System Software

Agenda

1. Inter Process Communications
2. Signals
3. Multithreading
4. Timers and Resource Limits
5. xv6 Kernel Internals

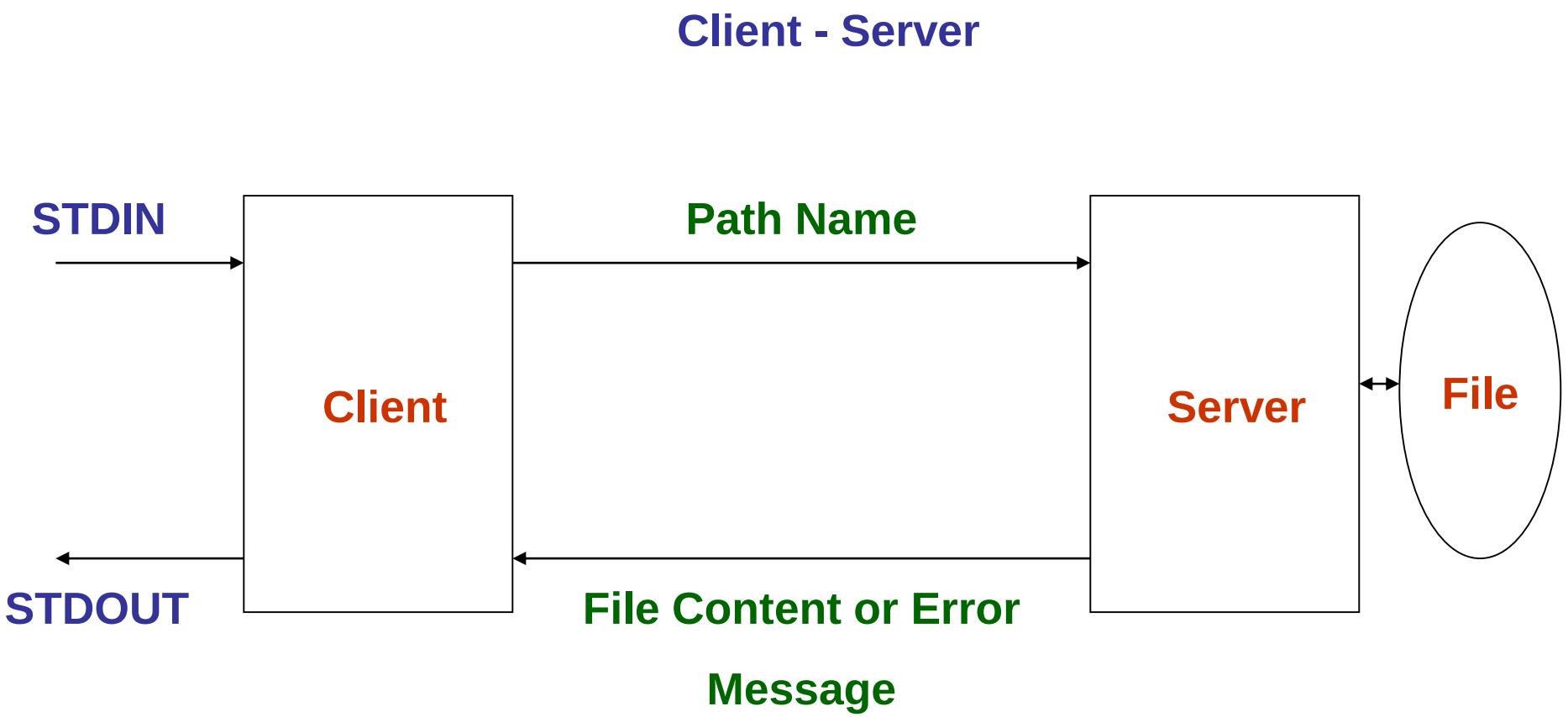
Inter Process Communications (IPC) Mechanisms

- In a multiprocessing environment, often many processes are in need to communicate with each other and share some of the resources.
- The shared resources must also be synchronized from the concurrent access by many processes.
- IPC mechanisms have many distinct purposes: for example

* Data transfer
* Sharing data
* Event notification
* Resource sharing
* Process control

- Primitive
  - Unnamed pipe
  - Named pipe (FIFO)
- System V IPC
  - Message queues
  - Shared memory
  - Semaphores
- Socket Programming

Pipe Example

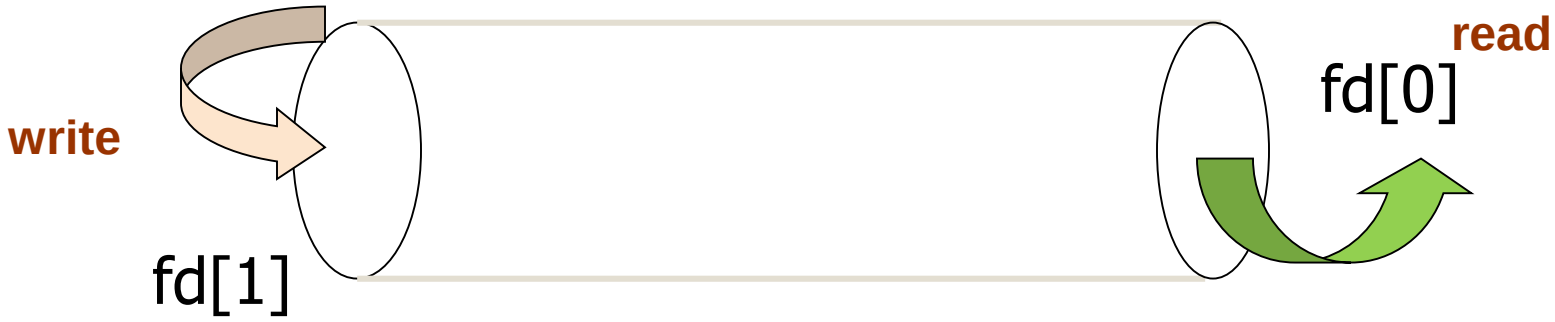


pipe (or unnamed pipe “|”)

- On command line pipe is represented as “|”
- It can be used in the shell to link two or more commands
  - For example ls –Rl | wc
- Two ends of a pipe is represented as a set of two descriptors.
- A pipe is used to communicate between related processes.

- Half duplex
- Data is passed in order.
- Pipe uses circular buffer and it has zero buffering capacity
- The read and write system calls are blocking calls.

Pipe – half duplex



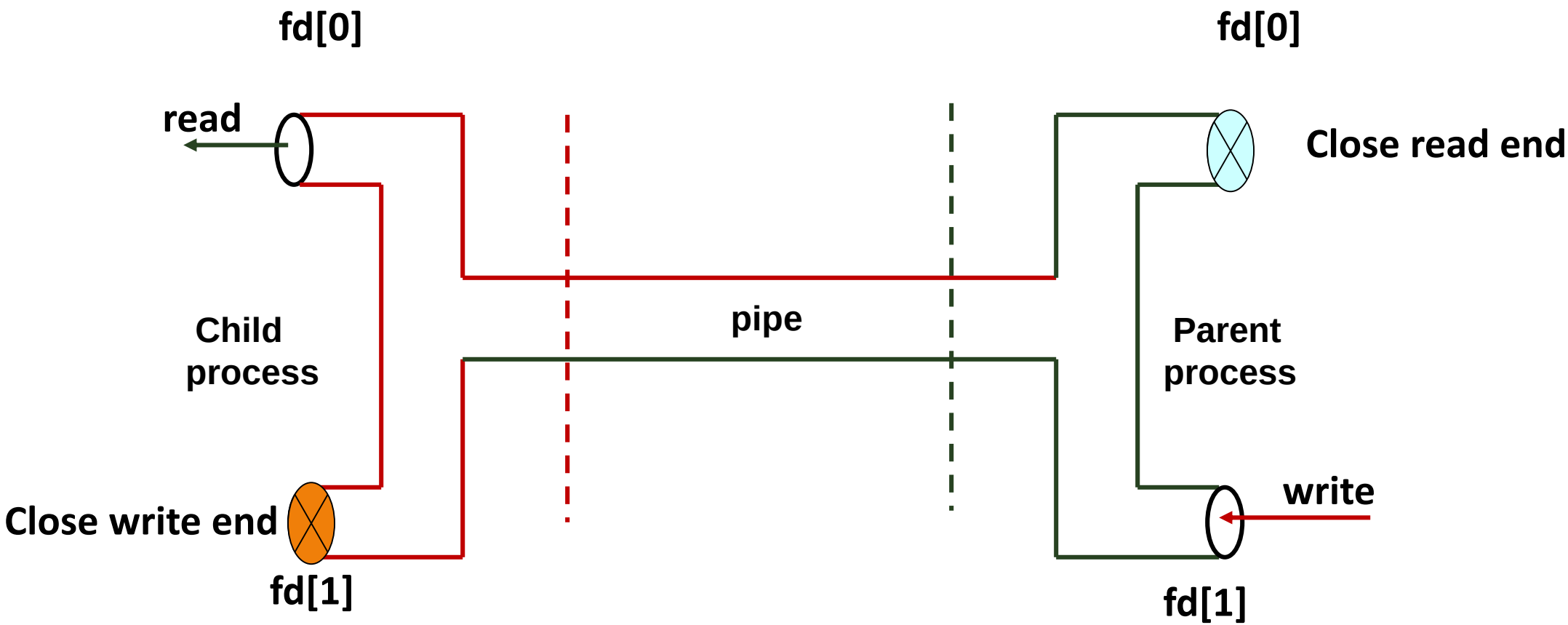

```
int fd[2];
pipe(fd);
    -returns with fd[0], fd[1];


write(fd[1], ……);
read(fd[0], ……);
```

- Create a pipe.
- Call fork.
- Parent can send data and child can read the data or vice versa.
- Unused ends (descriptors) should be closed.

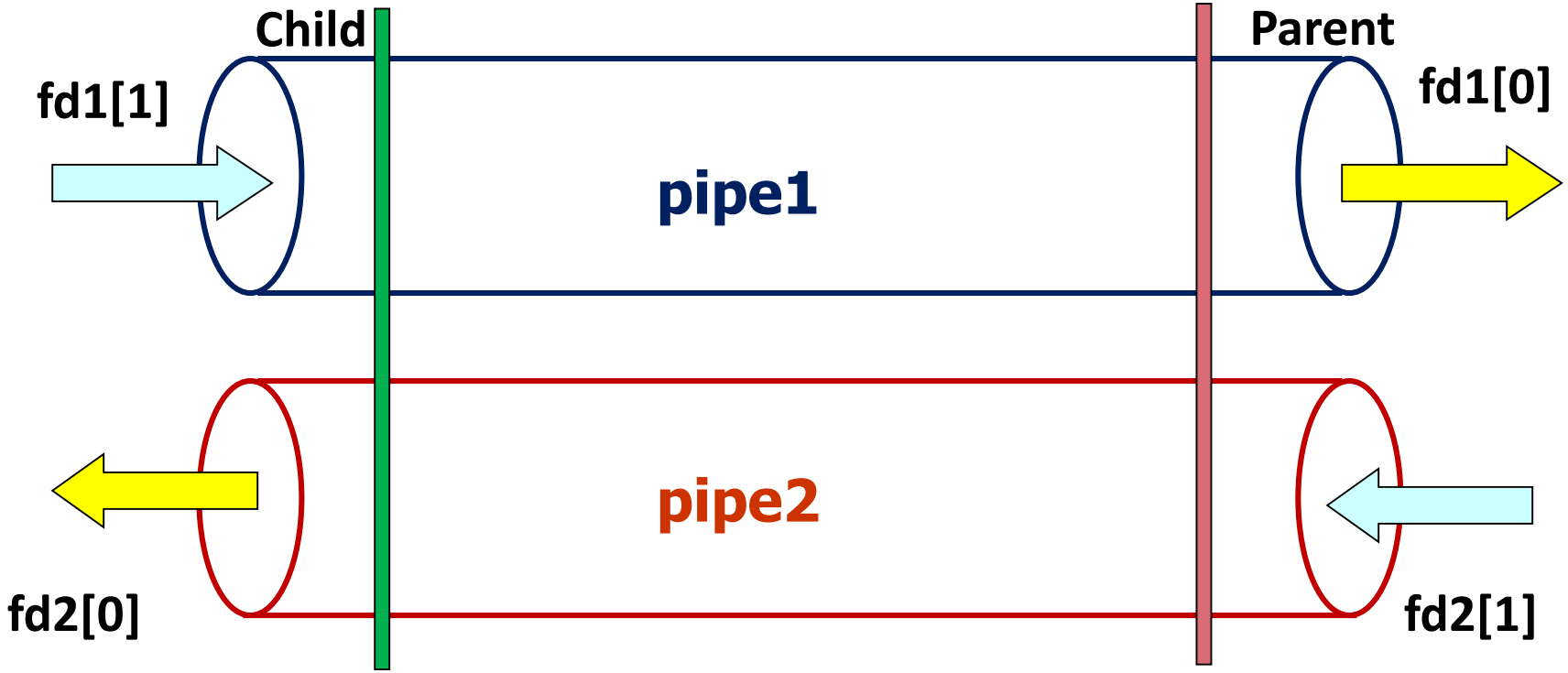
One way data transfer from related process

