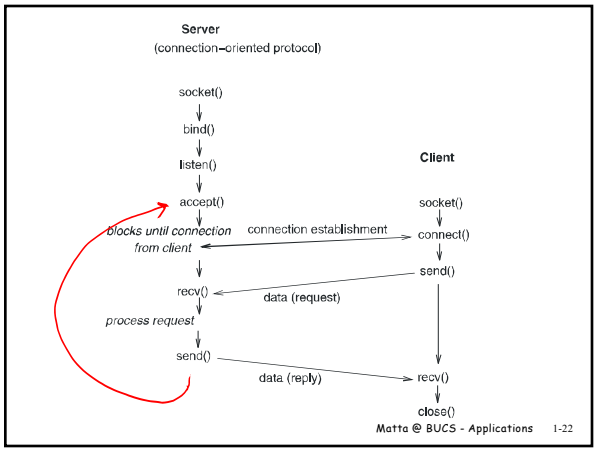

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Socket Operations in C/C++

- Creating a socket

  int socket(int domain, int type, int protocol)
  - domain=AF_INET (for TCP/IP protocols)
  - type=SOCK_STREAM (for TCP-based application)
- Passive open on server

  int bind(int socket, struct sockaddr *address, int addr_len)

  int listen(int socket, int backlog)

  int accept(int socket, struct sockaddr *address, int addr_len)

IP address (4B)
port number (2B)
client's

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Socket Operations (cont'd)

- Active open on client

  int connect(int socket, struct sockaddr *address, int addr_len)

  server's
- Sending and receiving messages

  int send(int socket, char *message, int msg_len, int flags)

  int recv(int socket, char *buffer, int buf_len, int flags)

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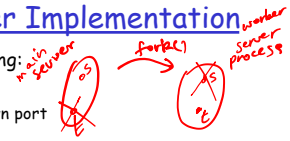
Concurrent Server Implementation

Main server does the following:

- Open port:
  - Main server opens well-known port
- Wait for client:
  - Main server waits for a new client request
- Start Worker:
  - Main server (parent) starts a worker (child) to handle request (e.g., in UNIX/Linux, it ***forks*** a copy of the server process)
  - parent closes ``connected'' socket, and child closes ``listening'' socket
  - child dies when done
- Continue:
  - parent returns to the ***wait*** step



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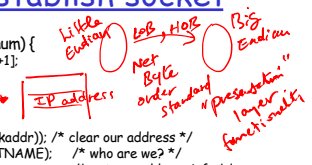
Server Code: establish socket

```
/* code to establish a socket */
int establish(unsigned short portnum) {
    char   myname[MAXHOSTNAME+1];
    int    s;
    struct sockaddr_in sa;
    struct hostent *hp;

    memset(&sa, 0, sizeof(struct sockaddr)); /* clear our address */
    gethostname(myname, MAXHOSTNAME);    /* who are we? */
    hp= gethostbyname(myname);           /* get our address info */
    if  (hp == NULL)                     /* we don't exist !? */
        return(-1);
    sa.sin_family= hp->h_addrtype;   /* this is our host address */
    sa.sin_addr = htonl(INADDR_ANY); /* this is our default IP address */
    sa.sin_port= htons(portnum);     /* this is our port number */
    if ((s= socket(AF_INET, SOCK_STREAM, 0)) < 0)  /* create socket */
        return(-1);
    if (bind(s,(struct sockaddr *)&sa,sizeof(sa))) < 0) {
        close(s);
        return(-1);              /* bind address to socket */
    }
    listen(s, 3);            /* max # of queued connects */
    return(s); }
```



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Server Code: wait for clients

```
/* wait for a connection to occur on a socket created with establish() */
int get_connection(int s) {
    int t;          /* socket of connection */

    if ((t = accept(s,NULL,NULL)) < 0)   /* accept connection if there is one */
      return(-1);
    return(t); }
```


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Server Code: main program

```
#include <errno.h>      /* obligatory includes */
#include <signal.h>
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <sys/wait.h>
#include <netinet/in.h>
#include <netdb.h>

#define PORTNUM 5000    /* random port number, we need something */
void do_something(int);

main() {
    int s, t;

    if ((s = establish(PORTNUM)) < 0) {  /* plug in the phone */
        perror("establish");
        exit(1);
    }
```


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Server Code: main (cont' d)

```
    for (;;) {              /* loop for phone calls */
        if ((t= get_connection(s)) < 0) { /* get a connection */
            perror("accept");      /* bad */
            exit(1);
        }
        do_something(t);
        close(t);                  /* another connection */
        continue;
    }
} /* end of main */

/* this is the function that plays with the socket.  It will
   be called after getting a connection. */
void do_something(int t) {
    /* do your thing with the socket here */
}
```


