CSE 421/521 - Operating Systems
Fall 2011 Recitations

Recitation - III

Networking & Concurrent Programming

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Presented by ....

University at Buffalo
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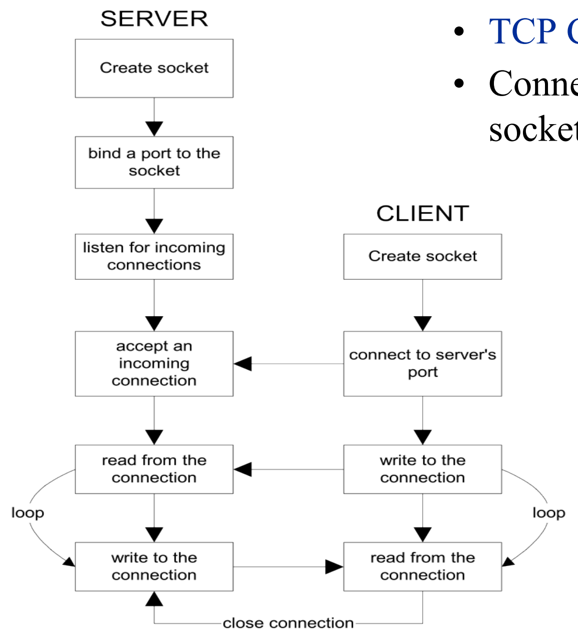
Network Programming



- TCP Client-Server view
- Connection-oriented socket connections

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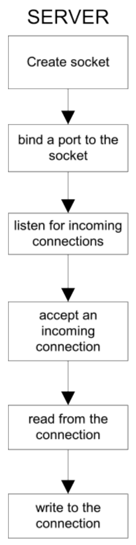
Server Side Socket Details


SERVER
Create socket
bind a port to the socket
listen for incoming connections
accept an incoming connection
read from the connection
write to the connection

int socket(int domain, int type, int protocol)
sockfd = socket(PF_INET, SOCK_STREAM, 0);

int bind(int sockfd, struct sockaddr *server_addr, socklen_t length)
bind(sockfd, &server, sizeof(server));

int listen(int sockfd, int num_queued_requests)
listen(sockfd, 5);

int accept(int sockfd, struct sockaddr *incoming_address, socklen_t length)
newfd = accept(sockfd, &client, sizeof(client)); /* BLOCKS */

int read(int sockfd, void * buffer, size_t buffer_size)
read(newfd, buffer, sizeof(buffer));

int write(int sockfd, void * buffer, size_t buffer_size)
write(newfd, buffer, sizeof(buffer));

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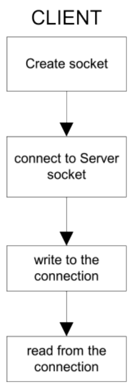
Client Side Socket Details



int socket(int domain, int type, int protocol)
sockfd = socket(PF_INET, SOCK_STREAM, 0);

int connect(int sockfd, struct sockaddr *server_address, socklen_t length)
connect(sockfd, &server, sizeof(server));

int write(int sockfd, void * buffer, size_t buffer_size)
write(sockfd, buffer, sizeof(buffer));

int read(int sockfd, void * buffer, size_t buffer_size)
read(sockfd, buffer, sizeof(buffer));

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Example: A Simple Time Server

```
#include  <stdio.h>
#include  <sys/types.h>
#include  <sys/socket.h>
#include  <netinet/in.h>
#include  <netdb.h>

#define   PORTNUM  8824
#define   oops(msg)     { perror(msg) ; exit(1) ; }
```