One-way communication from parent to child

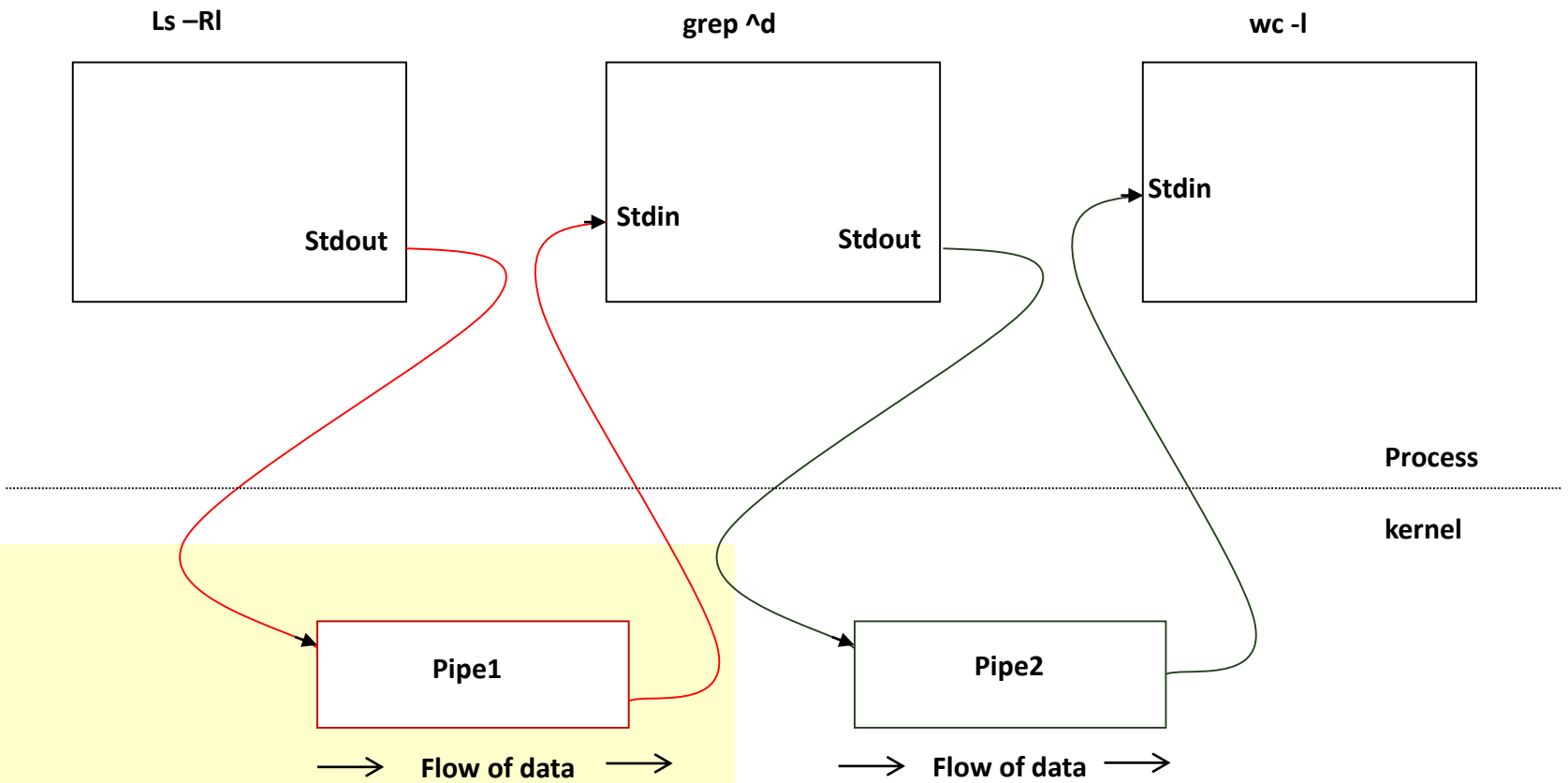


Two Way Communication

- Create two pipes say fd1, fd2.
- Four descriptors for each process (fd1[0], fd1[1], fd2[0], fd2[1]).
- Parent closes read end of fd1 and write end of fd2 close(fd1[0], fd2[1]);
- child closes read end of fd2 and write end of fd1 close(fd2[0], fd1[1]);



Execution of command: $ ls –Rl | grep ^d | wc -l



Pipe advantages:

- **Simplest form of IPC**
- **Persistence in process level**
- **Can be used in shell**

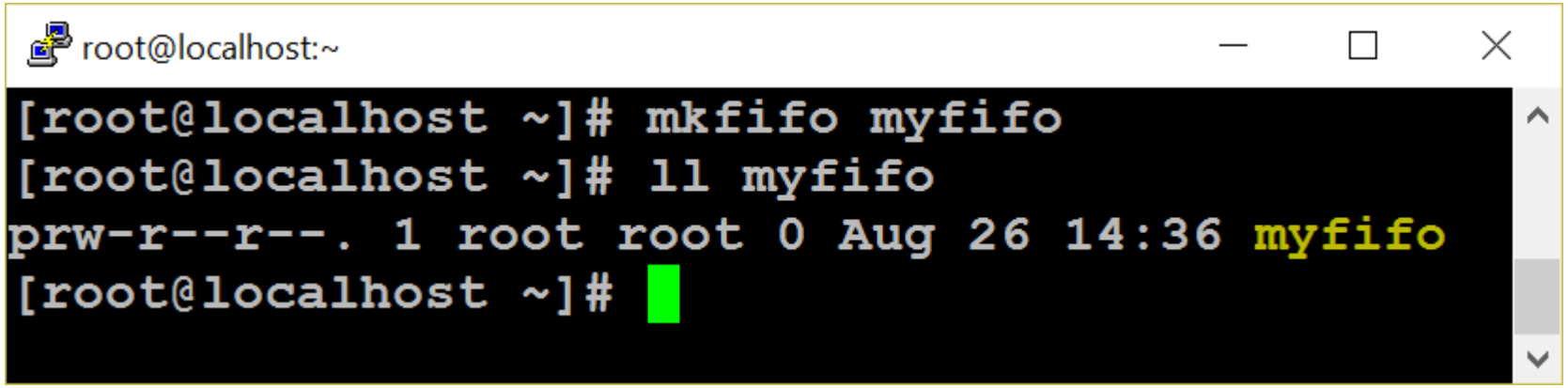
Disadvantages:

- **Cannot be used to communicate between unrelated processes**

popen ( ) Library Function

- The popen library function opens a process by creating a pipe, execute fork and invoke a shell.
- FILE *popen (const char *executable, const char *mode);
- On success returns file pointer else NULL (if fork or pipe system calls failed).
- int pclose (FILE *STREAM);
- Used to read or write to a file at a specified offset value.
- Same as read/write except the starting position is from the given offset.
- On success the system calls return number of bytes read or written.
- If 0 returns
  - pwrite: nothing has been written
  - pread: end of file

FIFO -Introduction



- FIFO works much like a pipe
  - Half duplex, data passed in FIFO order, circular buffer and zero buffering capacity.
- FIFO is created on a file system as a device special file
- It can be used to communicate between unrelated processes
- It can be reused.
- Persist till the file is deleted.

- FIFO can be created in a shell by using mknod or mkfifo command.
  - mknod myfifo p
  - mkfifo a=rw myfifo
- In a C program mknod system call or mkfifo library function can be used.
  - int mkfifo (char *file_name, mode_t mode);
  - int mknod (char *file_name, mode_t mode, dev_t dev);
    - mknod("./MYFIFO", S_IFIFO|0666, 0);

FIFO

- Once a FIFO is created, you can use file's related system calls (open, read, write, select, close etc.,) to access the FIFO.
- For example: Process 1 may open a FIFO in write only mode and write some data.
- Process 2 may open the FIFO in read only mode, read the data and display on the monitor.

FIFO - Disadvantages

- Data cannot be broadcast to multiple receivers.
- If there are multiple receivers, there is no way to direct to a specific reader or vice versa.
- Cannot store data and you cannot use FIFO across network.
- Less secure than a pipe, since any process with valid access permission can access data.
- No message boundaries. Data is treated as a stream of bytes.

FIFO Limitation

- System imposed limits on pipes
  1. Maximum number of files can be open within a process is determined by OPEN_MAX macro.
  2. Maximum amount of data that can be written to a pipe of FIFO atomically is determined by PIPE_BUF macro (size of a circular buffer).

```
#include <unistd.h>
 main () {
  long PIPE_BUF, OPEN_MAX;
  PIPE_BUF = pathconf(".", _PC_PIPE_BUF);
  OPEN_MAX = sysconf (_SC_OPEN_MAX);
  printf ("Pipe_buf = %ld\t OPEN_MAX =
                        %ld\n", PIPE_BUF, OPEN_MAX);
 }
```

System V IPC

root@localhost:/home/raju

```
SVIPC(7)                    Linux Programmer's Manual                   SVIPC(7)

NAME
       svipc - System V interprocess communication mechanisms

SYNOPSIS
       #include <sys/msg.h>
       #include <sys/sem.h>
       #include <sys/shm.h>

DESCRIPTION
       This  manual  page refers to the Linux implementation of the System V inter
       process communication (IPC) mechanisms: message queues, semaphore sets,  and
       shared  memory  segments.   In  the  following,  the  word resource means an
 Manual page ipc(5) line 1 (press h for help or q to quit)
```

- Pipe and FIFO do not satisfy many requirements of many applications.
- Sys V IPC is implemented as a single unit
- System V IPC Provides three mechanisms namely : MQ, SHM and SEM
- Persist till explicitly delete or reboot the system

Attributes

- Each IPC objects has the following attributes.
  - key
  - id
  - Owner
  - Permission
  - Size
    - Message queue – used-bytes, number of messages
    - Shared memory – size, number of attach, status
    - Semaphore – number of semaphores in a set
- The ipc_perm structure holds the common attributes of the resources.

Key:

- the first step is to create a shared unique identifier.
- The simplest form of the identifier is a number
- the system generates this number dynamically by using the *ftok* library function.
- Syntax: key_t ftok (const char *filename, int id);

ID

- The syntax for a *get* function is:

int xxxget (key_t key, int xxxflg);

(xxx may be msg or shm or sem)

- If successful, returns to an identifier; otherwise -1 for error.

- The key can be generated in three different ways
  - from the *ftok* library function
  - by choosing some static positive integer value
  - by using the IPC_PRIVATE macro
- flags commonly used with this function are IPC_CREAT and IPC_EXCL.

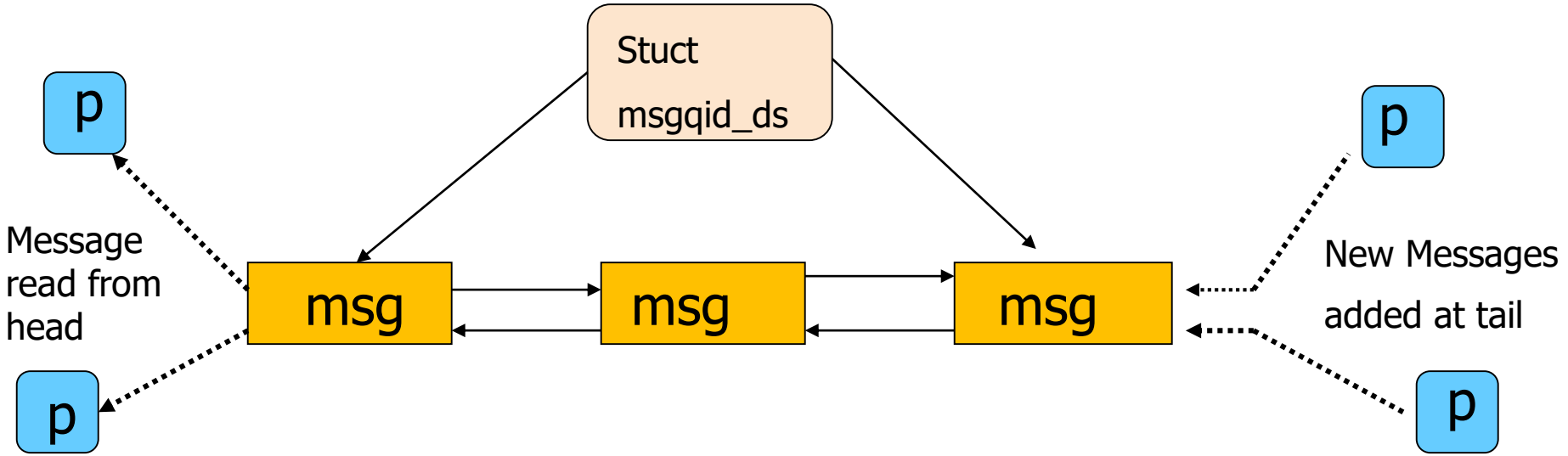
- The syntax for the *control* function is:

int xxxctl (int xxxid, int cmd, struct xxxid_ds *buffer); (xxx may be msg or shm or sem);

- If successful, the *xxxctl* function returns zero, otherwise it returns -1.
- The command argument may be
  - IPC_STAT
  - IPC_SET
  - IPC_RMID

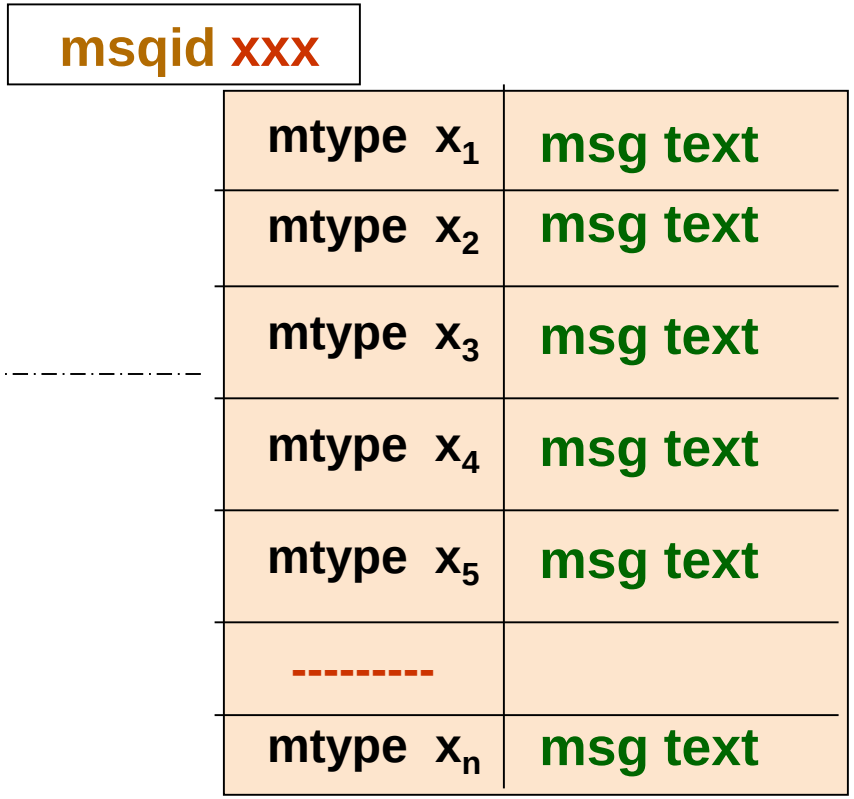
Message Q

- Message queue overcomes FIFO limitation like storing data and setting message boundaries.
- Create a message queue
- Send message (s) to the queue
- Any process who has permission to access the queue can retrieve message (s).
- remove the message queue.