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Concurrent Server

```
/* how a concurrent server looks like */

for (;;) {                  /* loop for phone calls */
    if ((t= get_connection(s)) < 0) {     /* get a connection */
        perror("accept");          /* bad */
        exit(1);
    }
    switch( fork() ) {             /* try to handle connection */
    case -1 :                  /* bad news.  scream and die */
        perror("fork");
        close(s);
        close(t);
        exit(1);
    case 0 :                   /* we're the child, do something */
        close(s);
        do_something(t);
        close(t);
        exit(0);
    default :                  /* we're the parent so look for */
        close(t);              /* another connection */
        continue;
    }
}
```


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Client Code

```
int call_socket(char *hostname, unsigned short portnum) {
    struct sockaddr_in sa;
    struct hostent    *hp;
    int a, c;

    if  ((hp= gethostbyname(hostname)) == NULL) { /* do we know the host's address?*/
          return(-1);    /* no */
    }
    memset(&sa,0,sizeof(sa));
    memcpy((char *)&sa.sin_addr,hp->h_addr,hp->h_length);  /* set address */
    sa.sin_family= hp->h_addrtype;
    sa.sin_port= htons(portnum);
    if ((c= socket(hp->h_addrtype,SOCK_STREAM,0)) < 0)     /* get socket */
          return(-1);
    if (connect(c,(struct sockaddr *)&sa,sizeof(sa)) < 0) { /* connect */
          close(s);
          return(-1);
    }
    return(c);
}
```


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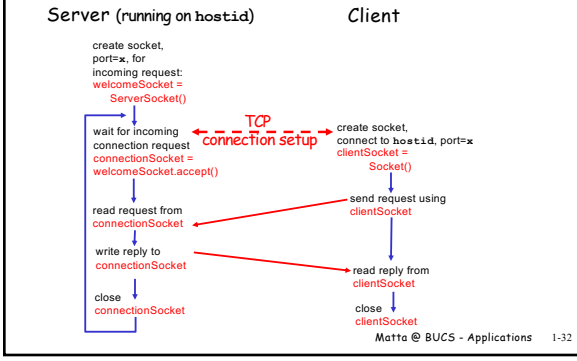
Java client/server socket interaction: TCP



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Example: Java client (TCP)

```
import java.io.*;
import java.net.*;
class TCPClient {

    public static void main(String argv[]) throws Exception
    {
        String sentence;
        String modifiedSentence;

        BufferedReader inFromUser =
          new BufferedReader(new InputStreamReader(System.in));

        Socket clientSocket = new Socket("hostname", 6789);

        DataOutputStream outToServer =
          new DataOutputStream(clientSocket.getOutputStream());
```

Create input stream

Create client socket, connect to server

Create output stream attached to socket

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Example: Java client (TCP), cont.

```
                    BufferedReader inFromServer =
                      new BufferedReader(new
                      InputStreamReader(clientSocket.getInputStream()));

                    sentence = inFromUser.readLine();

                    outToServer.writeBytes(sentence + '\n');

                    modifiedSentence = inFromServer.readLine();

                    System.out.println("FROM SERVER: " + modifiedSentence);

                    clientSocket.close();

                  }
                }
```

Create input stream attached to socket

Send line to server

Read line from server

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Example: Java server (TCP)

```
import java.io.*;
import java.net.*;

class TCPServer {

  public static void main(String argv[]) throws Exception
  {
    String clientSentence;
    String capitalizedSentence;

    ServerSocket welcomeSocket = new ServerSocket(6789);

    while(true) {

      Socket connectionSocket = welcomeSocket.accept();

      BufferedReader inFromClient =
        new BufferedReader(new
        InputStreamReader(connectionSocket.getInputStream()));
```

Create welcoming socket at port 6789

Wait, on welcoming socket for contact by client

Create input stream, attached to socket

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Example: Java server (TCP), cont

```
                    DataOutputStream  outToClient =
                      new DataOutputStream(connectionSocket.getOutputStream());

                    clientSentence = inFromClient.readLine();

                    capitalizedSentence = clientSentence.toUpperCase() + '\n';

                    outToClient.writeBytes(capitalizedSentence);
                    connectionSocket.close();
                  }
                }
              }
```

Create output stream, attached to socket

Read in line from socket

Write out line to socket

End of while loop, loop back and wait for another client connection

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Multi-threaded Programs

- A thread is a lightweight process
- A process can have one or more threads
- A thread runs in the context of a process
  - All threads share access to code and data, but each thread has its own private PC, registers, stack and state
- A server would have a thread to handle each request
- A client could also have multiple threads, e.g., one to send requests to server and another to receive responses from server
- Java threads (discussed in lab)

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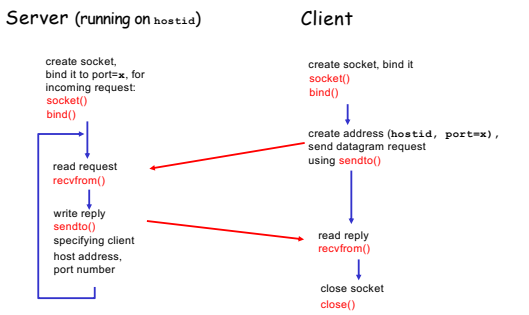
Client/server Socket Interaction in C/C++: UDP