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```
void main(int ac, char **av)
{
     struct  sockaddr_in   saddr;   /* build our address here */
         struct   hostent            *hp;   /* this is part of our    */
         char     hostname[256];         /* address             */
         int      slen,sock_id,sock_fd;  /* line id, file desc     */
         FILE     *sock_fp;              /* use socket as stream   */
     char    *ctime();              /* convert secs to string */
     long    time(), thetime;       /* time and the val       */


       gethostname( hostname , 256);           /* where am I ?         */
       hp = gethostbyname( hostname );         /* get info about host  */
       bzero( &saddr, sizeof(saddr) );         /* zero struct          */
                                              /* fill in hostaddr     */
       bcopy( hp->h_addr, &saddr.sin_addr, hp->h_length);
       saddr.sin_family = AF_INET ;            /* fill in socket type  */
       saddr.sin_port = htons(PORTNUM);        /* fill in socket port  */

       sock_id = socket( AF_INET, SOCK_STREAM, 0 );    /* get a socket */
       if ( sock_id == -1 ) oops( "socket" );

       if ( bind(sock_id, &saddr, sizeof(saddr)) != 0 )/* bind it to   */
```

```
while ( 1 ){
              sock_fd = accept(sock_id, NULL, NULL); /* wait for call */
                 printf("** Server: A new client connected!");
              if ( sock_fd == -1 )
                      oops( "accept" );       /* error getting calls  */

              sock_fp = fdopen(sock_fd,"w");  /* we'll write to the   */
              if ( sock_fp == NULL )          /* socket as a stream   */
                      oops( "fdopen" );       /* unless we can't      */

              thetime = time(NULL);           /* get time             */
                                              /* and convert to strng */
              fprintf( sock_fp, "**************************************\n");
              fprintf( sock_fp, "** From Server: The current time is: ");
              fprintf( sock_fp, "%s", ctime(&thetime) );
              fprintf( sock_fp, "**************************************\n");

              fclose( sock_fp );              /* release connection   */
                  fflush(stdout);                     /* force output  */
      }
}
```

Client-Server Implementation

1.server code

```
main(int argc, char **argv){
    int    len, port_sk,  client_sk;
    char *errmess;

    port_sk = tcp_passive_open(port);  /*  establish port   */
    if ( port_sk < 0 ) { perror("socket"); exit(1); }
    printf("start up complete\n");

    client_sk = tcp_accept(port_sk);  /*  wait for client to connect  */

    close(port_sk);  /*  only want one client, so close port_sk  */

    for(;;) {  /*  talk to client  */
        len = read(client_sk,buff,buf_len);  //listen
        printf("client says: %s\n",buff);
         ....
        if ( gets(buff) == NULL ) {    /* user typed end of file  */
            close(client_sk); break;
        }
        write(client_sk,buff,strlen(buff));    //server's turn
    } exit(0);
}
```

passive open

```
int  tcp_passive_open(portno)
    int    portno;
{
    int     sd, code;
    struct  sockaddr_in bind_addr;
    bind_addr.sin_family = AF_INET;
    bind_addr.sin_addr.s_addr = 0;    /*  0.0.0.0  ==  this host  */
    bzero(bind_addr.sin_zero, 8);
    bind_addr.sin_port = portno;
    sd = socket(AF_INET, SOCK_STREAM,0);
    if ( sd < 0 ) return sd;
    code = bind(sd, &bind_addr, sizeof(bind_addr) );
    if ( code < 0 ) { close(sd); return code; }
    code = listen(sd, 1);
    if ( code < 0 ) { close(sd); return code; }
    return sd;
}
```

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tcp_accept

```
int  tcp_accept(sock)
    int sock;
{
    int     sd;
    struct  sockaddr bind_addr;
    int len=sizeof(bind_addr);
    sd = accept(sock, &bind_addr, &len);
    return sd;
}
```

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2. client code

```
main( int argc, char**argv )
{
    int  serv_sk, len;
    char *errmess;
     serv_sk = tcp_active_open(host,port);  /*  request connection  */
    if ( serv_sk < 0 ) { perror("socket"); exit(1); }
    printf("You can send now\n");

    for(;;) { /*  talk to server  */
        if ( gets(buff) == NULL ) {    /* client's turn  */
            close(serv_sk);  break;
        }
        write(serv_sk,buff,strlen(buff));

        len = read(serv_sk,buff,buf_len); //wait for server's response
        if (len == 0) {
            printf("server finished the conversation\n");break;
            }
        buff[len] = '\0';
        printf("server says: %s\n",buff);
    }   exit(0);
}
```

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active open