Message Q

```
struct msgbuf {
        long mtype;
        char mtext [1];
}; Standard structure
```




```
struct My_msgQ {
        long mtype;
        char mtext [1024];
        void *   xyz;
}; Our own structure
```

MQ System Calls

- int msgget (key_t key, int msgflg);
- The first argument key can be passed from the return value of the ftok function or made IPC_PRIVATE.
- To create a message queue, IPC_CREAT ORed with access permission is set for the msgflg argument.
- Ex: msgid = msgget (key, IPC_CREAT | 0744);

  msgid = msgget (key, 0);

- The syntax of the function is:

int msgsnd (int msqid, structu msgbuf *msgp, size_t msgsz, int msgflg);

- Arguments:
  - message queue ID, address of the structure.
  - size of the message text
  - message flag = 0 or IPC_NOWAIT

- syntax of the function is:

ssize_t msgrcv (int msqid, struct msgbuf *msgp, size_t msgsz, long msgtype, int msgflg);

- msgtype argument is used to retrieve a particular message.
  - 0 -retrieve in FIFO order
  - +ve - retrieve the the exact value of the message type
  - –ve - first message or <= to the absolute value.
- on success, msgrcv returns with the number of bytes actually copied into the message text

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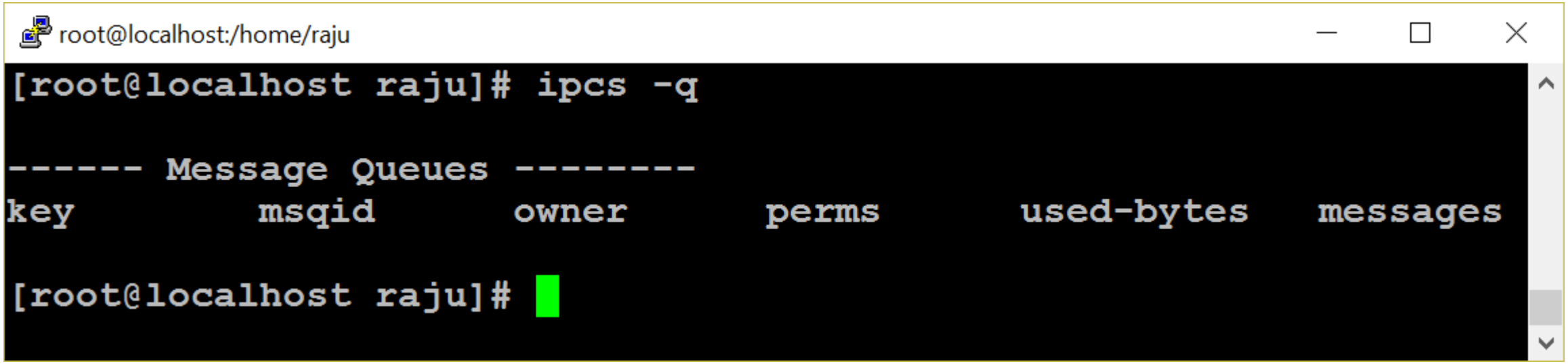
  - –ve - first message or <= to the absolute value.
- on success, msgrcv returns with the number of bytes actually copied into the message text

- key = ftok (“.“, ‘a‘);
- msqid = msgget (key, IPC_CREAT|0666);
- msgsnd (msqid, &struct, sizeof (struct), 0);
- msgrcv (msqid, &struct, sizeof (struct), mtype, 0);
- msgctl (msqid, IPC_RMID, NULL);
- $ipcrm msg msqid

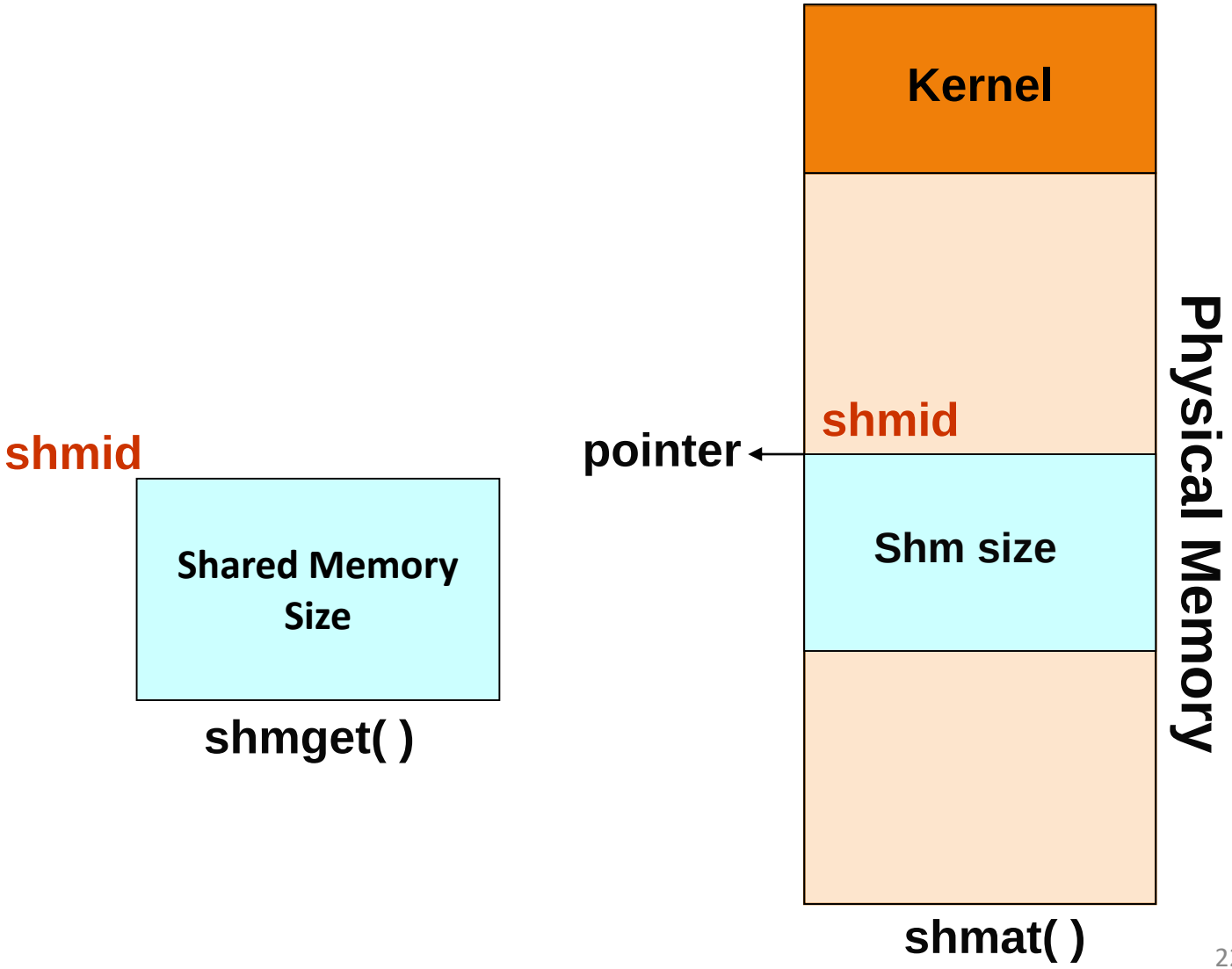
MQ Limitations

- Message queues are effective if a small amount of data is transferred.
- Very expensive for large transfers.
- During message sending and receiving, the message is copied from user buffer into kernel buffer and vice versa
- So each message transfer involves two data copy operations, which results in poor performance of a system.
- A message in a queue can not be reused



Shared Memory - Introduction

- Very flexible and ease of use.
- Fastest IPC mechanisms
- shared memory is used to provide access to
  - Global variable
  - Shared libraries
  - Word processors
  - Multi-player gaming environment
  - Http daemons
  - Other programs written in languages like Perl, C etc.,



Shared Memory

- Shared memory is a much faster method of communication than either semaphores or message queues.
- Does not require an intermediate kernel buffer
- Using shared memory is quite easy. After a shared memory segment is set up, it is manipulated exactly like any other memory area.

- The steps involved are
  - Creating shared memory
  - Connecting to the memory & obtaining a pointer to the memory
  - Reading/Writing & changing access mode to the memory
  - Detaching from memory
  - Deleting the shared segment

shm – system calls

- shmget system call is used to create a shared memory segment.
- The syntax:

  int shmget (key_t key, int size, int shmflg);

  key: the return value of ftok function.
  size: size of the shared memory.
  shmflg: IPC_CREAT|0744
- On success the shmget returns the shared memory ID or else it returns -1.

- used to attach the created shared memory segment onto a process address space.
- void *shmat(int shmid,void *shmaddr,int shmflg)
- Example: data=shmat(shmid,(void *)0,0);
- A pointer is returned on the successful execution of the system call and the process can read or write to the segment using the pointer.

shm – system calls

- Reading or writing to a shared memory is the easiest part.
- The data is written on to the shared memory as we do it with normal memory using the pointers

Example -

- Read:
  - printf (“SHM contents : %s \n”, data);
- Write:
  - printf (“”Enter a String : ”);
  - scanf (“ %[^\n]”,data);

- The detachment of an attached shared memory segment is done by shmdt to pass the address of the pointer as an argument.
- Syntax: int shmdt (void *shmaddr);
- To remove shared memory call:

  int shmctl (shmid,IPC_RMID,NULL);

- These functions return –1 on error and 0 on successful execution.

shm –system calls

- shmid = shmget (key, 1024, IPC_CREAT|0744);
- void *shmat (int shmid, void *shmaddr, int shmflg); if the shm is read only pass SHM_RDONLY else 0
- (void *)data = shmat (shmid, (void *)0, 0);
- int shmdt (void *shmaddr);
- int shmctl (shmid, IPC_RMID, NULL);

- Data can either be read or written only. Append ?
- Race condition
  - Since many processes can access the shared memory, any modification done by one process in the address space is visible to all other processes.
  - Since the address space is a shared resource, the developer should implement a proper locking mechanism to prevent the race condition in the shared memory.

Semaphore

- Synchronization Tool
- An Integer Number
- P ( ) And V ( ) Operators
- Avoid Busy Waiting
- Types of Semaphore

Used in :

- shared memory segment
- message queue
- file

p and v operations

Incrementing Operations:

```
int v (int i)
 {
  i = i + 1; (unlock)
  return i;
 }
```

- If a process wants to use the shared object, it will “lock” it by asking the semaphore to decrement the counter
- Depending upon the current value of the counter, the semaphore will either be able to carry out this operation, or will have to wait until the operation becomes possible
- The current value of counter is >0, the decrement operation will be possible. Otherwise, the process will have to wait

Decrementing Operations:

```
int p (int i)  {
  if (i > 0)
   then
    i--; (lock)
   else
    wait till i > 0;
   return i;
  }
```

- System V semaphore provides a semaphore set - that can include a number of semaphores. It is up to user to decide the number of semaphores in the set
- Each semaphore in the set can be a binary or a counting semaphore. Each semaphore can be used to control access to one resource - by changing the value of semaphore count

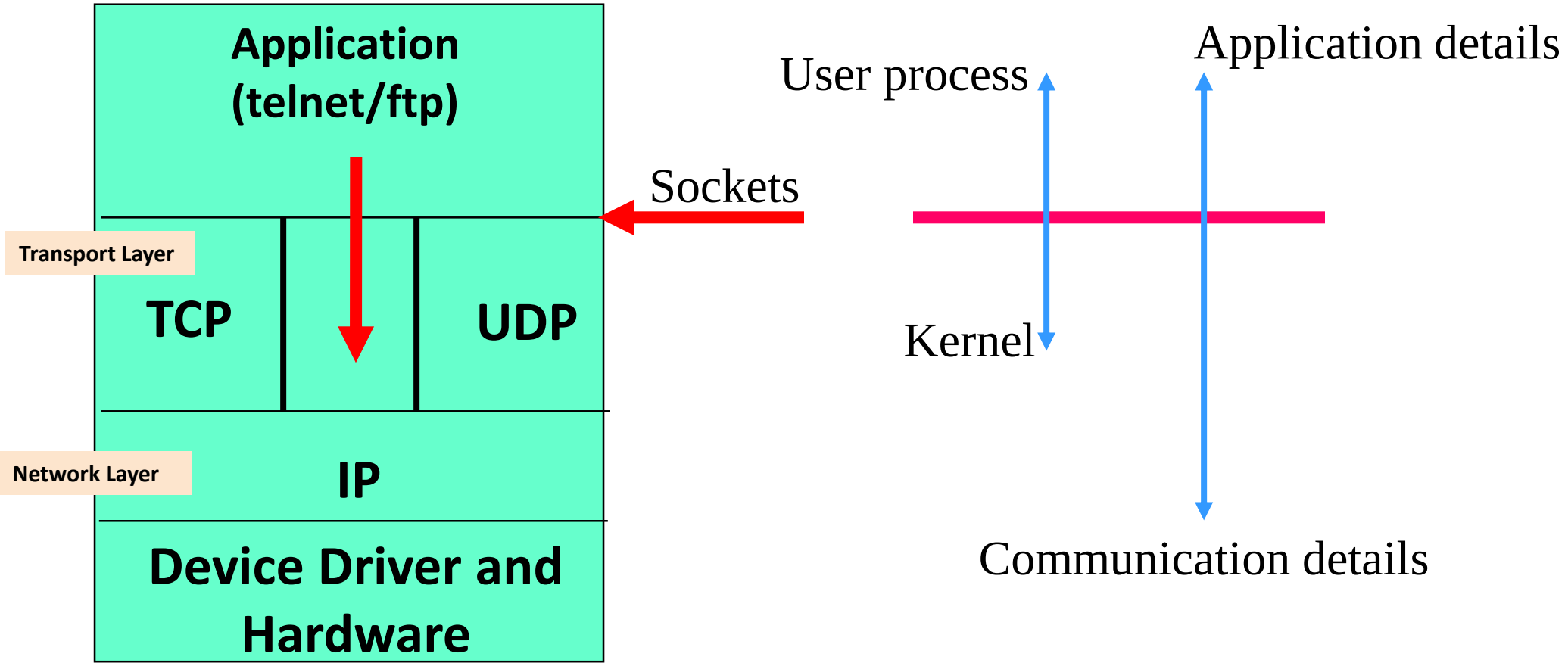
Semaphore Implementation

```
union semun {
  int val;      // value for SETVAL
  struct semid_ds *buf;  // buffer for
   IPC_STAT, IPC_SET
  unsigned short int *array;  // array for
   GETALL, SETALL
 };

union semun arg;
semid = semget (key, 1, IPC_CREAT | 0644);
arg.val = 1;
/* 1 for binary else > 1 for Counting Semaphore */
semctl (semid, 0, SETVAL, arg);
```