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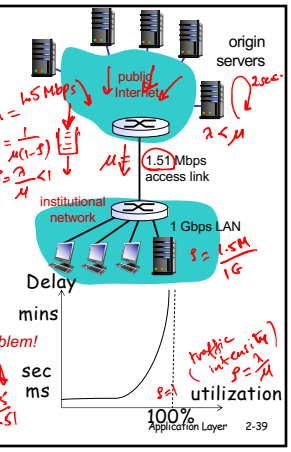
Caching example:

assumptions:

- avg object size: 100,000 bits
- avg request rate from browsers to origin servers: 15/sec
  - avg data rate to browsers: 1.50 Mbps
- RTT over the Internet: 2 sec
- access link rate: 1.51 Mbps

consequences:

- LAN utilization: 0.15%
  - Assume LAN delay ~ usecs
- access link utilization = 99% *problem!*
- total delay = Internet delay + access delay + LAN delay
  = 2 sec + minutes + usecs



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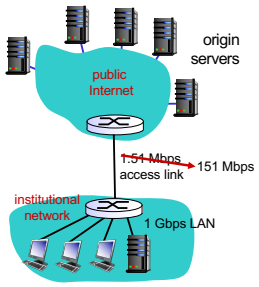
Caching example: fatter access link

assumptions:

- avg object size: 100K bits
- avg request rate from browsers to origin servers: 15/sec
  - avg data rate to browsers: 1.50 Mbps
- RTT over the Internet: 2 sec
- access link rate: 1.51 Mbps → 151 Mbps

consequences:

- LAN utilization: 0.15%
- access link utilization = 99% → 0.99%
- total delay = Internet delay + access delay + LAN delay
  = 2 sec + minutes + usecs → msecs ≈ 2 sec



Cost: increased access link speed (not cheap!)

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Caching example: install local cache

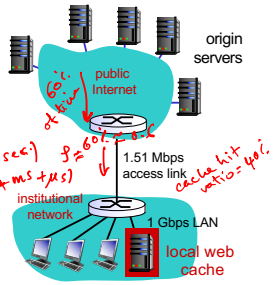
assumptions:

- avg object size: 100K bits
- avg request rate from browsers to origin servers: 15/sec
  - avg data rate to browsers: 1.50 Mbps
- RTT over the Internet: 2 sec
- access link rate: 1.51 Mbps

consequences:

- LAN utilization: 0.15%
- access link utilization = ?
- total delay = ?

How to compute link utilization, delay?



Cost: web cache (cheap!)

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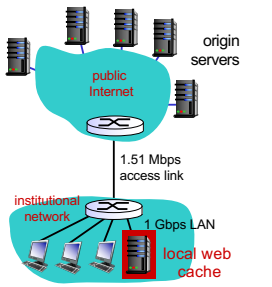
Caching example: install local cache

Calculating access link utilization, delay with cache:

- suppose cache hit rate is 0.4
  - 40% requests satisfied at cache, 60% requests satisfied at origin



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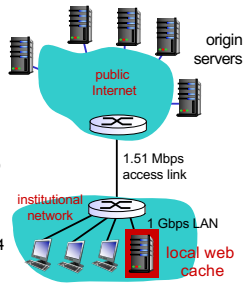
Caching example: install local cache

Calculating access link utilization, delay with cache:

- suppose cache hit rate is 0.4
  - 40% requests satisfied at cache, 60% requests satisfied at origin
- access link utilization:
  - 60% of requests use access link
- data rate to browsers over access link = 0.6*1.50 Mbps = .9 Mbps
  - utilization = 0.9/1.51 = .6
  - Assume access delay ~ 700ms
- total delay
  - = 0.6 * (delay from origin servers) +0.4 * (delay when satisfied at cache)
  - = 0.6 (~ 2.7) + 0.4 (~usecs)
  - = ~ 1.6 secs
  - less than with 151 Mbps link (and cheaper too!)



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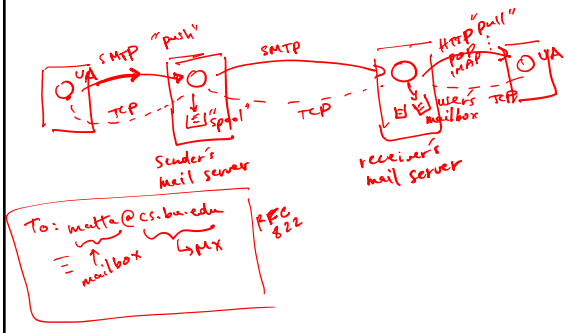
Application Example: TCP/IP Email



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