```
int  tcp_active_open(char* hostname,int portno)
{
    int     sd, code;
    struct  sockaddr_in bind_addr;
    struct hostent *host;

    host = gethostbyname(hostname);
    if (host == NULL ) return -1;
    bind_addr.sin_family = PF_INET;
    bind_addr.sin_addr = *((struct in_addr *) (host->h_addr));
    bind_addr.sin_port = portno;
    sd = socket(AF_INET, SOCK_STREAM, 0);
    if ( sd < 0 ) return sd;
    code = connect(sd, &bind_addr, sizeof(bind_addr) );
    if ( code < 0 ) { close(sd); return code; }
    return sd;
}
```

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Threads

- In certain cases, a single application may need to run several tasks at the same time
  - Creating a new process for each task is time consuming
  - Use a single process with multiple threads
    - faster
    - less overhead for creation, switching, and termination
    - share the same address space

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Thread Creation

- **pthread_create**

```
// creates a new thread executing start_routine
int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine)(void*), void
   *arg);
```

- **pthread_join**

```
// suspends execution of the calling thread until the target
// thread terminates
int pthread_join(pthread_t thread, void **value_ptr);
```

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Thread Example

```
main()
{
pthread_t thread1, thread2;  /* thread variables */

pthread_create(&thread1, NULL, (void *) &print_message_function,(void*)"hello ");
pthread_create(&thread2, NULL, (void *) &print_message_function,(void*)"world!");

pthread_join(thread1, NULL);
pthread_join(thread2, NULL);

printf("\n");
exit(0);
}
```

Why use pthread_join?

To force main block to wait for both threads to terminate, before it exits. If main block exits, both threads exit, even if the threads have not finished their work.

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Thread Example *(cont.)*

```
void print_message_function ( void *ptr )
{
    char *cp = (char*)ptr;
    int i;
    for (i=0;i<3;i++){
        printf("%s \n", cp);
        fflush(stdout);
        sleep(1);
    }

    pthread_exit(0); /* exit */
}
```

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Example: Interthread Cooperation

```
void* print_count ( void *ptr );
void* increment_count ( void *ptr );

int NUM=5;
int counter =0;

int main()
{
   pthread_t thread1, thread2;

   pthread_create (&thread1, NULL, increment_count, NULL);
   pthread_create (&thread2, NULL,  print_count, NULL);

   pthread_join(thread1, NULL);
   pthread_join(thread2, NULL);

   exit(0);
}
```

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Interthread Cooperation *(cont.)*

```
void* print_count ( void *ptr )
{
   int i;
   for (i=0;i<NUM;i++){
      printf("counter = %d \n", counter);
      //sleep(1);
   }
   pthread_exit(0);
}

void* increment_count ( void *ptr )
{
   int i;
   for (i=0;i<NUM;i++){
      counter++;
      //sleep(1);
   }
   pthread_exit(0);
}
```

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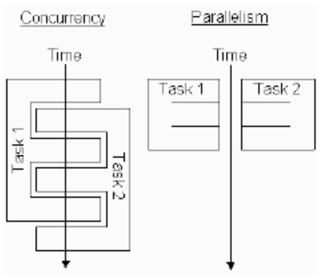
Concurrency Issues

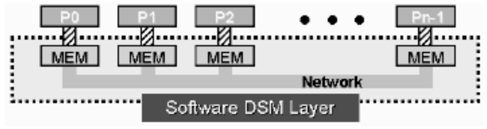
P1:	`X:=1`
P2:	`X:=0; X:=X+1`



- If programs are independent, the results are the same (X=1)
- If programs are executed concurrently and one program is `X:=1,` are results of P1 and P2 different
- **"interleaving" makes it difficult to deal with global properties from the local analysis!**
- assumption: access to the memory is atomic

Concurrency Issues

- Shared variables are an effective way to communicate between processes
- X:=X+1 is implemented as 3 different instructions
  - load the value of X to the register
  - increment the register
  - store the value of register to X
- Two processes updating same variable concurrently causes erroneous results
- Correctivity of the program needs that this updating will be indivisible (or atomic)
- Reading a variable can also be a critical section
  - e.g. reading four bytes that are not volatile



```
LD      AX, CARS
INC     AX
LD      CARS, AX
```

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POSIX Threads: MUTEX