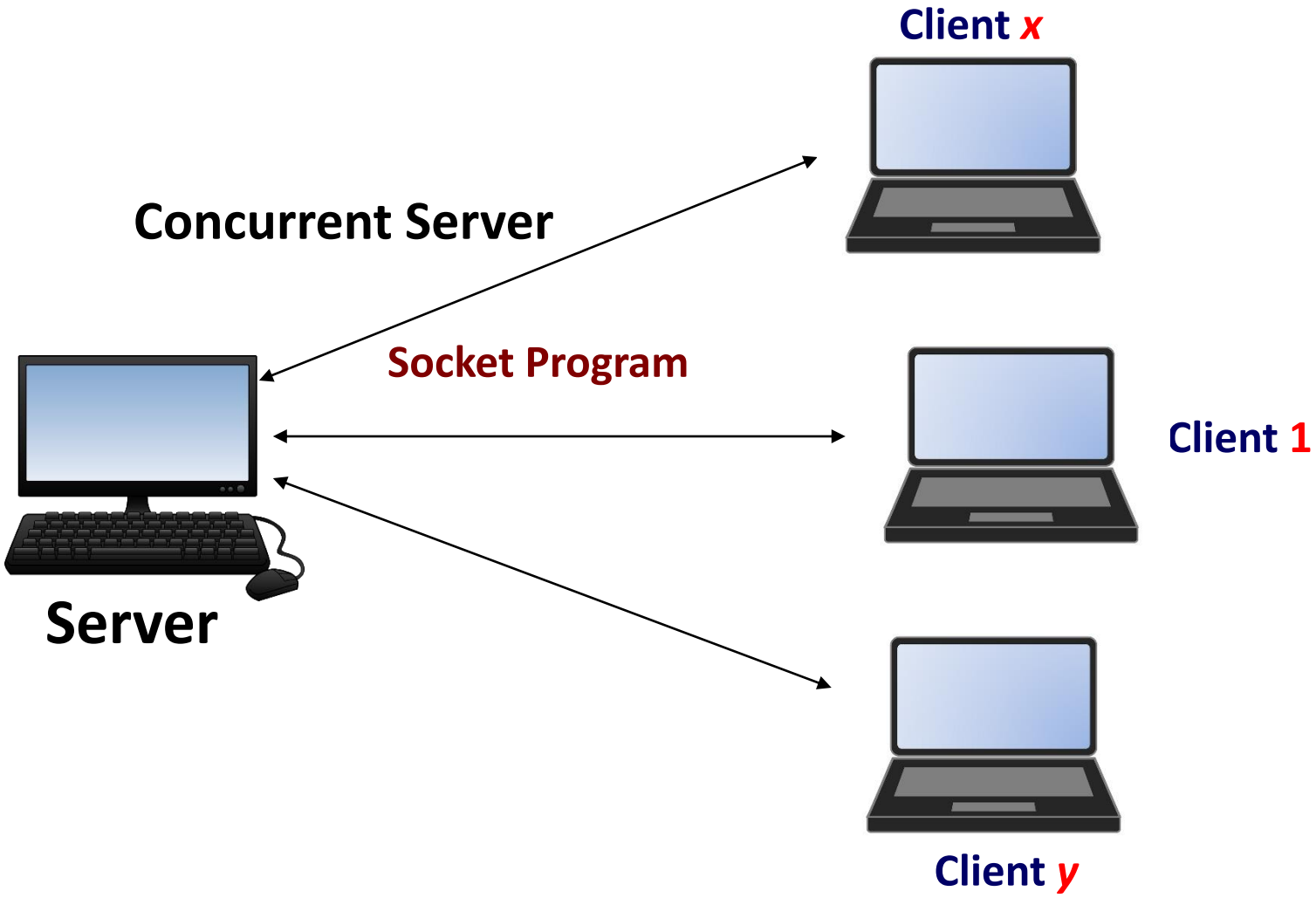
```
struct sembuf {
  short sem_num;  /* semaphore number: 0 means first */
  short sem_op;   /* semaphore operation: lock or unlock */
  short sem_flg;  /* operation flags : 0, SEM_UNDO, IPC_NOWAIT */
   };
struct sembuf buf = {0, -1, 0};  /* (-1 + previous value) */
semid = semget (key, 1, 0);

semop (semid, &buf, 1); /* locked */
-----Critical section--------
buf.sem_op = 1;
semop (semid, &buf, 1); /* unlocked */
```

Socket Programming - TCP/IP Protocol Stack

A socket is used to communicate between different machines (different IP addresses). Socket of type SOCK_STREAM is full-duplex byte streams.



Socket Programming – Client Server Model



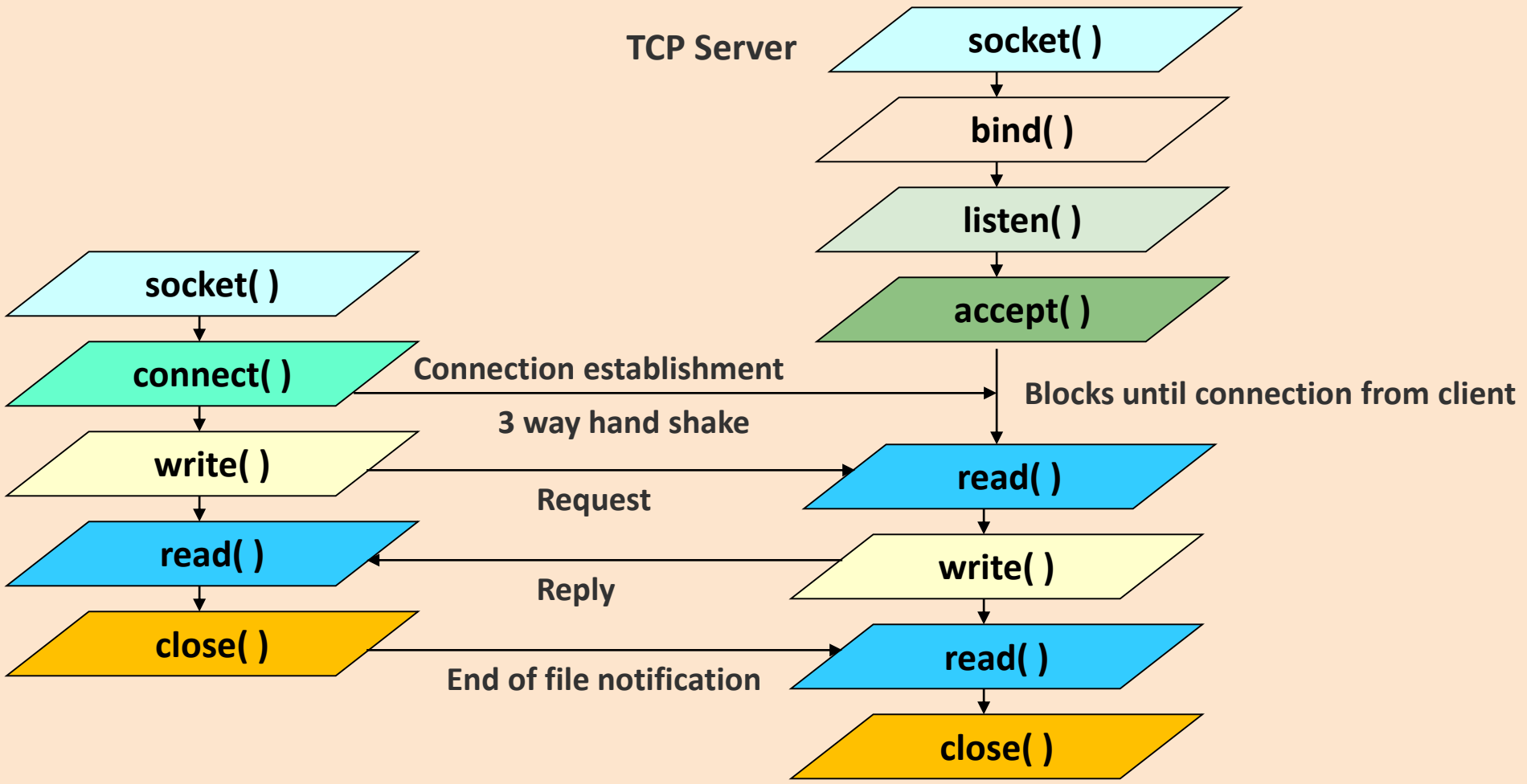
- A socket is a communication endpoint and represents abstract object that a process may use to send or receive messages.
- The two most prevalent communication APIs for Unix Systems are Berkeley Sockets and System V Transport Layer Interface(TLI)

socket ( ) system call

- The typical client -server relationship is not symmetrical
- Network Connection can be connection-oriented or connectionless
- More parameters must be specified for network connection, than for file I/O
- The Unix I/O system is stream oriented
- The network interface should support multiple communication protocol

- int socket (int domain,int type,int protocol);
- Domain (AF – Address Family)
  - AF_UNIX for UNIX domain
  - AF_INET for Internet domain
- Socket type
  - SOCK_STREAM for TCP (Connection Oriented)
  - SOCK_DGRAM for UDP (Connectionless)
- Protocol
  - Protocol number is used to identify an application. List of the protocol number and the corresponding applications can be seen at /etc/protocols.
- The socket system call returns a socket descriptor on success and -1 for failure.

Socket Functions



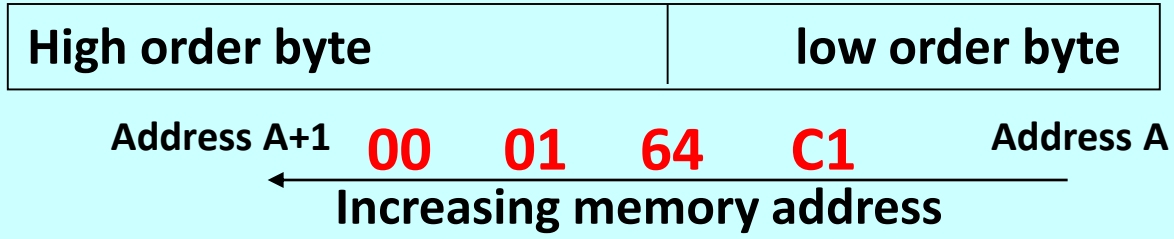
sock structure

- struct sockaddr_in {
  short int sin_family;
  unsigned short int sin_port;
  struct in_addr sin_addr;
  }
- sin_family - address family
- sin_port - port number
- sin_addr - internet address (IP addr)

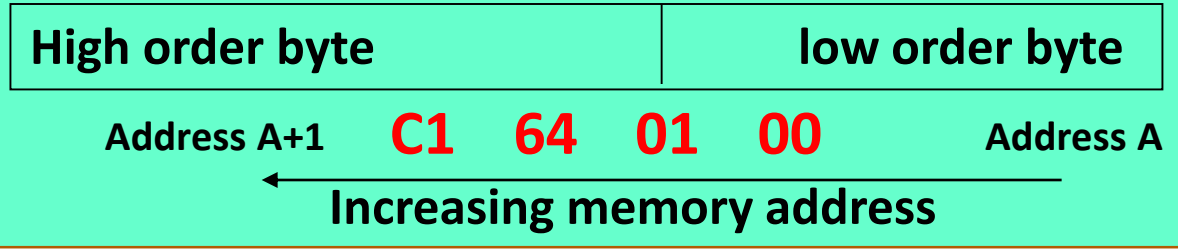
- The in_addr structure used to define sin_addr is as under

```
struct in_addr {
    unsigned long s_addr;
/* refers to the four byte IP address */
 }
```

Little endian byte order : example: Intel series



Big endian byte order : example: IBM 370, Motorola



Byte ordering ex: 91,329 hex: 00 01 64 C1

Socket system calls

- Internet protocols use big endian byte ordering called network byte order
- The following functions allow conversions between the formats.

#include <netinet/in.h>

htons() – "Host to Network Short"

htonl() – "Host to Network Long"

ntohs() – "Network to Host Short"

ntohl() – "Network to Host Long"

- h stands for host n stands for network
- s stands for short l stands for long

- int bind (int sockfd, struct sockaddr *my_addr,int addrlen);
- sockfd - the socket file descriptor returned by socket().
- my_addr - a pointer to a struct sockaddr that contains information about IP address and port number.
- addrlen - set to sizeof (struct sockaddr)

Socket system calls

int connect (int sockfd, struct sockaddr *serv_addr, int addrlen);

- **sockfd - the socket file descriptor returned by socket().**
- **serv_addr - is a struct sockaddr containing the destination port and IP address.**
- **addrlen - set to sizeof (struct sockaddr).**

int listen (int sockfd,int backlog);

- **sockfd - the socket file descriptor returned by socket().**
- **backlog - the number of connections allowed on the incoming queue.**
- **Backlog should never be zero as servers always expect connection from client.**
- **The listen function converts an unconnected socket into a passive socket,**
- **On successful execution of listen is indicating that the kernel should accept incoming connection requests directed to this socket.**

Socket system calls

- int accept (int sockfd, void *addr, int *addrlen);
- sockfd
  - the socket file descriptor returned by socket().
- addr
  - a pointer to a struct sockaddr_in. The information about the incoming connection like IP address and port number are stored.
- addrlen
  - a local integer variable that should be set to sizeof (struct sockaddr_in) before its address is passed to accept().

- Socket descriptor can be closed like file descriptor.

close (sockfd);

- Close system call prevents any more reads and writes to the socket. For attempting to read or write the socket on the remote end will receive an error.

Socket system calls

- int shutdown (int sockfd, int how);
- sockfd - socket file descriptor of the socket to be shutdown.
- how – if it is
  - 0 - Further receives are disallowed
  - 1 - Further sends are disallowed
  - 2 - Further sends and receives are disallowed.
- The shutdown system call gives more control (than close (sockfd) over how the socket descriptor can be closed.

