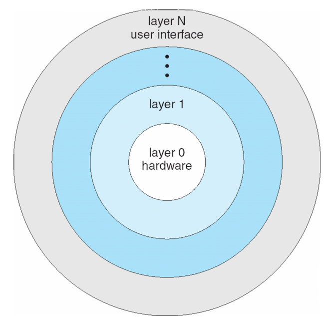
Bucknell UNIVERSITY

Processes and More

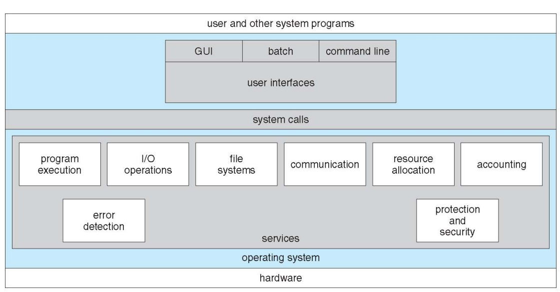
CSCI 315 Operating Systems Design
Department of Computer Science

Notice: The slides for this lecture have been largely based on those accompanying the textbook *Operating Systems Concepts*, 9th ed., by Silberschatz, Galvin, and Gagne. Many, if not all, the illustrations contained in this presentation come from this source.

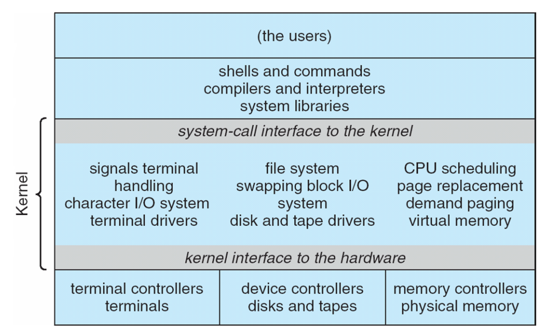
Abstractions and Layers



OS Services



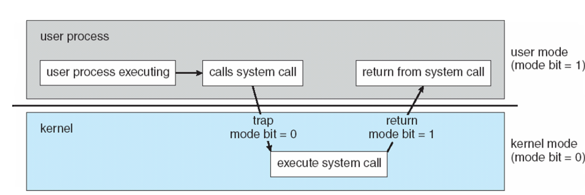
Unix Structure



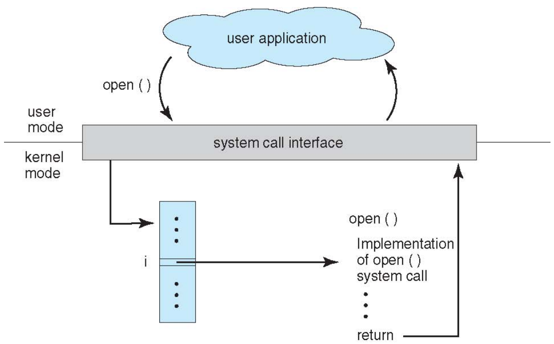
OS Operations

- **Interrupt driven** by hardware
- Software error or request creates **exception** or **trap**
  - Division by zero, request for operating system service
- Other process problems include infinite loop, processes modifying each other or the operating system
- **Dual-mode** operation allows OS to protect itself and other system components
  - **User mode** and **kernel mode**
  - **Mode bit** provided by hardware
    - Provides ability to distinguish when system is running user code or kernel code
    - Some instructions designated as **privileged**, only executable in kernel mode
    - System call changes mode to kernel, return from call resets it to user
- Increasingly CPUs support multi-mode operations
  - i.e. **virtual machine manager** (**VMM**) mode for guest **VMs**

