox)
- Q: How do you choose which port a socket connects to?

The bind function

- associates and (can exclusively) reserves a port for use by the socket
- int status = bind(sockid, &addrport, size);
  - status: error status, = -1 if bind failed
  - sockid: integer, socket descriptor
  - addrport: struct sockaddr, the (IP) address and port of the machine (address usually set to INADDR_ANY – chooses a local address)
  - size: the size (in bytes) of the addrport structure
- bind can be skipped for both types of sockets. When and why?

Skipping the bind

- SOCK_DGRAM:
  - if only sending, no need to bind. The OS finds a port each time the socket sends a pkt
  - if receiving, need to bind
- SOCK_STREAM:
  - destination determined during conn. setup
  - don't need to know port sending from (during connection setup, receiving end is informed of port)

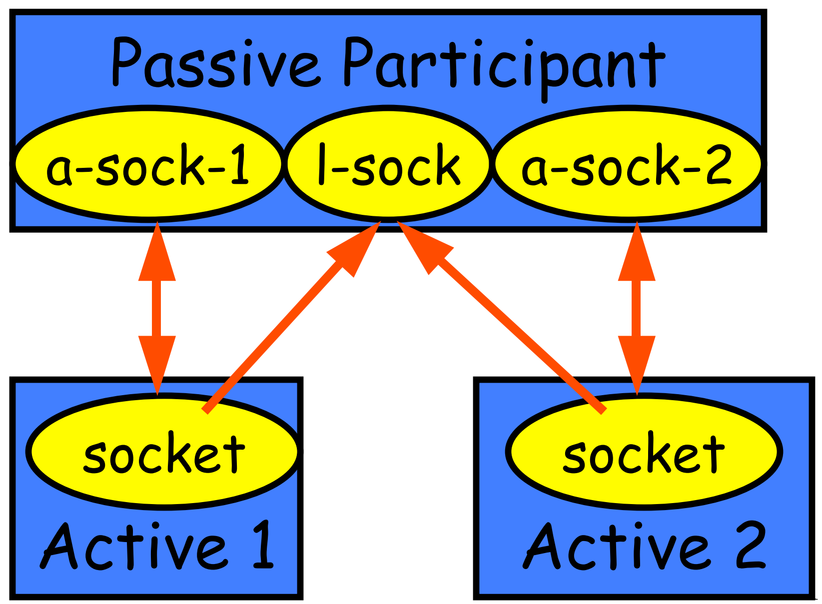
Connection Setup (SOCK_STREAM)

- Recall: no connection setup for SOCK_DGRAM
- A connection occurs between two kinds of participants
  - passive: waits for an active participant to request connection
  - active: initiates connection request to passive side
- Once connection is established, passive and active participants are "similar"
  - both can send & receive data
  - either can terminate the connection

Connection setup cont'd

- Passive participant
  - step 1: listen (for incoming requests)
  - step 3: accept (a request)
  - step 4: data transfer
- The accepted connection is on a new socket
- The old socket continues to listen for other active participants
- Why?

- Active participant
  - step 2: request & establish connection
  - step 4: data transfer



Connection setup: listen & accept

- Called by passive participant
- int status = listen(sock, queuelen);
  - status: 0 if listening, -1 if error
  - sock: integer, socket descriptor
  - queuelen: integer, # of active participants that can "wait" for a connection
  - listen is **non-blocking**: returns immediately
- int s = accept(sock, &name, &namelen);
  - s: integer, the new socket (used for data-transfer)
  - sock: integer, the orig. socket (being listened on)
  - name: struct sockaddr, address of the active participant
  - namelen: sizeof(name): value/result parameter
    - must be set appropriately before call
    - adjusted by OS upon return
  - accept is **blocking**: waits for connection before returning

connect call

- int status = connect(sock, &name, namelen);
  - status: 0 if successful connect, -1 otherwise
  - sock: integer, socket to be used in connection
  - name: struct sockaddr: address of passive participant
  - namelen: integer, sizeof(name)
- connect is **blocking**

Sending / Receiving Data

- With a connection (SOCK_STREAM):
  - int count = send(sock, &buf, len, flags);
    - count: # bytes transmitted (-1 if error)
    - buf: char[], buffer to be transmitted
    - len: integer, length of buffer (in bytes) to transmit
    - flags: integer, special options, usually just 0
  - int count = recv(sock, &buf, len, flags);
    - count: # bytes received (-1 if error)
    - buf: void[], stores received bytes
    - len: # bytes received
    - flags: integer, special options, usually just 0
  - Calls are **blocking** [returns only after data is sent (to socket buf) / received]