Socket Programming

SERVER

```
struct sockaddr_in serv, cli;

sd = socket (AF_INET, SOCK_STREAM, 0);

serv.sin_family = AF_INET;
serv.sin_addr.s_addr = INADDR_ANY;
serv.sin_port = htons (portno);

bind (sd, &serv, sizeof (serv));
listen (sd, 5);

nsd = accept (sd, &cli, &sizeof (cli));
read / write (nsd, ….);
```

CLIENT

```
struct sockaddr_in serv;
sd = socket (AF_INET, SOCK_STREM, 0);

serv.sin_family = AF_INET;
serv.sin_addr.s_addr = inet_addr (“ser ip”);
serv.sin_port = htons (portno);

connect (sd, &server, sizeof  (server));
read / write (sd, ….);
```

Iterative Vs Concurrent Server

- One client request at a time.

```
nsd = accept (sd, &cli,…);
while (1) {
   read/write(nsd, …);
}
```

Many clients requests can be serviced concurrently

```
while (1) {
   nsd =(accept (sd, &cli, ….);
    if (!fork( )) {
          close(sd);
          read/write(nsd, …..);
          exit();
    } else
          close(nsd);
}
```

Alarm and Timers

- **unsigned int alarm (unsigned int seconds);**
- **It is used to set an alarm for delivering SIGALARM signal.**
- **On success it returns zero.**

- **Three interval timers.**
  - **ITIMER_REAL**
    - This timer counts down in real (i.e., wall clock) time. At each expiration, a ***SIGALRM*** signal is generated.
  - **ITIMER_VIRTUAL**
    - This timer counts down against the user-mode CPU time consumed by the process. (The measurement includes CPU time consumed by all threads in the process.) At each expiration, a ***SIGVTALRM*** signal is generated.
  - **ITIMER_PROF**
    - This timer counts down against the total (i.e., both user and system) CPU time consumed by the process. At each expiration, a ***SIGPROF*** signal is generated.

get and *set* timer

- get value of an interval timer
- int *getitimer* (int which, struct itimerval *val);
- On success it returns zero and the timer value is stored in the itimverval structure.
- Example: ret = getitimer (ITIMER_REAL, val);

- Set value for a interval timer
- int *setitimer* (int interval_timers, const struct itimerval *val, struct itimvferval *old_value);
- On success it returns zero.
- Example: ret = setitimer(ITIMER_REAL, &value, 0);

Time Stamp Counter

System can provide very high resolution time measurements through the time-stamp counter which counts the number of instructions since boot.

To measure Time Stamp Counter (TSC)

```
# include <sys/time.h>
unsigned long long rdtsc ( )
{
    unsigned long long dst;
   _ _asm_ _    _ _volatile_ _ (“rdtsc”:”=A” (dst));
    return dst;
 }
```

```
main ( )
 {
   long long int start, end;

   start = rdtsc();

   /* Give your job;  */

   end = rdtsc();

   printf (" Difference is : %llu\n", end - start);

}
   /*  This is the most accurate way of time
    measurement */
```

Resource Limits

- The OS imposes limits for certain system resources it can use.
- Applicable to a specific process.
- The “ulimit” shell built-in can be used to set/query the status.
- “ulimit –a” returns the user limit values

```
[root@localhost ~]# ulimit -a
core file size          (blocks, -c) 0
data seg size           (kbytes, -d) unlimited
scheduling priority             (-e) 0
file size               (blocks, -f) unlimited
pending signals                 (-i) 7892
max locked memory       (kbytes, -l) 64
max memory size         (kbytes, -m) unlimited
open files                      (-n) 1024
pipe size            (512 bytes, -p) 8
POSIX message queues     (bytes, -q) 819200
real-time priority              (-r) 0
stack size              (kbytes, -s) 8192
cpu time               (seconds, -t) unlimited
max user processes              (-u) 7892
virtual memory          (kbytes, -v) unlimited
file locks                      (-x) unlimited
[root@localhost ~]#
```

Hard and Soft Limits

-c → Maximum size of “core” files created.

-f → Maximum size of the files created.

-l → Maximum amount of memory that can be locked using mlock() system call.

-n → Maximum number of open file descriptors.

-s → Maximum stack size allowed per process.

-u → Maximum number of processes available to a single user.

- Each resource has two limits –Hard and Soft
- Hard Limits
  - Absolute limit for a particular resource. It can be a fixed value or “unlimited”
  - Only superuser can set hard limit.
- “ulimit” command has –H or –S option to set hard/soft limits. Default is soft limit.
- Hard limit cannot be increased once it is set.

- Soft Limits
  - User-definable parameter for a particular resource.
  - Can have a value of 0 till <hard limit> value.
  - Any user can set soft limit.
- Limits are inherited (the new values are applicable to the descendent processes).

Resource Limitation

- getrlimit()/setrlimit() are system-call interfaces for getting and setting resource limits.
- Syntax
  - getrlimit(<resource>, &r)
  - setrlimit (<resource>, &r)
  - where r is of type “struct rlimit”

```
int getrlimit(int resource, struct rlimit *rlim);
int setrlimit(int resource, const struct rlimit *rlim);
int prlimit(pid_t pid, int resource, const struct rlimit *new_limit, struct rlimit *old_limit);

struct rlimit {
        rlim_t rlim_cur;  /* Soft limit */
        rlim_t rlim_max;  /* Hard limit (ceiling for rlim_cur) */
    };
```

Resource Usage

```
struct rusage {
        struct timeval ru_utime; /* user CPU time used */
        struct timeval ru_stime; /* system CPU time used */
        long   ru_maxrss;       /* maximum resident set size */
        long   ru_ixrss;       /* integral shared memory size */
        long   ru_idrss;       /* integral unshared data size */
        long   ru_isrss;       /* integral unshared stack size */
        long   ru_minflt;       /* page reclaims (soft page faults) */
        long   ru_majflt;       /* page faults (hard page faults) */
        long   ru_nswap;        /* swaps */
        long   ru_inblock;      /* block input operations */
        long   ru_oublock;      /* block output operations */
        long   ru_msgsnd;       /* IPC messages sent */
        long   ru_msgrcv;       /* IPC messages received */
        long   ru_nsignals;     /* signals received */
        long   ru_nvcsw;        /* voluntary context switches */
        long   ru_nivcsw;       /* involuntary context switches */
      };
```

int getrusage(int who, struct rusage *usage);
getrusage() returns resource usage measures for who, which can be one of the following:
RUSAGE_SELF
RUSAGE_CHILDREN
RUSAGE_THREAD

sysconf - get configuration information at run time:

long sysconf(int name);

Example: ret= sysconf(_SC_CLK_TCK);

On success it returns the value of the given system limits.

Multi Threading

Thread is a sequential flow of control through a program.
If a process is defined as a program in execution then a thread is defined as a function in execution.
If a thread is created, it will execute a specified function.
Two type of threading: 1. Single Threading and 2. Multi threading

The created threads within a process share

1. instructions of a process
2. process address space and data
3. open file descriptors
4. Signal Handlers
5. pwd, uid and gid

The created threads maintain it's own

1. thread identification number (tid);
2. pc, sp, set of registers
3. stack
4. priority of the threads
5. scheduling policy

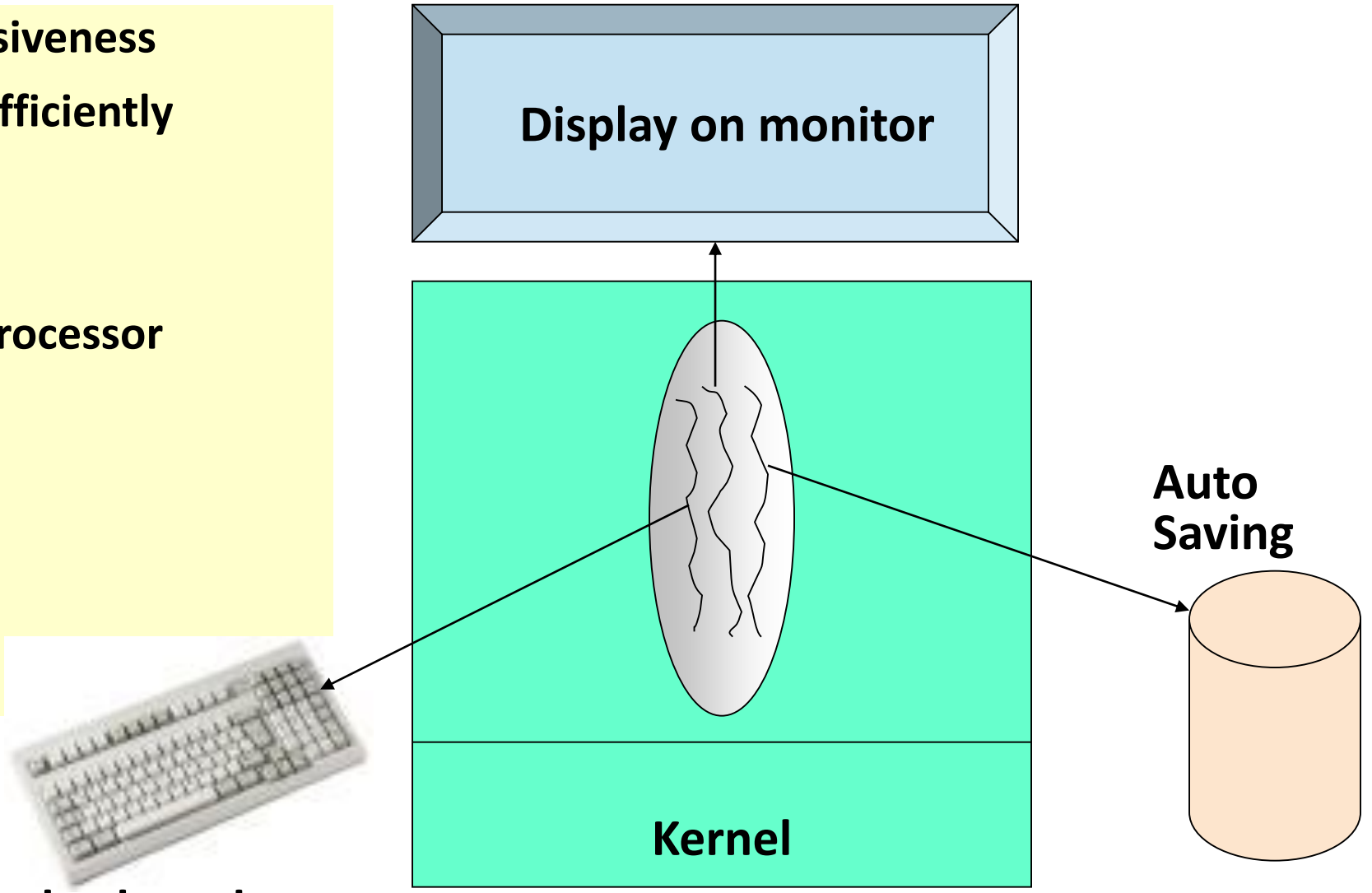
Advantages of Threads:
Takes less time for creation of a new thread, termination of a thread and communication between threads are easier.

Advantages

- Improve application responsiveness
- Use multiprocessors more efficiently
- Improve program structure
- use fewer system resources
- Specific applications in uniprocessor machines

Applications

- A file server on a LAN
- GUI
- web applications



Thread Creation

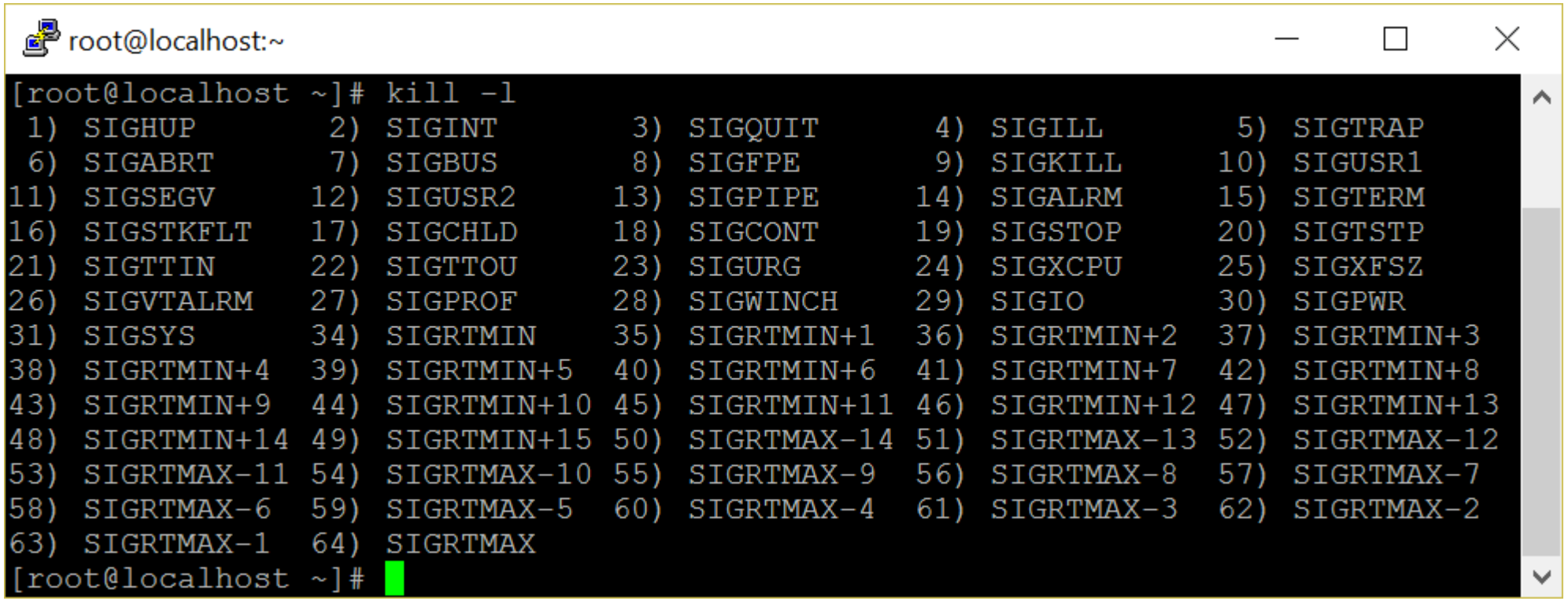
```
#include <pthread.h>
void thread_func(void) { printf(“ Thread id is %d”, pthread_self()); }
main ( ) {
pthread_t mythread;  pthread_create ( &mythread, NULL, (void *) thread_func, NULL);
 }
```

This needs to be compiled as follows...$gcc pthread.c –lpthread

pthread_t is type-defined as unsigned long int. It takes the thread address as the first argument, the second argument is used to set the attributes for the thread-like stack size, scheduling policy, priority; if NULL is specified, then it takes default values for the attributes.