```
int pthread_mutex_init(pthread_mutex_t *mutex, const pthread_mutexattr_t
                                                              *mutexattr);

int pthread_mutex_lock(pthread_mutex_t *mutex);

int pthread_mutex_unlock(pthread_mutex_t *mutex);

int pthread_mutex_destroy(pthread_mutex_t *mutex);
```

- a new data type named pthread_mutex_t is designated for mutexes
- a mutex is like a key (to access the code section) that is handed to only one thread at a time
- the attribute of a mutex can be controlled by using the pthread_mutex_init() function
- the lock/unlock functions work in tandem

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MUTEX Example

```
#include <pthread.h>
...
pthread_mutex_t my_mutex;     // should be of global scope
...
int main()
{
                int tmp;
                ...
                // initialize the mutex
                tmp = pthread_mutex_init( &my_mutex, NULL );
                ...
                // create threads
                ...
                pthread_mutex_lock( &my_mutex );
                    do_something_private();
                pthread_mutex_unlock( &my_mutex );
                ...
                return 0;
}
```

Whenever a thread reaches the lock/unlock block, it first determines if the mutex is locked. If so, it waits until it is unlocked. Otherwise, it takes the mutex, locks the succeeding code, then frees the mutex and unlocks the code when it's done.

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POSIX: Semaphores

- creating a semaphore:

int sem_init(sem_t *sem, int pshared, unsigned int value);

initializes a semaphore object pointed to by sem

pshared is a sharing option; a value of 0 means the semaphore is local to the calling process

gives an initial value value to the semaphore

- terminating a semaphore:

int sem_destroy(sem_t *sem);

frees the resources allocated to the semaphore sem

usually called after pthread_join()

an error will occur if a semaphore is destroyed for which a thread

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POSIX: Semaphores *(cont.)*

- semaphore control:

int sem_post(sem_t *sem);

int sem_wait(sem_t *sem);

sem_post atomically increases the value of a semaphore by 1, i.e., when 2 threads call sem_post simultaneously, the semaphore's value will also be increased by 2 (there are 2 atoms calling)

sem_wait atomically decreases the value of a semaphore by 1; but always waits until the semaphore has a non-zero value first

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Semaphore: Example

```
#include <pthread.h>
#include <semaphore.h>
...
void *thread_function( void *arg );
...
sem_t semaphore;        // also a global variable just like mutexes
...
int main()
{
                int tmp;
                ...
                // initialize the semaphore
                tmp = sem_init( &semaphore, 0, 0 );
                ...
                // create threads
                pthread_create( &thread[i], NULL, thread_function, NULL );
                ...
                while ( still_has_something_to_do() )
                {
                                sem_post( &semaphore );
```

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Semaphore: Example *(cont.)*

```
void *thread_function( void *arg )
{
                sem_wait( &semaphore );
                perform_task_when_sem_open();
                ...
                pthread_exit( NULL );
}
```

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Exercises
Threads (True or False Questions):

- A thread cannot see the variables on another thread's stack.
- ***False*** *-- they can since they share memory*

- In a non-preemptive thread system, you do not have to worry about race conditions.
- ***False*** *-- as threads block and unblock, they may do so in unspecified orders, so you can still have race race conditions.*

- A thread may only call **pthread_join()** on threads which it has created with **pthread_create()**
- ***False* --** *Any thread can join with any other*

- With mutexes, you may have a thread execute instructions atomically with respect to other threads that lock the mutex.
- ***True*** *-- That's most often how mutexes are used.*

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Exercises
Threads (True or False Questions):

- pthread_create() always returns to the caller
- True.

- pthread_mutex_lock() never returns
- False -- It may block, but it when it unblocks, it will return.

- pthread_exit() returns if there is no error
- False -- never returns.

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Exercises

Processes:

Please provide two reasons on why an invocation to fork() might fail

(1) too many processes in the system (2) the total number of processes for the real uid exceeds the limit (3) too many PID in the system (4) memory exceeds the limit,

When a process terminates, what would be the PID of its child processes? Why?

It would become 1. Because when any of the child processes terminate, init would be informed and fetch termination status of the process so that the system is not cogged by zombie processes.

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Daemon Processes

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Daemon Characteristics

Commonly, dæmon processes are created to offer a specific service.

Dæmon processes usually

- live for a long time
- are started at boot time
- terminate only during shutdown
- have no controlling terminal

The previously listed characteristics have certain implications:

- do one thing, and one thing only
- no (or only limited) user-interaction possible
- consider current working directory
- how to create (debugging) output

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Writing a Daemon

- fork off the parent process
- change file mode mask (umask)
- create a unique Session ID (SID)
- change the current working directory to a safe place
- close (or redirect) standard file descriptors
- open any logs for writing
- enter actual dæmon code

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Example Daemon Creation