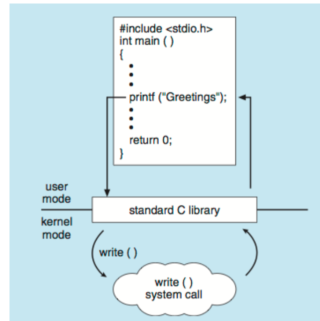
User and Kernel Modes



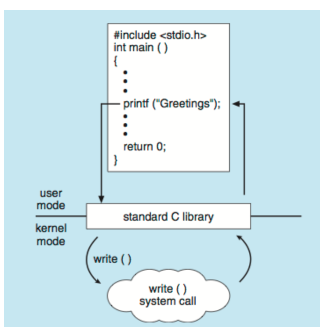
System Calls and the OS



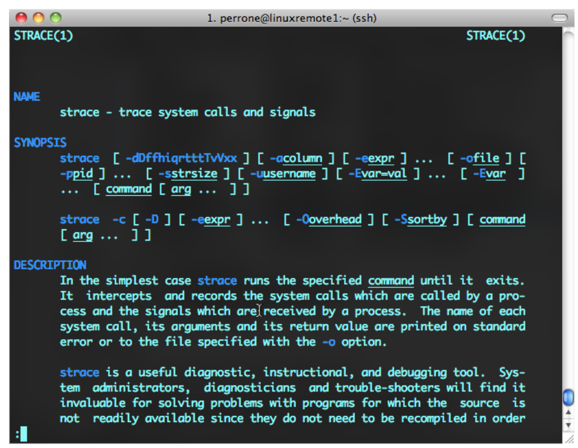
System Calls and Libraries



System Calls and Libraries



strace



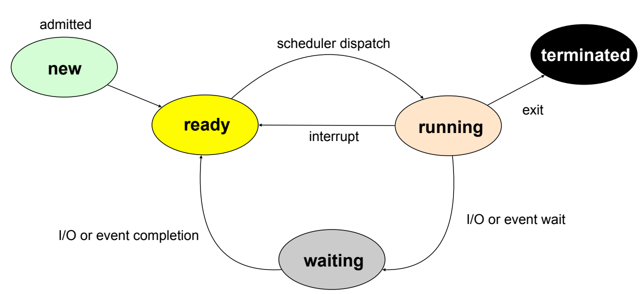
```
1. perrone@linuxremote1:~ (ssh)
STRACE(1)                                                        STRACE(1)

NAME
       strace - trace system calls and signals

SYNOPSIS
       strace  [ -dDffhiqrtttTvVxx ] [ -acolumn ] [ -eexpr ] ...  [ -ofile ] [
       -ppid ] ...  [ -sstrsize ] [ -uusername ] [ -Evar=val ] ...  [ -Evar  ]
       ...  [ command [ arg ...  ] ]

       strace  -c [ -D ] [ -eexpr ] ...  [ -Ooverhead ] [ -Ssortby ] [ command
       [ arg ...  ] ]

DESCRIPTION
       In the simplest case strace runs the specified command until it  exits.
       It  intercepts  and records the system calls which are called by a pro-
       cess and the signals which are received by a process.  The name of each
       system call, its arguments and its return value are printed on standard
       error or to the file specified with the -o option.

       strace is a useful diagnostic, instructional, and debugging tool.  Sys-
       tem  administrators,  diagnosticians  and trouble-shooters will find it
       invaluable for solving problems with programs for which the  source  is
       not  readily available since they do not need to be recompiled in order
:
```

Process State

As a process executes, it changes ***state***:

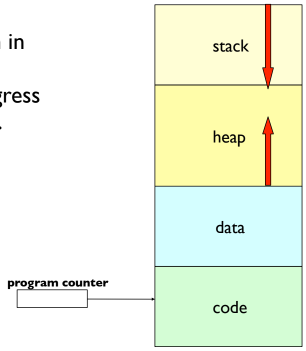
- **new:** The process is being created.
- **running:** Instructions are being executed.
- **waiting:** The process is waiting for some event to occur.
- **ready:** The process is waiting to be assigned to a processor.
- **terminated:** The process has finished execution.

Process State Transition Diagram



Process Concept

- Process – a program in execution; process execution must progress in sequential fashion.
- A process includes:
  - program counter,
  - stack,
  - data section.

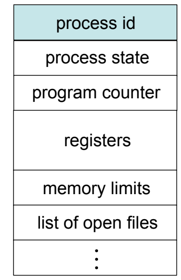


Process Control Block (PCB)

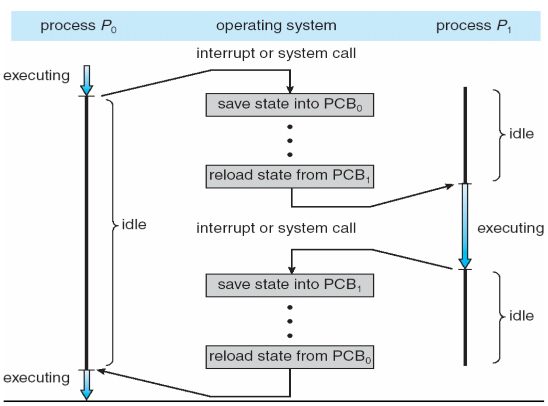
OS bookkeeping information associated with each process:

- Process state,
- Program counter,
- CPU registers,
- CPU scheduling information,
- Memory-management information,
- Accounting information,
- I/O status information,