The third argument is the function that the thread should execute when created. The fourth argument is the argument for the thread function. If that function has a single argument to be passed, we can specify it here. If it has more than one argument, then we have to use a structure and declare all the arguments and pass the address of the structure.

Linux Signals



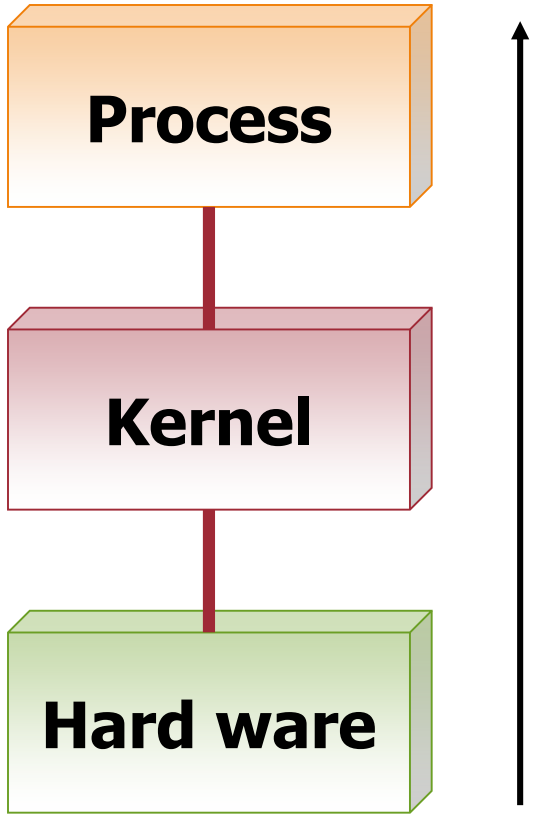
Introduction

- Signals are a fundamental method for inter process communication and are used in everything from network servers to media players.
- A signal is generated when
  - an event occurs (timer expires, alarm, etc.,)
  - a user quota exceeds (file size, no of processes etc.,)
  - an I/O device is ready
  - encountering an illegal instruction
  - a terminal interrupt like Ctrl-C or Ctrl-Z.
  - some other process send (kill -9 pid)

- Each signal starts with macro SIGxxx.
- Each signal may also specifies with its integer number
- For help: $ kill –l , $ man 7 signal
- When a signal is sent to a process, kernel stops the execution and "forces" it to call the signal handler.
- When a process executes a signal handler, if some other signal arrives the new signal is blocked until the handler returns.

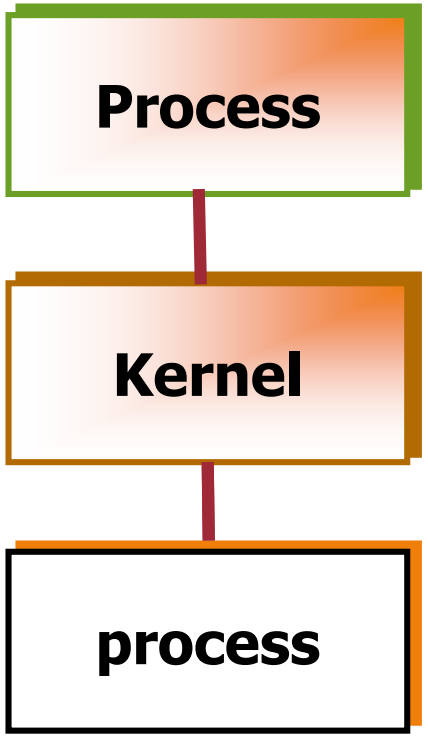
Signal Vs Interrupt

Interrupt

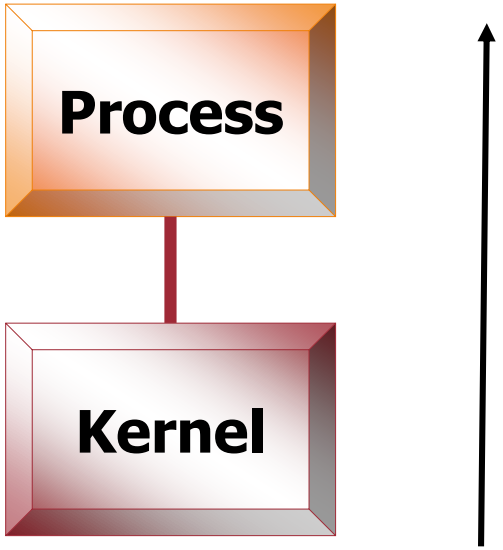


I/O operation (ex: mouse click)

Signal



$ kill -9 pid



Illegal instruction

signal System Call

- How a process receives a signal, when it is
  - executing in user mode
  - executing in kernel mode
  - not running
  - in interruptible sleep state
  - in uninterruptible sleep state

- When a signal occurs, a process could
  - Catch the signal
  - Ignore the signal
  - Execute a default signal handler
- Two signals that cannot be caught or ignored
  - SIGSTOP
  - SIGKILL

- signal system call is used to catch, ignore or set the default action of a specified signal.
- int signal (int signum, (void *) handler);
- It takes two arguments: a signal number and a pointer to a user-defined signal handler.
- Two reserved predefined signal handlers are :
  - SIG_IGN
  - SIG_DFL

signal System Call

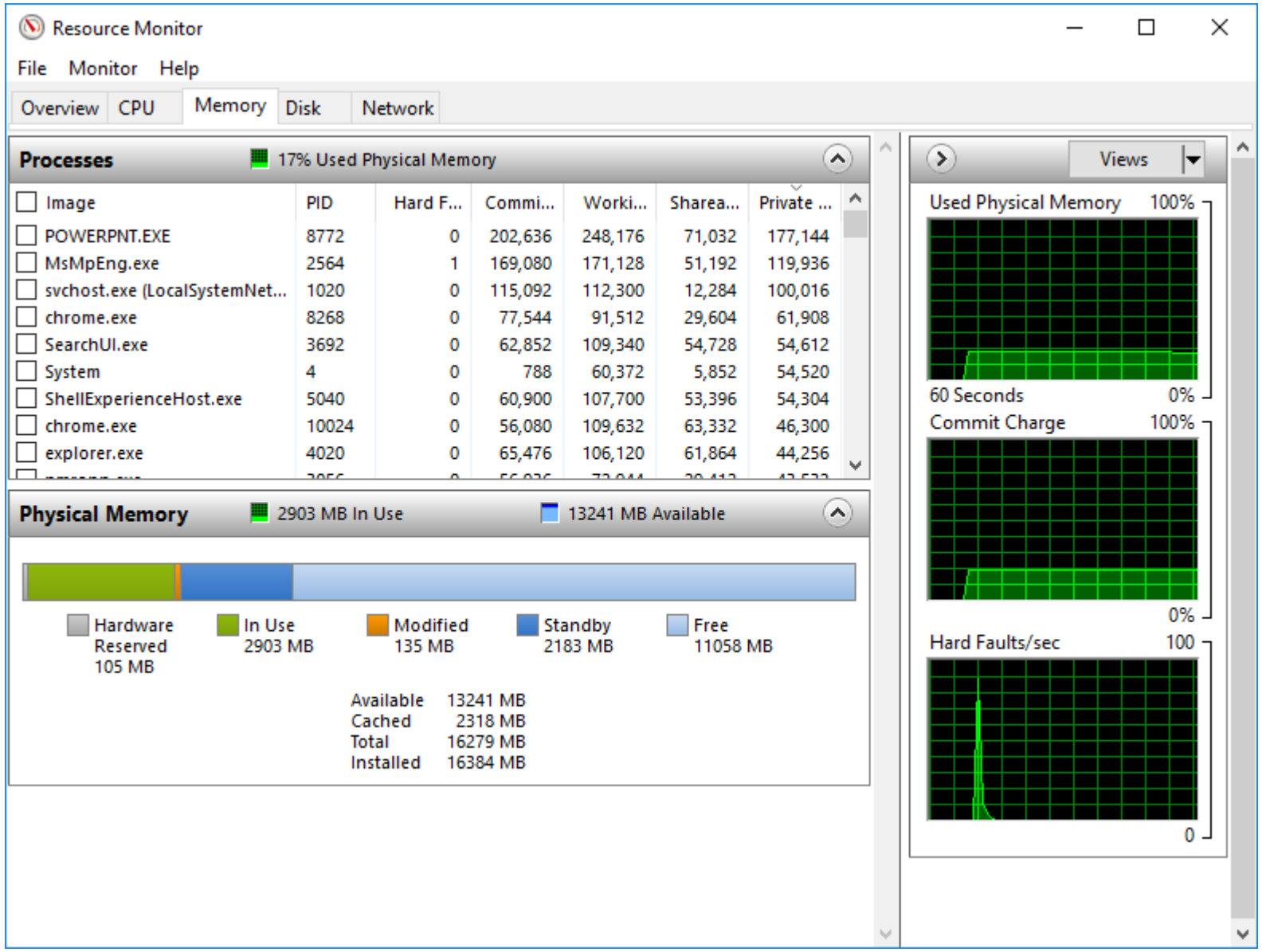
- sigaction ( ) is ame as signal( ) but it has lot of control over a given signal.
- The syntax of sigaction is:

int sigaction (int signum, const struct sigaction *act, struct sigaction *oldact);

  - signum, is a specified signal
  - act is used to set the new action of the signal signum;
  - oldact is used to store the previous action, usually NULL.

- Kill system call is used to send a given signal to a specific process
- int kill (pid_t process_id, int signal_number);
- it accepts two arguments, process ID and signal number
- If the pid is positive, the signal is sent to a particular process.
- If the pid is negative, the signal is sent to the process whose group ID matches the absolute value of pid.

Memory Management



Virtual Memory

- Memory management: one of the most important kernel subsystems
- Virtual Memory: Programmer need not to worry about the size of RAM (Large address space)
- Static allocation: internal Fragmentation
- Dynamic allocation: External Fragmentation
- Avoid Fragmentation: Thrashing - overhead

- Large address space: virtual memory is many times larger than the physical memory in a system.
- For a 32 bit OS, the virtual memory size will be 2 to the power of 32 i.e 4GB. But the RAM size may be much smaller.
- Each process has a separate virtual address space.
- Each process space is protected from other processes.
- It supports shared virtual memory, i.e more than one process can share a shared page.
- Uses paging technique.

Page Table

- Hard ware support (MMU, TLB) is required.
- Fair share allocation
- static allocation
- Minimize internal fragmentation
- identified by a PFN (Page Frame Number)
- virtual address is split into two parts namely an offset and a virtual page frame number.

- Translate a process virtual address into physical address since processor use only virtual address space
- The size of a page table is normally size of a page
- if it is 4kb, each page address size is 4byte, so 1024 page entries in a page table.
- holds info about
  - Whether valid page table or not?
  - PFN
  - access control information
- Stored in TLB (Translation Look-aside Buffer)

Memory Mapping

- Executable image spilt into equal sized small parts (normally a page size)
- Virtual memory assigns virtual address to a each part
- Linking of an executable image into a process virtual memory

Swapping

- Swap space is in hard disk partition
- If a page is waiting for certain event to occur, swap it.
- Use physical memory space efficiently
- If there is no space in Physical memory, swap LRU pages into swap space

- Demand Paging - don't load all the pages of a process into memory
- Load only necessary pages initially
- if a required page is not found, generate page fault then the page fault handler brings the corresponding page into memory.

Kernel Data Structure

- **Source Code: /usr/src/linux-4.12/mm**

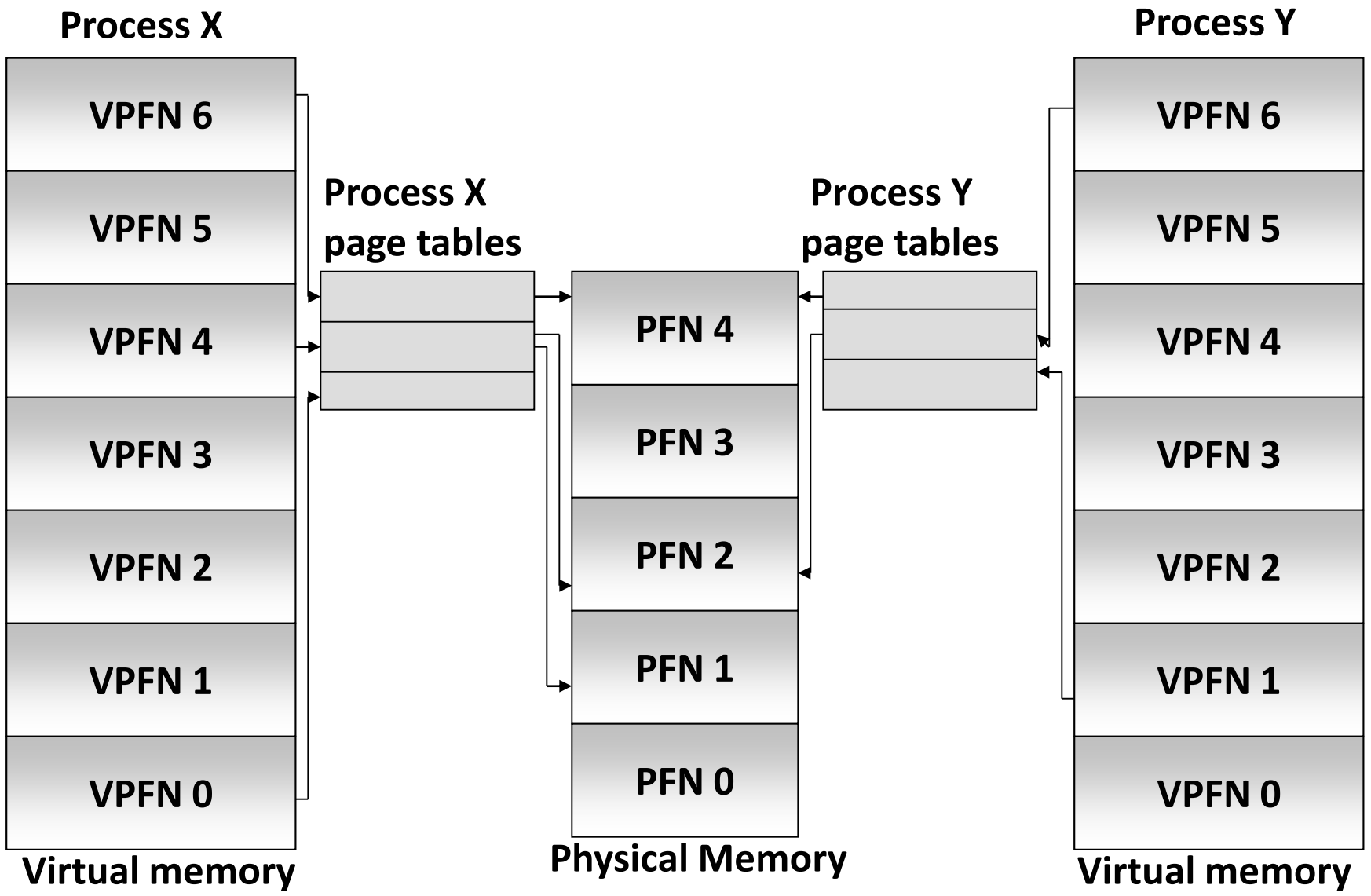
  /usr/src/linux-4.12/include/linux
- **virtual memory is represented by an mm_struct data structure**
- **it has pointers to vm_area_struct data structure**
  - **created when an executable image is mapped with the process virtual address**
  - **has starting and end points of virtual memory**
  - **represents a process's image like text, data and stack portion**
  - **has control access info**

mm_types.h

```
struct mm_struct {
        struct vm_area_struct *mmap;          /* list of VMAs */
        ……..
```

```
struct vm_area_struct {
        /* The first cache line has the info for VMA tree walking. */
        unsigned long vm_start;
        unsigned long vm_end;
        /* linked list of VM areas per task, sorted by address */
        struct vm_area_struct *vm_next, *vm_prev;
        ……..
```