```
int daemon_init(void)
{
   pid_t pid;
   if ((pid=fork())<0)  return (-1);
   else if (pid!=0) exit (0); //parent goes away
   setsid(); //becomes session leader
   chdir("/"); //cwd
   umask(0);   //clear file creation mask
return (0)
}
```

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Daemon Logging

A daemon cannot simply print error messages to the terminal or standard error. Also, we would not want each daemon writing their error messages into separate files in different formats. A central logging facility is needed.

There are three ways to generate log messages:

- via the kernel routine `log(9)`
- via the userland routine `syslog(3)`
- via UDP messages to port 514

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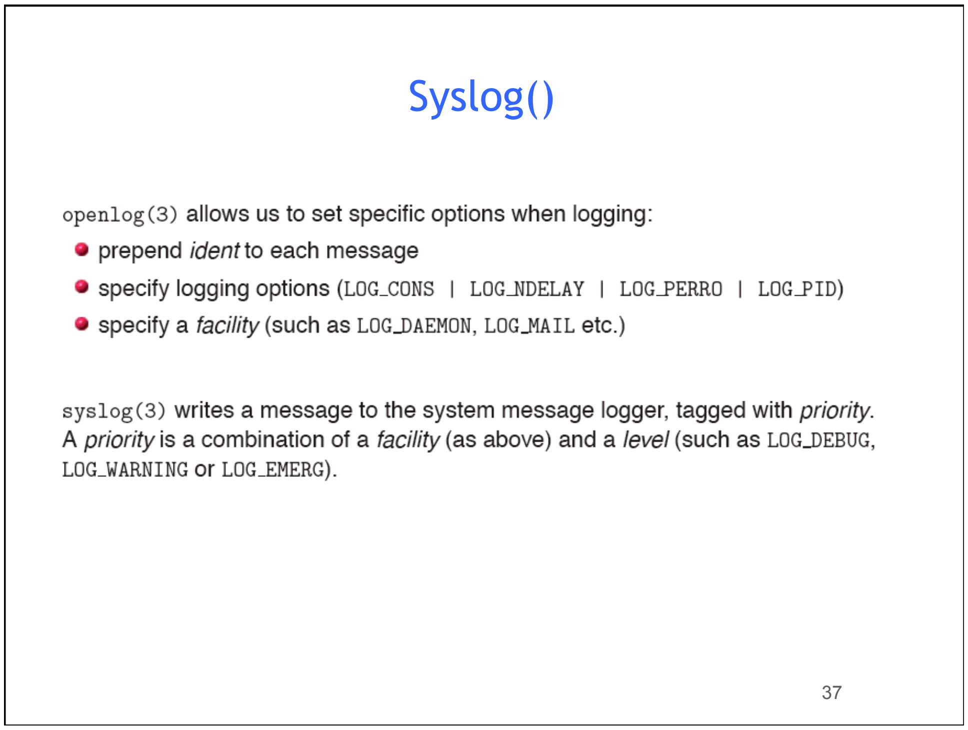

Syslog()

`openlog(3)` allows us to set specific options when logging:

- prepend *ident* to each message
- specify logging options (`LOG_CONS | LOG_NDELAY | LOG_PERRO | LOG_PID`)
- specify a *facility* (such as `LOG_DAEMON`, `LOG_MAIL` etc.)

`syslog(3)` writes a message to the system message logger, tagged with *priority*. A *priority* is a combination of a *facility* (as above) and a *level* (such as `LOG_DEBUG`, `LOG_WARNING` or `LOG_EMERG`).

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