⋮



CPU Switching

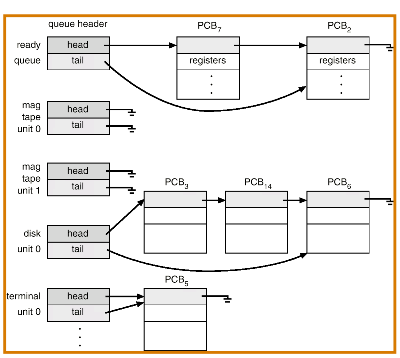


Process Scheduling Queues

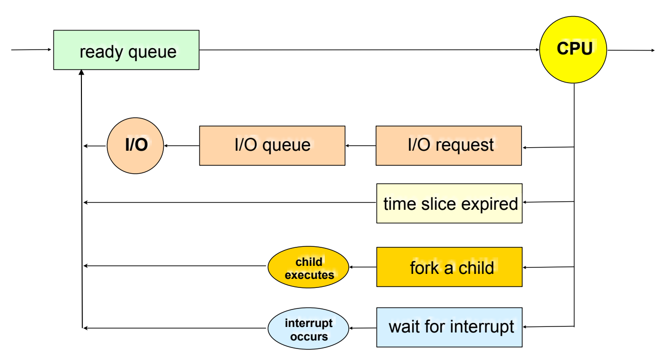
- ***Job queue*** – set of all processes in the system.
- ***Ready queue*** – set of all processes residing in main memory, ready and waiting to execute.
- ***Device queues*** – set of processes waiting for an I/O device.

Processes migrate between the various queues.

Processes and OS Queues



Process Scheduling



Schedulers

- ***Long-term scheduler*** (or job scheduler) – selects which processes should be brought into the ready queue
- ***Short-term scheduler*** (or CPU scheduler) – selects which process should be executed next and allocates CPU

Schedulers

- Short-term scheduler is invoked very frequently (milliseconds) ⇒ (must be fast)
- Long-term scheduler is invoked very infrequently (seconds, minutes) ⇒ (may be slow; controls the *degree of multiprogramming*)
- Processes can be described as either:
  - ***I/O-bound process*** – spends more time doing I/O than computations, many short CPU bursts
  - ***CPU-bound process*** – spends more time doing computations; few very long CPU bursts

Context Switch

- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process.
- Context-switch time is overhead; the system does no useful work while switching.
- Time dependent on hardware support.

Process Creation

- Parent process create children processes, which, in turn can create other processes, forming a tree of processes.
- Resource sharing:
  - Parent and children share all resources,
  - Children share subset of parent's resources,
  - Parent and child share no resources.
- Execution:
  - Parent and children execute concurrently,
  - Parent may wait until children terminate.

Process Creation (Cont.)

- Address space:
  - Child has duplicate of parent's address space, or
  - Child can have a program loaded onto it.
- UNIX examples:
  - fork system call creates new process and returns with a pid (0 in child, > 0 in the parent),
  - exec system call can be used after a **fork** to replace the process' memory space with a new program.

Process Termination

- Process executes last statement and asks the operating system to terminate it (exit)
  - Output data from child to parent (via wait)
  - Process' resources are deallocated by operating system
- Parent may terminate execution of children processes (abort) if:
  - Child has exceeded allocated resources,
  - Task assigned to child is no longer required,
  - If parent is exiting (some operating system do not allow child to continue if its parent terminates)
    - All children terminated - *cascading termination*

Cooperating Processes

- An ***independent*** process **cannot** affect or be affected by the execution of another process.
- A ***cooperating*** process **can** affect or be affected by the execution of another process.
- Advantages of process cooperation:
  - Information sharing,
  - Computation speed-up,
  - Modularity,
  - Convenience.

Interprocess Communication (IPC)

- Mechanism for processes to communicate and to synchronize their actions
- Message system – processes communicate with each other without resorting to shared variables
- IPC facility provides two operations:
  - **send**(*message*) – message size fixed or variable
  - **receive**(*message*)
- If *P* and *Q* wish to communicate, they need to:
  - establish a *communication link* between them
  - exchange messages via send/receive
- Implementation of communication link
  - physical (e.g., shared memory, hardware bus)
  - logical (e.g., logical properties)

Implementation Questions

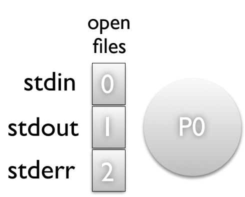
- How are links established?
- Can a link be associated with more than two processes?
- How many links can there be between every pair of communicating processes?
- What is the capacity of a link?
- Is the size of a message that the link can accommodate fixed or variable?
- Is a link unidirectional or bi-directional?

