

Lecture 03



UNIX Architecture

What services the OS provides to the programmer



Today's Goal

- UNIX architecture and service overview
 - a global image for you to write a program through out this semester



Today's material comes from

- Chap. 1 of [Stevens]
- Chap. 3 & 4 of your OS textbook [Silberschatz]
 - Chap. 3: operating system structure
 - Chap. 4: processes



What an OS provides?



What services UNIX provides (the textbook version)

- program execution
- user protection
 - user ID, group ID, file permissions
- file management
- I/O device control
- process synchronization
- network

Why these services?

parallel



What an OS should provides?

- for general users: ease to run application programs
- for programmers: ease of programming over all hardware resources
- security and users protection



What an OS should provides?

- for general users: ease to use application programs
 - program execution support (shell, command interpreter)
 - GUI (Graphics User Interface)
 - X-windows (on UNIX)
 - M\$-Windows
- for programmers: ease of programming over all hardware resources
- security and users protection



What an OS should provides?

- for general users: ease to use application programs
- for programmers: ease of programming over all hardware resources
 - manage CPUs and processes/threads scheduling
 - memory and storage devices management (e.g. virtual memory, file system, etc.)
 - API (application programmer interfaces) to I/O devices
- security and users protection



What an OS should provides?

- for general users: ease to use application programs
- for programmers: ease of programming over all hardware resources
- security and users protection
 - access permission for files, I/O devices for multi-users
 - network security



In-Class Exercise

- (1) create another account, say user2
- (2) trying to read a file in /home/user2
 - should be not able to read
- (3) do the following: (login as user2)
 - `chmod 777 /home/user2`
 - `cd /home/user2`
 - `chmod 666 /home/user2/test.c` (the file to read)
- (4) login as user1 and read /home/user2/test.c