Sending / Receiving Data (cont'd)

- Without a connection (SOCK_DGRAM):
  - int count = sendto(sock, &buf, len, flags, &addr, addrlen);
    - count, sock, buf, len, flags: same as send
    - addr: struct sockaddr, address of the destination
    - addrlen: sizeof(addr)
  - int count = recvfrom(sock, &buf, len, flags, &addr, &addrlen);
    - count, sock, buf, len, flags: same as recv
    - name: struct sockaddr, address of the source
    - namelen: sizeof(name): value/result parameter
- Calls are **blocking** [returns only after data is sent (to socket buf) / received]

close

- When finished using a socket, the socket should be closed:
- status = close(s);
  - status: 0 if successful, -1 if error
  - s: the file descriptor (socket being closed)
- Closing a socket
  - closes a connection (for SOCK_STREAM)
  - frees up the port used by the socket

The struct sockaddr

- The generic:

```
struct sockaddr {
    u_short sa_family;
    char sa_data[14];
};
```

  - sa_family
    - specifies which address family is being used
    - determines how the remaining 14 bytes are used

- The Internet-specific:

```
struct sockaddr_in {
    short sin_family;
    u_short sin_port;
    struct in_addr sin_addr;
    char sin_zero[8];
};
```

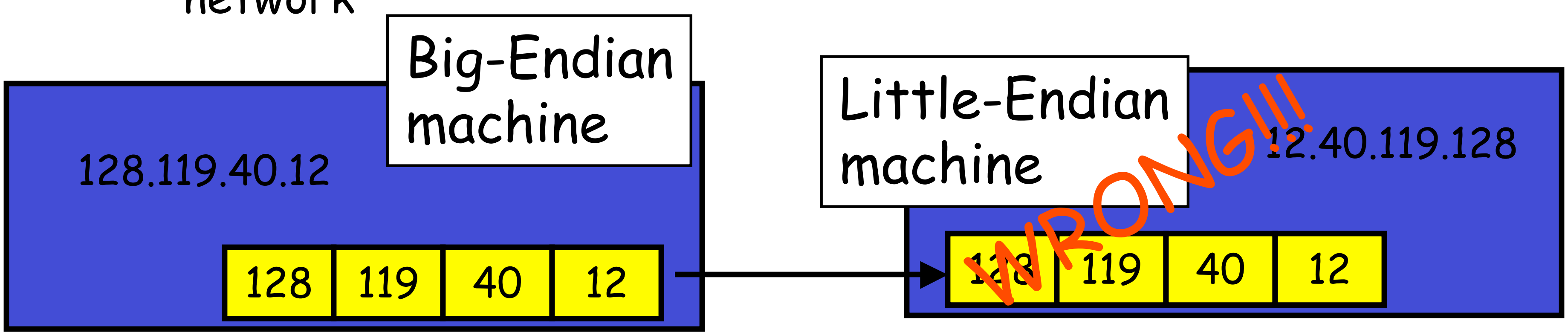
  - sin_family = AF_INET
  - sin_port: port # (0-65535)
  - sin_addr: IP-address
  - sin_zero: unused

Address and port byte-ordering

- Address and port are stored as integers
  - u_short sin_port; (16 bit)
  - in_addr sin_addr; (32 bit)

```
struct in_addr {
  u_long s_addr;
};
```

- Problem:
  - different machines / OS's use different word orderings
    - little-endian: lower bytes first
    - big-endian: higher bytes first
  - these machines may communicate with one another over the network