Unix pipe(2)

- Point to point
- Unidirectional
- For processes related by birth (same machine)
- Reliable delivery
- Stream of bytes
- FIFO
- Virtually identical to reading and writing to a file (low level file I/O)

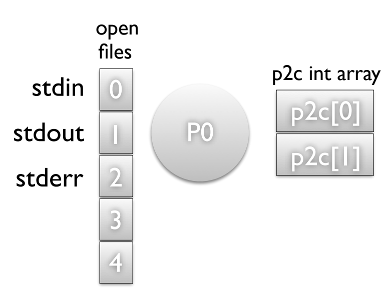
Unix pipe(2)

A process P0 is born

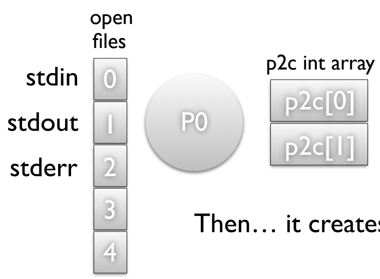


Before creating a child with whom it will communicate, it creates a pipe (system call).

Unix pipe(2)

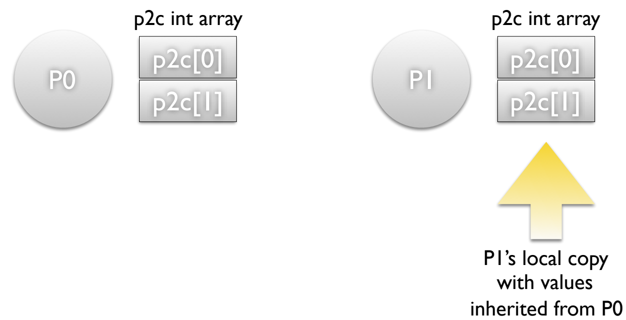


Unix pipe(2)



Then… it creates child P1 with fork

Unix pipe(2)

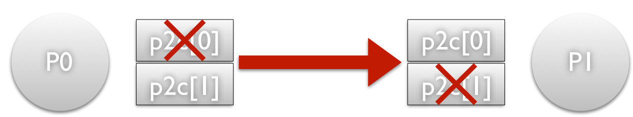


Unix pipe(2)

P0 closes the input end of the pipe (index 0)

P1 closes the output end of the pipe (index 1)

Unix pipe(2)



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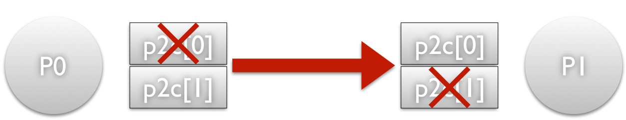

P0 writes to file descriptor p2c[1]

write(2)

P1 reads from file descriptor p2c[0]

read(2)

Direct Communication

- Processes must name each other explicitly:
  - **send** (*P, message*) – send a message to process P
  - **receive**(*Q, message*) – receive a message from process Q
- Properties of communication link
  - Links are established automatically
  - A link is associated with exactly one pair of communicating processes
  - Between each pair there exists exactly one link
  - The link may be unidirectional, but is usually bi-directional

Indirect Communication

- Messages are directed and received from mailboxes (also referred to as ports)
  - Each mailbox has a unique id
  - Processes can communicate only if they share a mailbox
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes
  - Each pair of processes may share several communication links
  - Link may be unidirectional or bi-directional

Indirect Communication

- Operations:
  - create a new mailbox,
  - send and receive messages through mailbox,
  - destroy a mailbox.
- Primitives are defined as:

  send(*A, message*) – send a message to mailbox A,

  receive(*A, message*) – receive a message from mailbox A.

Indirect Communication

- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A
  - P_1, sends; P_2 and P_3 receive
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes
  - Allow only one process at a time to execute a receive operation
  - Allow the system to select arbitrarily the receiver. Sender is notified who the receiver was.

Synchronization

- *Message passing* may be either blocking or non-blocking.
- Blocking is considered **synchronous**:
  - **Blocking send** has the sender block until the message is received.
  - **Blocking receive** has the receiver block until a message is available.
- Non-blocking is considered **asynchronous**
  - **Non-blocking** send has the sender send the message and continue.
  - **Non-blocking** receive has the receiver receive a valid message or null.

Buffering

Queue of messages attached to the link; implemented in one of three ways:

1. Zero capacity – 0 messages
   Sender must wait for receiver (rendezvous).
2. Bounded capacity – finite length of *n* messages.
   Sender must wait if link full.
3. Unbounded capacity – infinite length. Sender never waits.