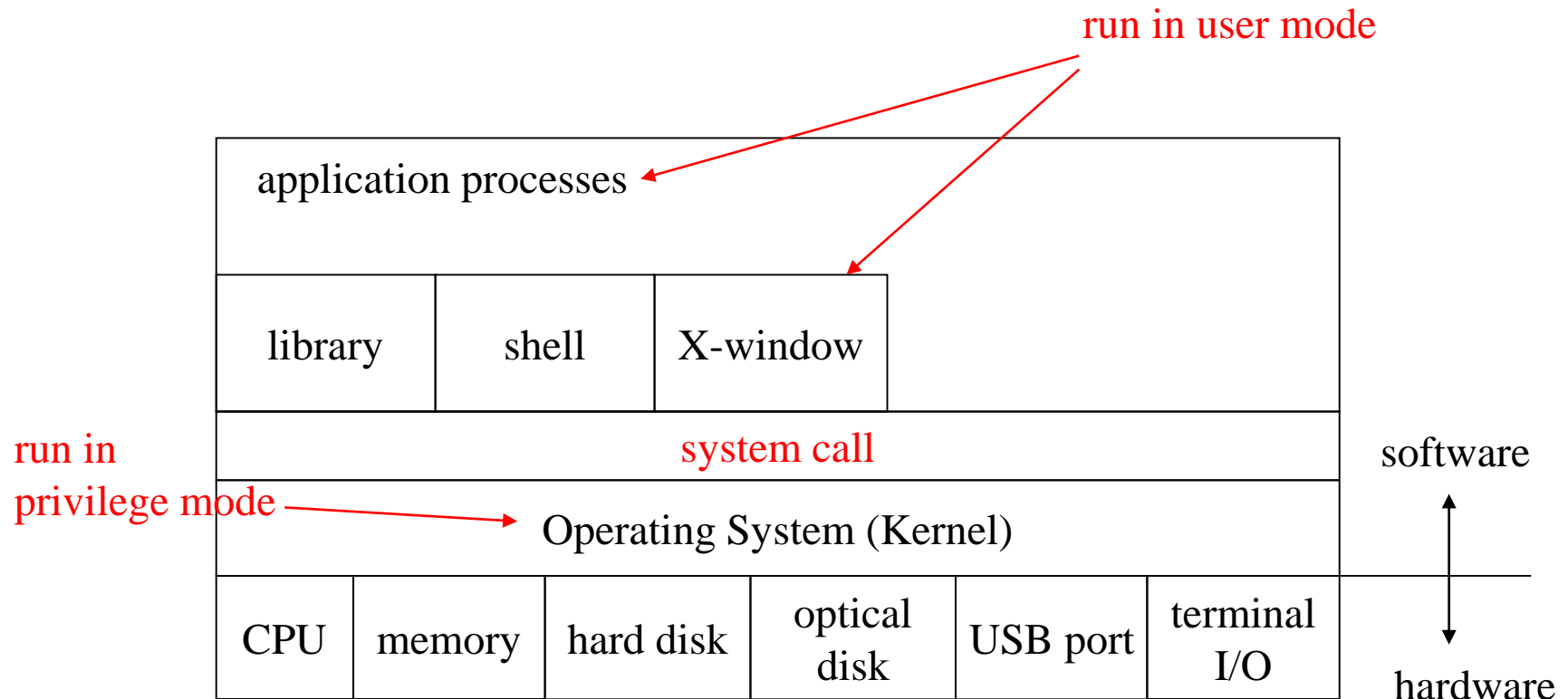


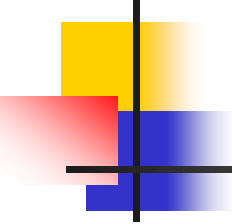
How the OS provides its services

the UNIX architecture overview

UNIX Architecture

- Hardware support: user mode and privilege mode



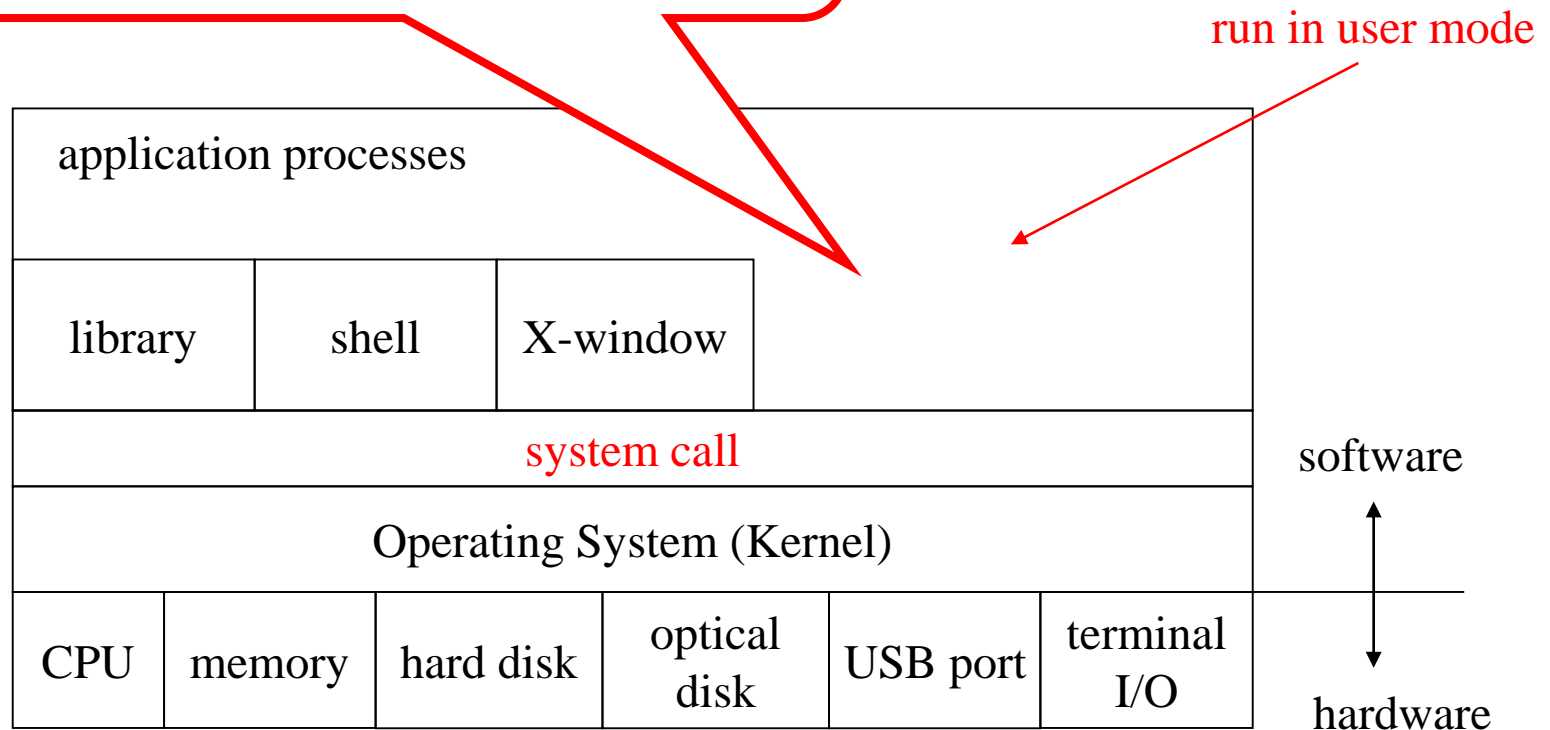


Execution modes supported by CPU

- CPU hardware has to support two execution modes
 - Privileged (kernel) mode: to execute the OS
 - everything the hardware can do
 - User mode: to execute application program
 - no I/O operation and low-level hardware control