Solution: Network Byte-Ordering

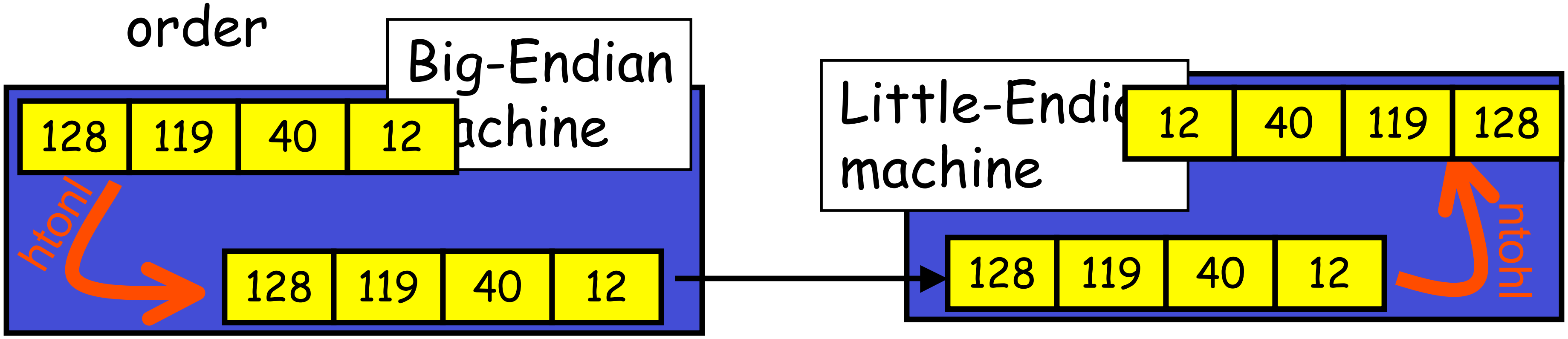
- Defs:
  - Host Byte-Ordering: the byte ordering used by a host (big or little)
  - Network Byte-Ordering: the byte ordering used by the network – always big-endian
- Any words sent through the network should be converted to Network Byte-Order prior to transmission (and back to Host Byte-Order once received)
- Q: should the socket perform the conversion automatically?

- Q: Given big-endian machines don't need conversion routines and little-endian machines do, how do we avoid writing two versions of code?

UNIX's byte-ordering funcs

- u_long htonl(u_long x);
- u_short htons(u_short x);
- u_long ntohl(u_long x);
- u_short ntohs(u_short x);

- On big-endian machines, these routines do nothing
- On little-endian machines, they reverse the byte order



- Same code would have worked regardless of endian-ness of the two machines

Dealing with blocking calls

- Many of the functions we saw block until a certain event
  - accept: until a connection comes in
  - connect: until the connection is established
  - recv, recvfrom: until a packet (of data) is received
  - send, sendto: until data is pushed into socket's buffer
    - Q: why not until received?
- For simple programs, blocking is convenient
- What about more complex programs?
  - multiple connections
  - simultaneous sends and receives
  - simultaneously doing non-networking processing

Dealing w/ blocking (cont'd)

- Options:
  - create multi-process or multi-threaded code
  - turn off the blocking feature (e.g., using the fcntl file-descriptor control function)
  - use the select function call.
- What does select do?
  - can be permanent blocking, time-limited blocking or non-blocking
  - input: a set of file-descriptors
  - output: info on the file-descriptors' status
  - i.e., can identify sockets that are "ready for use": calls involving that socket will return immediately

select function call

- int status = select(nfds, &readfds, &writefds, &exceptfds, &timeout);
  - status: # of ready objects, -1 if error
  - nfds: 1 + largest file descriptor to check
  - readfds: list of descriptors to check if read-ready
  - writefds: list of descriptors to check if write-ready
  - exceptfds: list of descriptors to check if an exception is registered
  - timeout: time after which select returns, even if nothing ready - can be 0 or ∞
    (point timeout parameter to NULL for ∞)

To be used with select:

- Recall select uses a structure, struct fd_set
  - it is just a bit-vector
  - if bit *i* is set in [readfds, writefds, exceptfds], select will check if file descriptor (i.e. socket) *i* is ready for [reading, writing, exception]
- Before calling select:
  - FD_ZERO(&fdvar): clears the structure
  - FD_SET(i, &fdvar): to check file desc. *i*
- After calling select:
  - int FD_ISSET(i, &fdvar): boolean returns TRUE iff *i* is "ready"

Other useful functions

- bzero(char* c, int n): 0's n bytes starting at c
- gethostname(char *name, int len): gets the name of the current host
- gethostbyaddr(char *addr, int len, int type): converts IP hostname to structure containing long integer
- inet_addr(const char *cp): converts dotted-decimal char-string to long integer
- inet_ntoa(const struct in_addr in): converts long to dotted-decimal notation

- Warning: check function assumptions about byte-ordering (host or network). Often, they assume parameters / return solutions in network byte-order

Release of ports

- Sometimes, a "rough" exit from a program (e.g., ctrl-c) does not properly free up a port
- Eventually (after a few minutes), the port will be freed
- To reduce the likelihood of this problem, include the following code:

```
#include <signal.h>
void cleanExit(){exit(0);}
```

  - in socket code:

```
signal(SIGTERM, cleanExit);
signal(SIGINT, cleanExit);
```

Final Thoughts

- Make sure to #include the header files that define used functions
- Check man-pages and course web-site for additional info