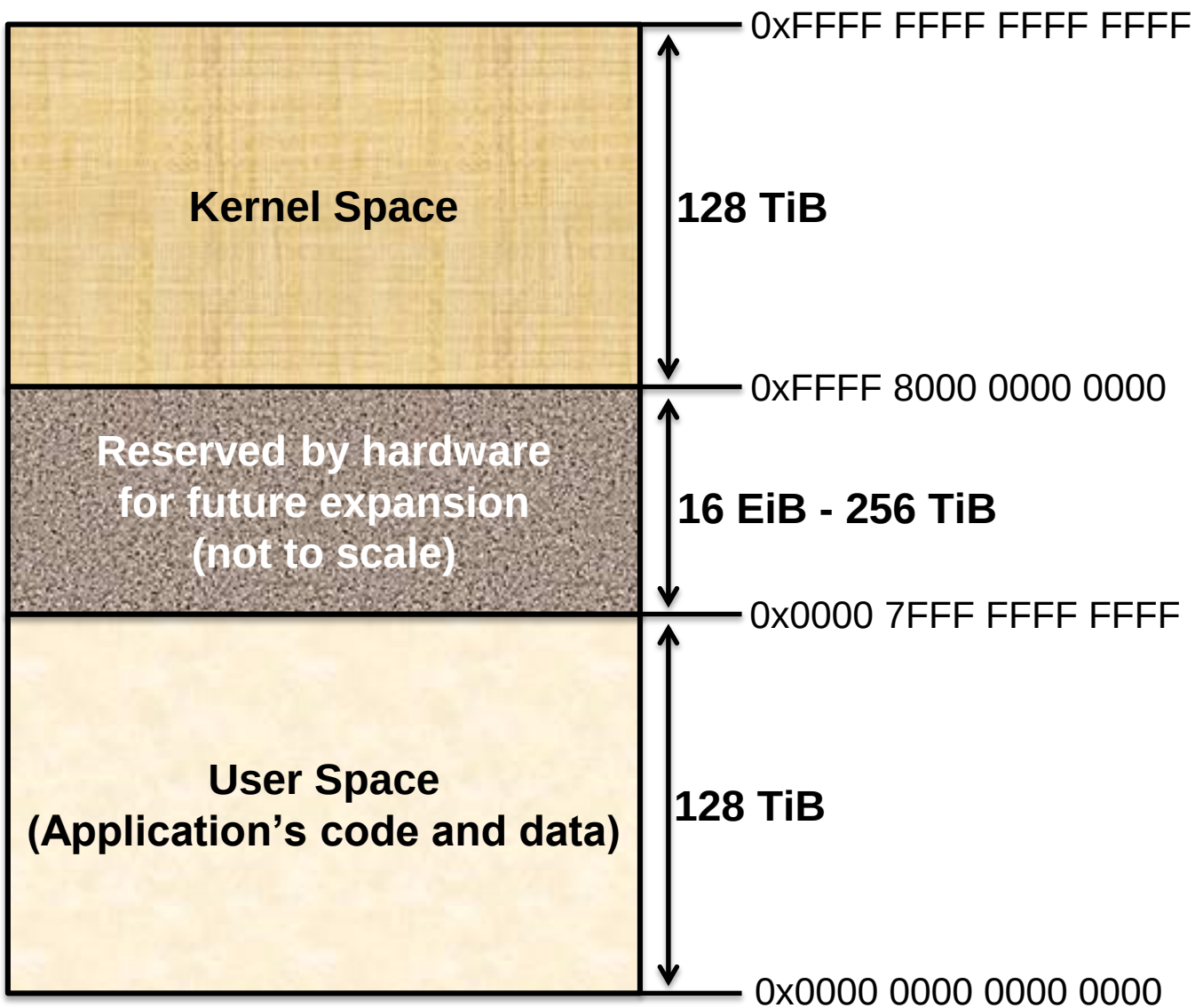
Virtual to Physical Memory Translation



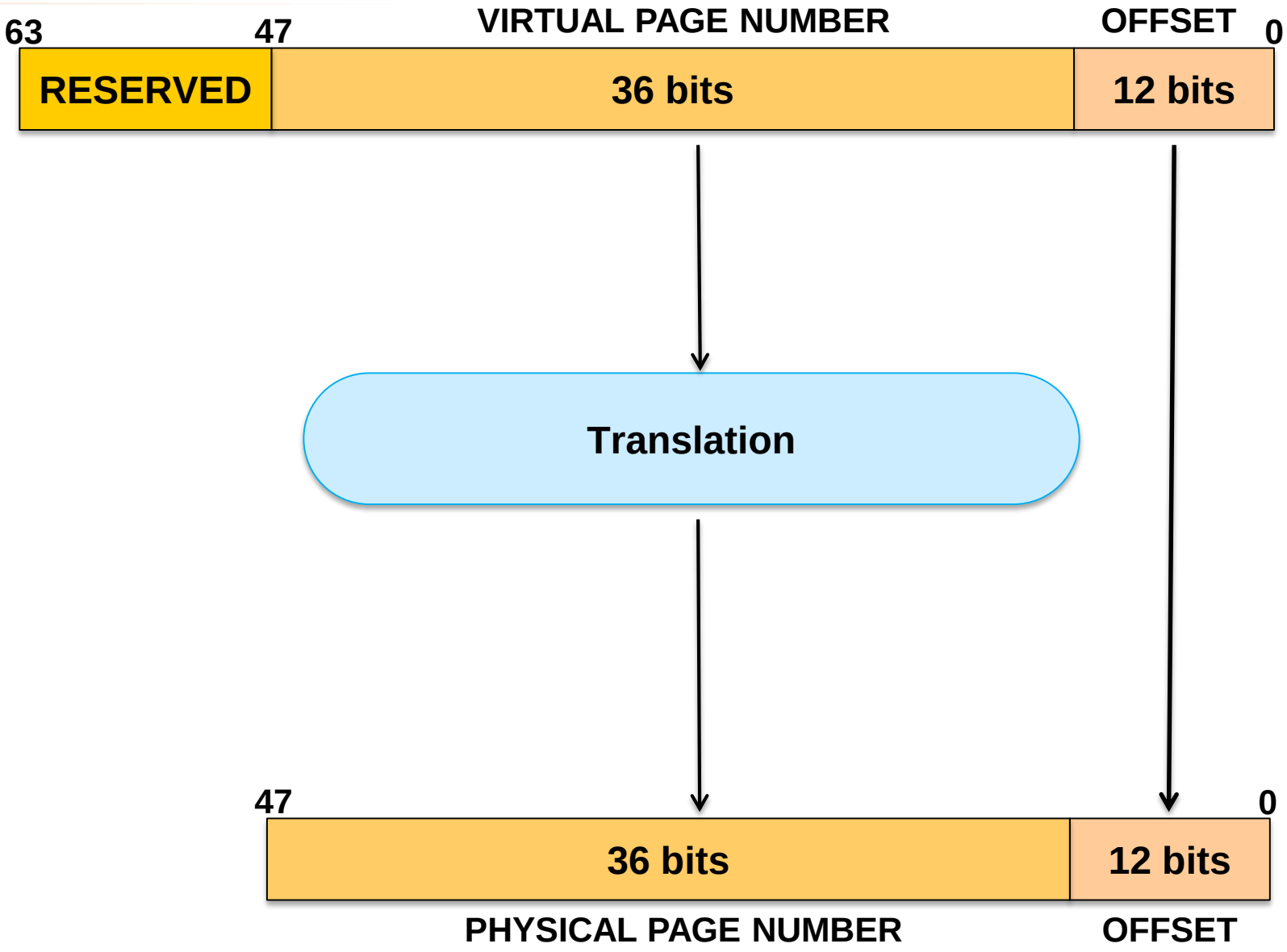
x86-64 Virtual Memory Layout

$pmap –x <pid>

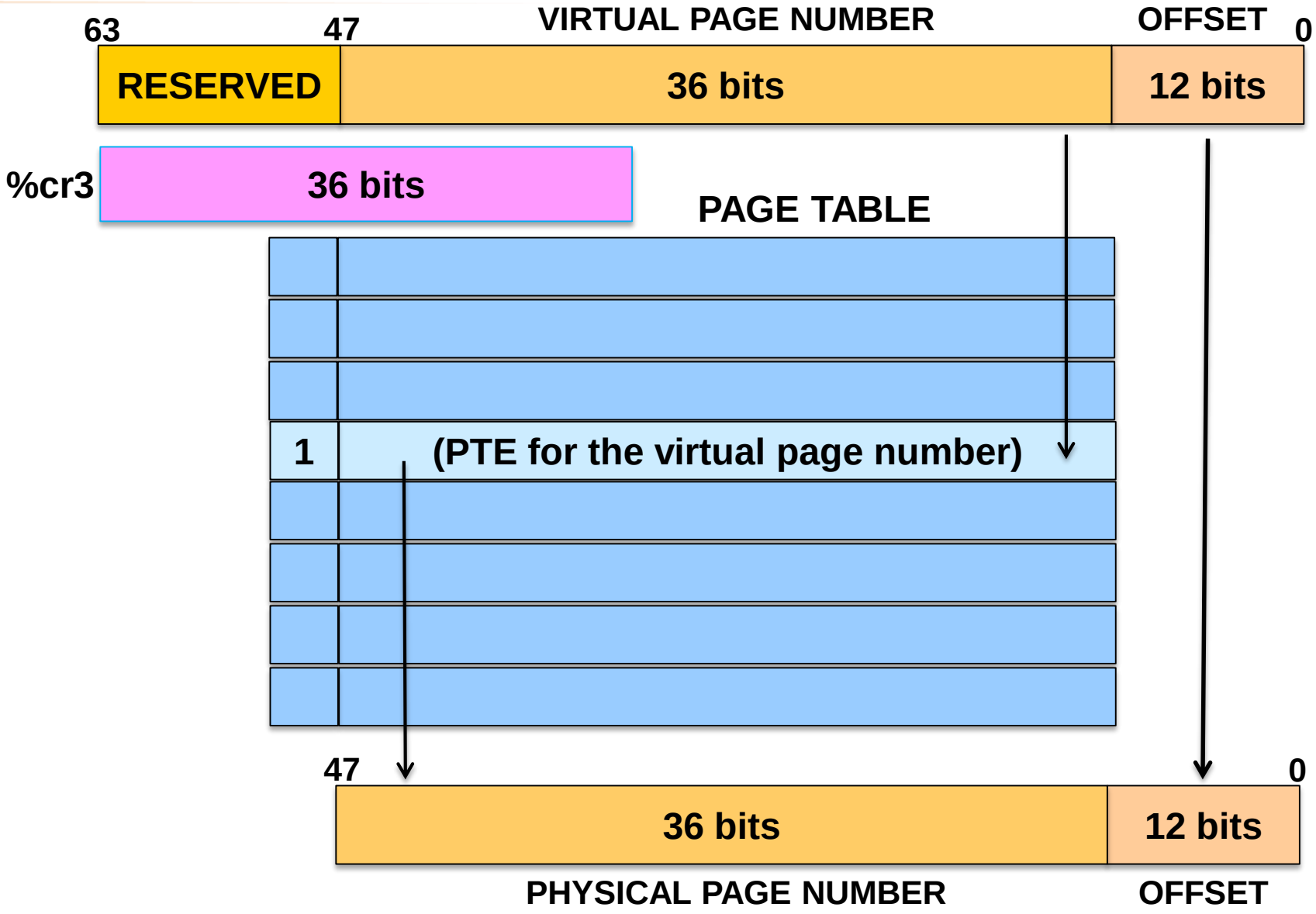
Prefix	Name			
Kibi	binary kilo	1 kibibyte (KiB)	2^{10} bytes	1024 B
Mebi	binary mega	1 Mebibyte (MiB)	2^{20} bytes	1024 KiB
Gibi	binary giga	1 Gibibyte (GiB)	2^{30} bytes	1024 MiB
Tebi	binary tera	1 Tebibyte (TiB)	2^{40} bytes	1024 GiB
Pebi	binary peta	1 Pebibyte (PiB)	2^{50} bytes	1024 TiB
Exbi	binary exa	1 Exbibyte (EiB)	2^{60} bytes	1024 PiB