UNIX Architecture

You cannot access the disk using assembly with direct I/O control

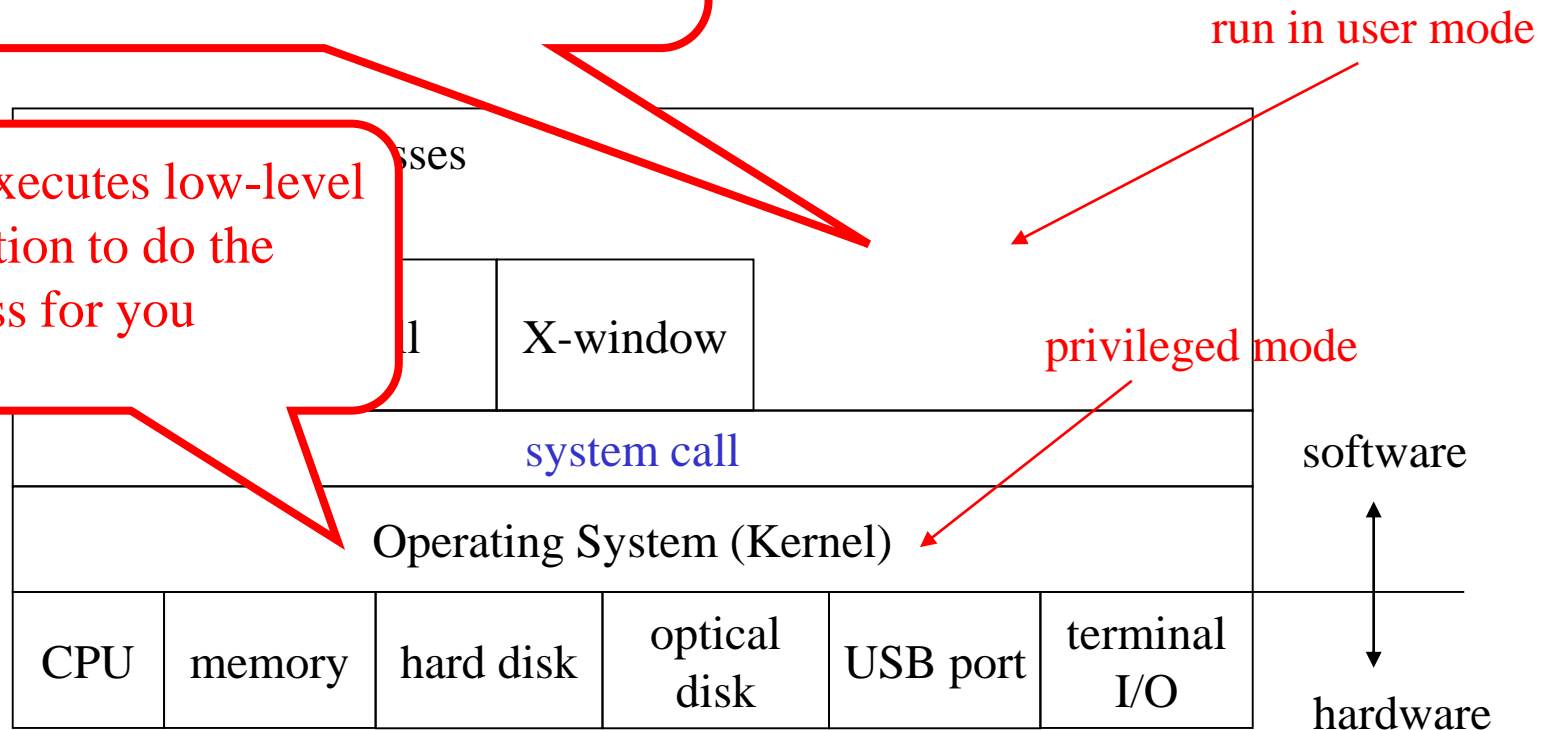


UNIX Architecture

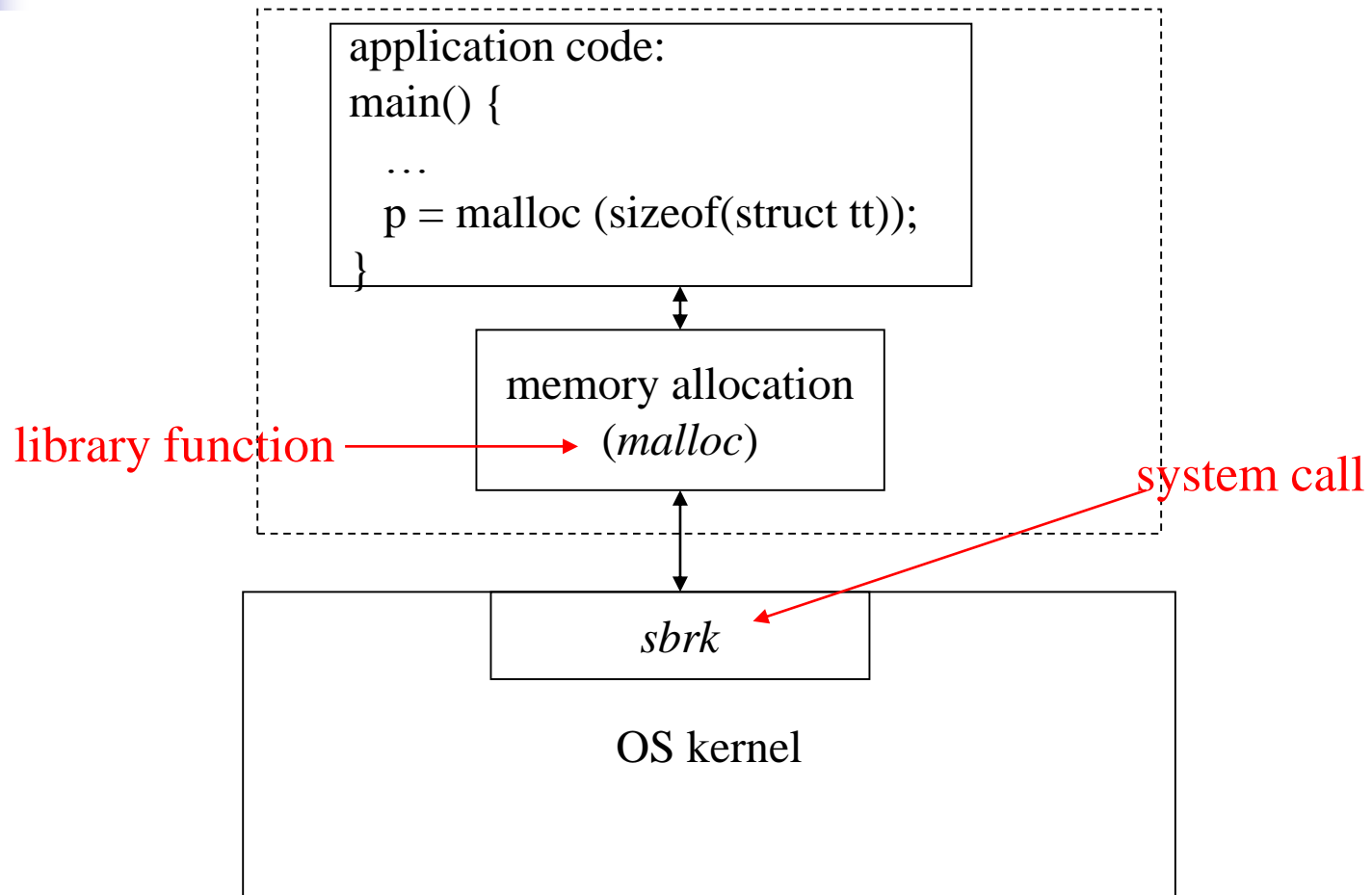
How should I access the disk?