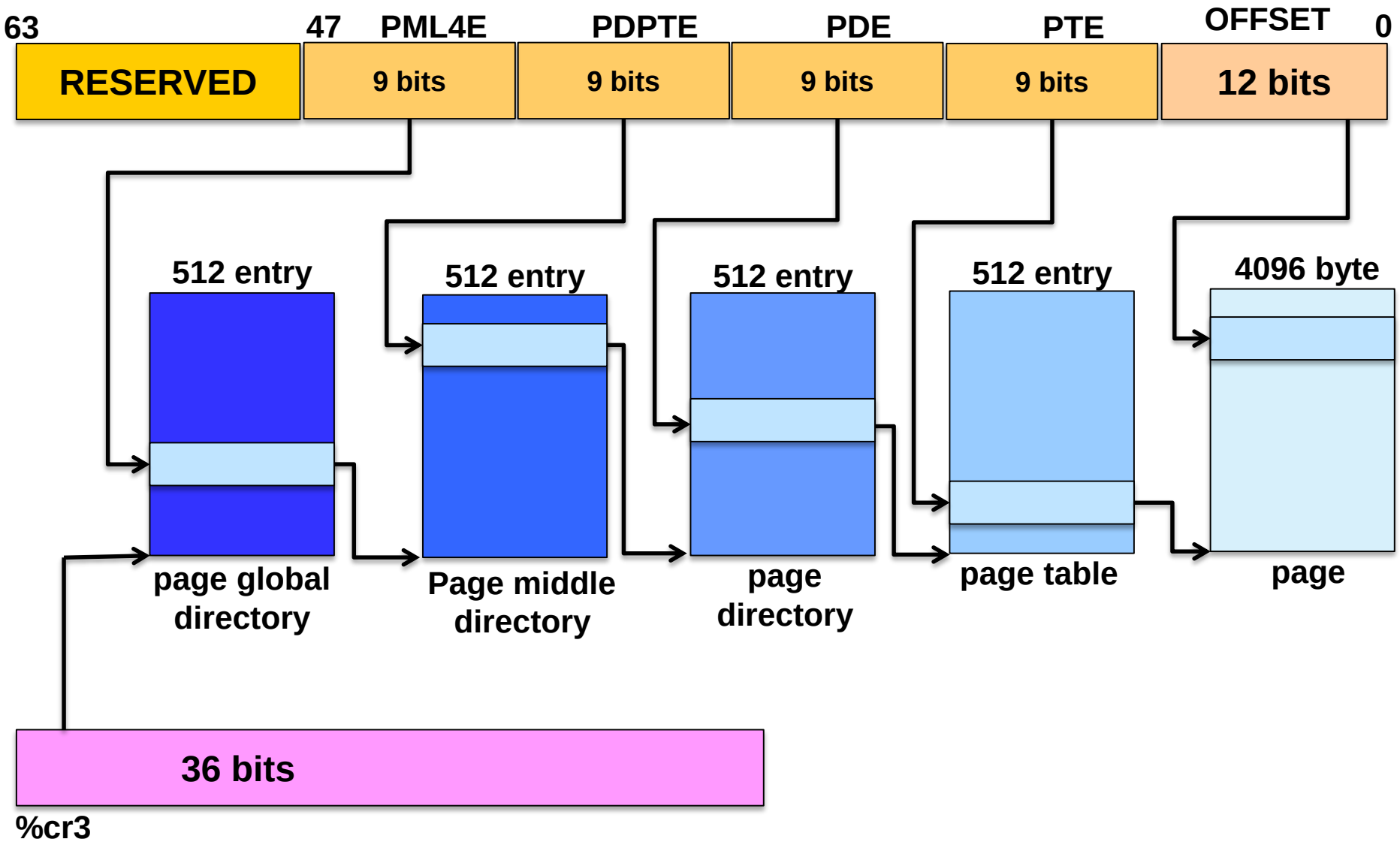
Virtual to Physical Transition



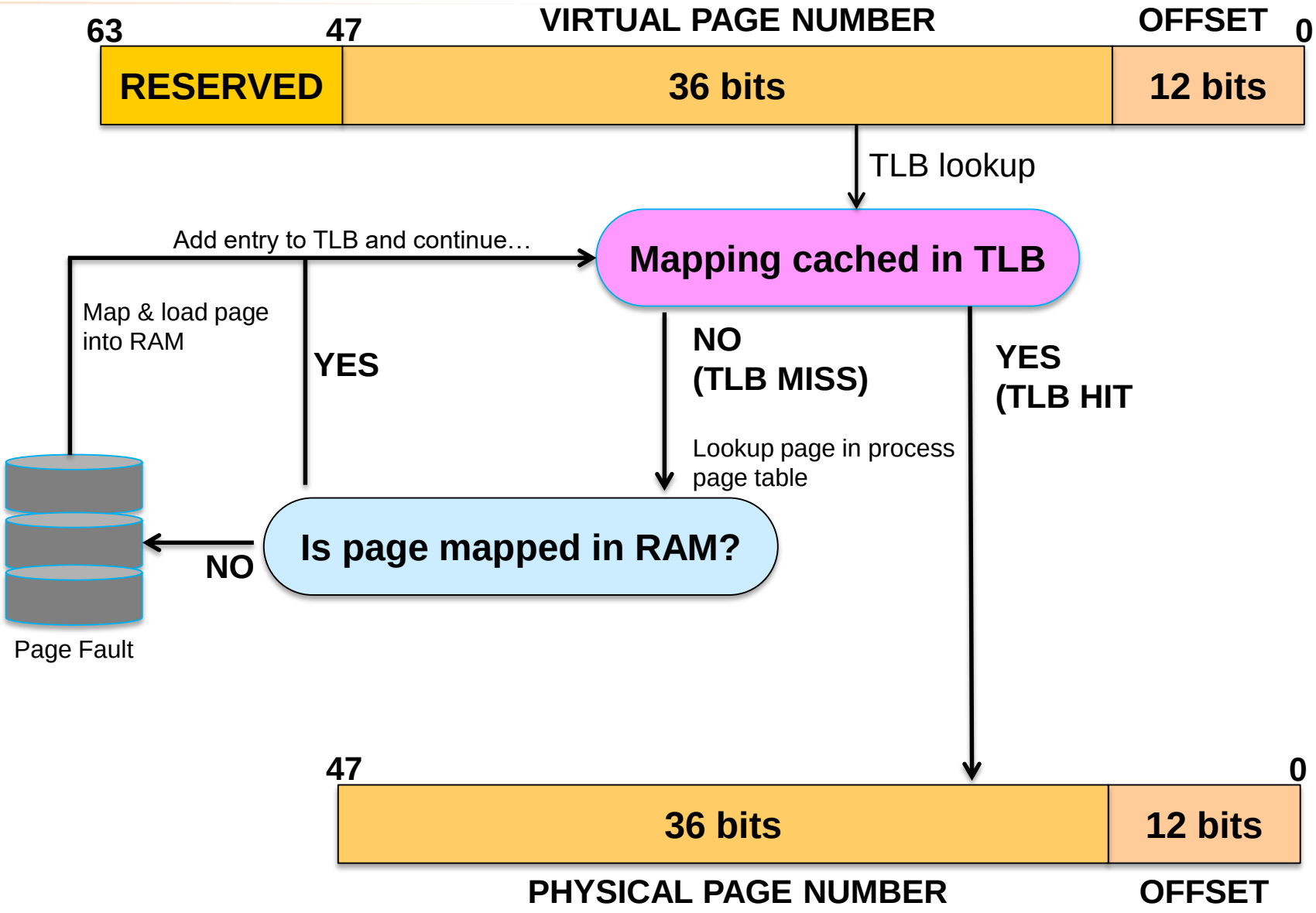
Memory Architecture – Page Table



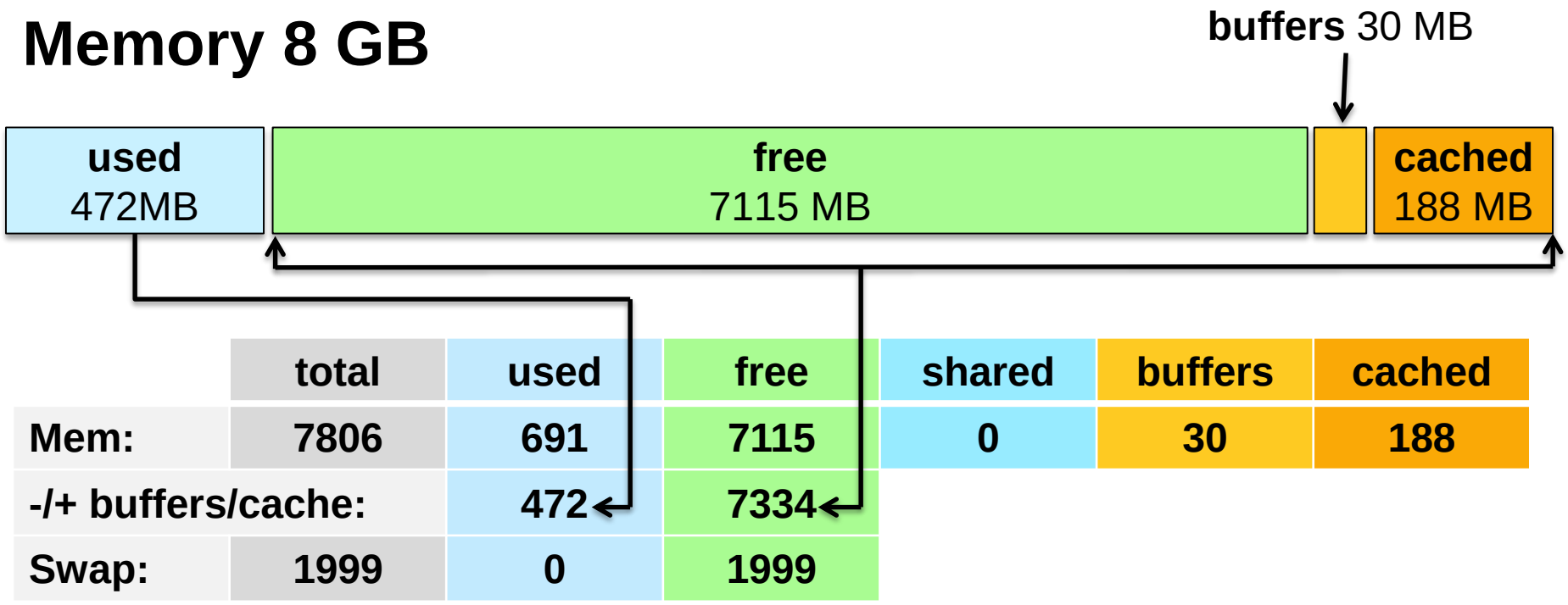
Page Table Hierarchy on x86-64



Memory Architecture



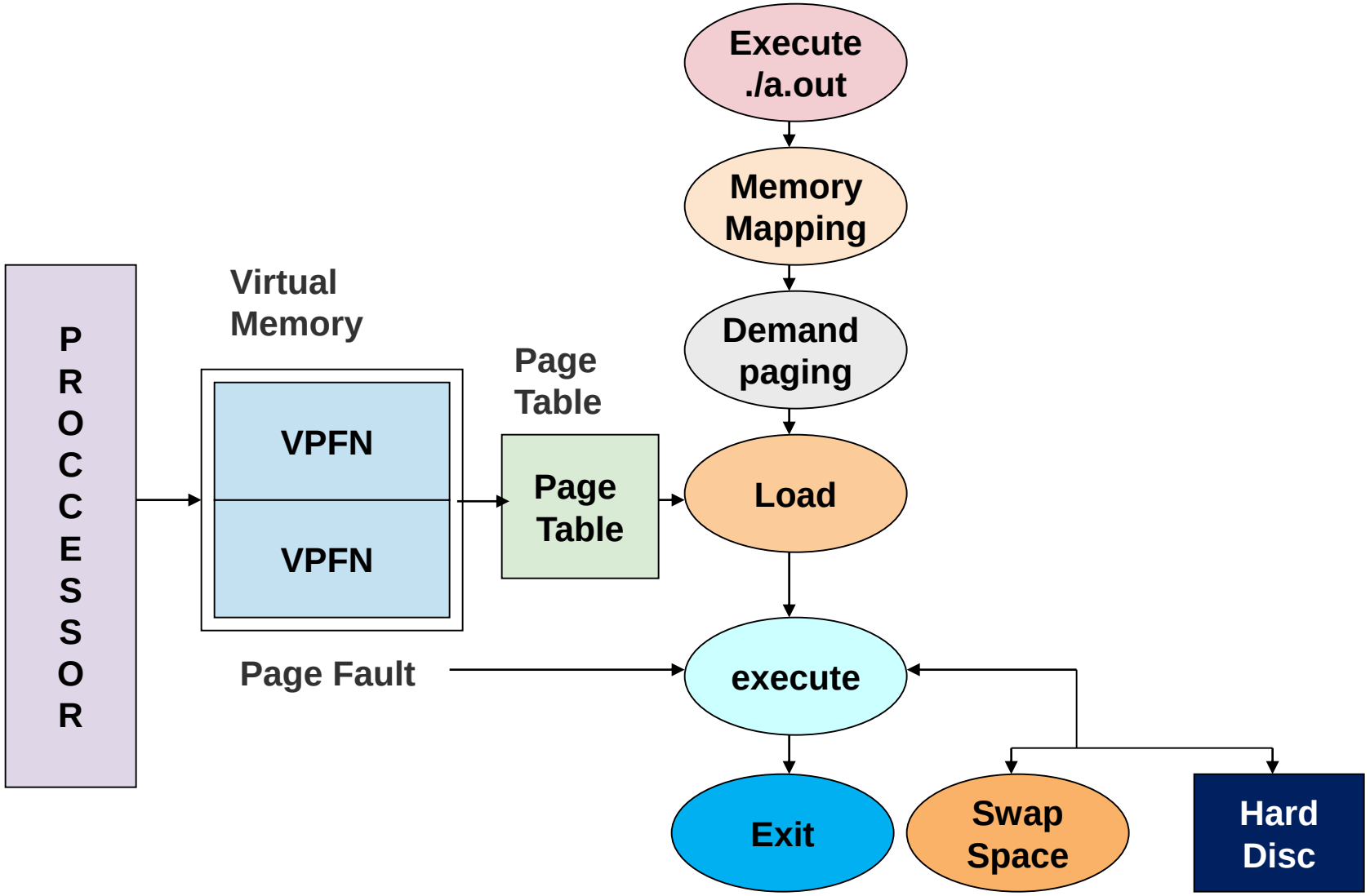
$ free -m



	total	used	free	shared	buffers	cached
Mem:	7806	691	7115	0	30	188
-/+ buffers/cache:		472	7334			
Swap:	1999	0	1999			

Mem: used = 472 + 30 + 188 = 690

Walk Through Program Execution



Thank You