- call the OS to do it for you
- through **system call** (e.g. `write ()`)

The OS executes low-level I/O operation to do the disk access for you



UNIX Architecture: from the view point of a single program





Basic concepts of a process

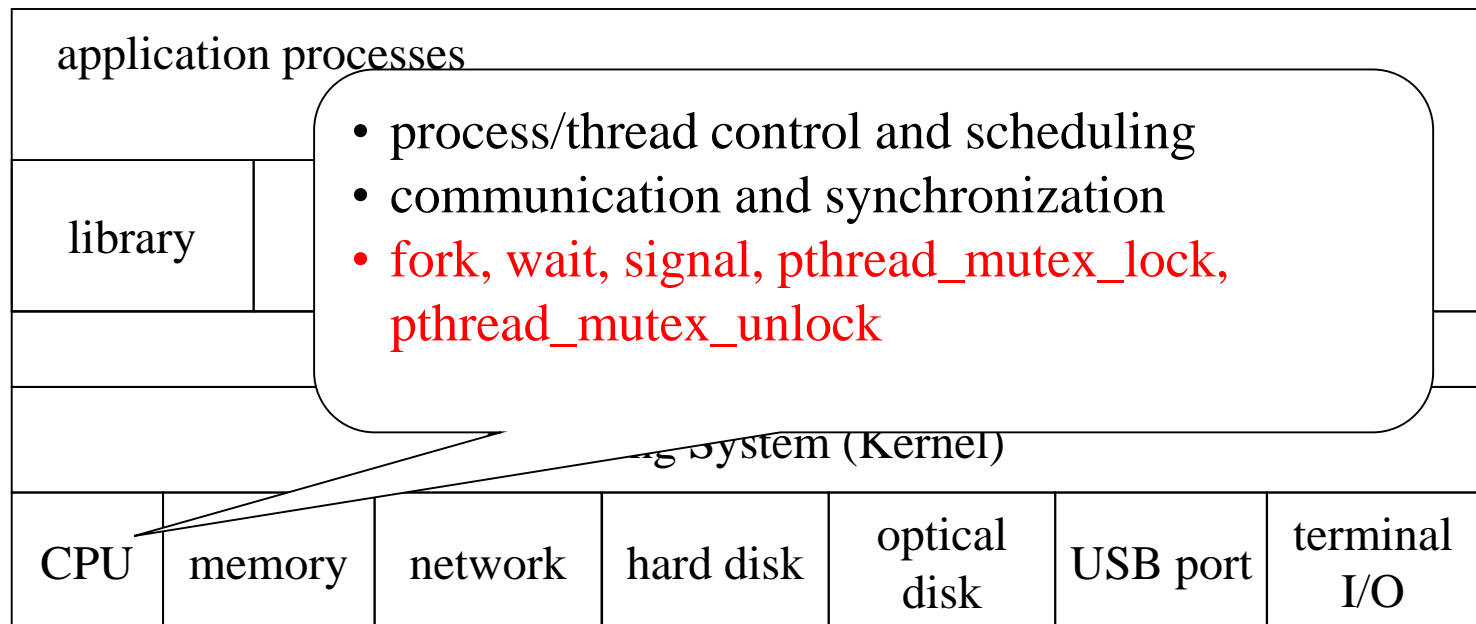


What an OS should provides?

- for general users: ease to use application programs
- for programmers: ease of programming over all hardware resources
 - manage CPUs and processes/threads scheduling
 - memory and storage devices management (e.g. virtual memory, file system, etc.)
 - API (application programmer interfaces) to I/O devices
- security and users protection



What services UNIX provides

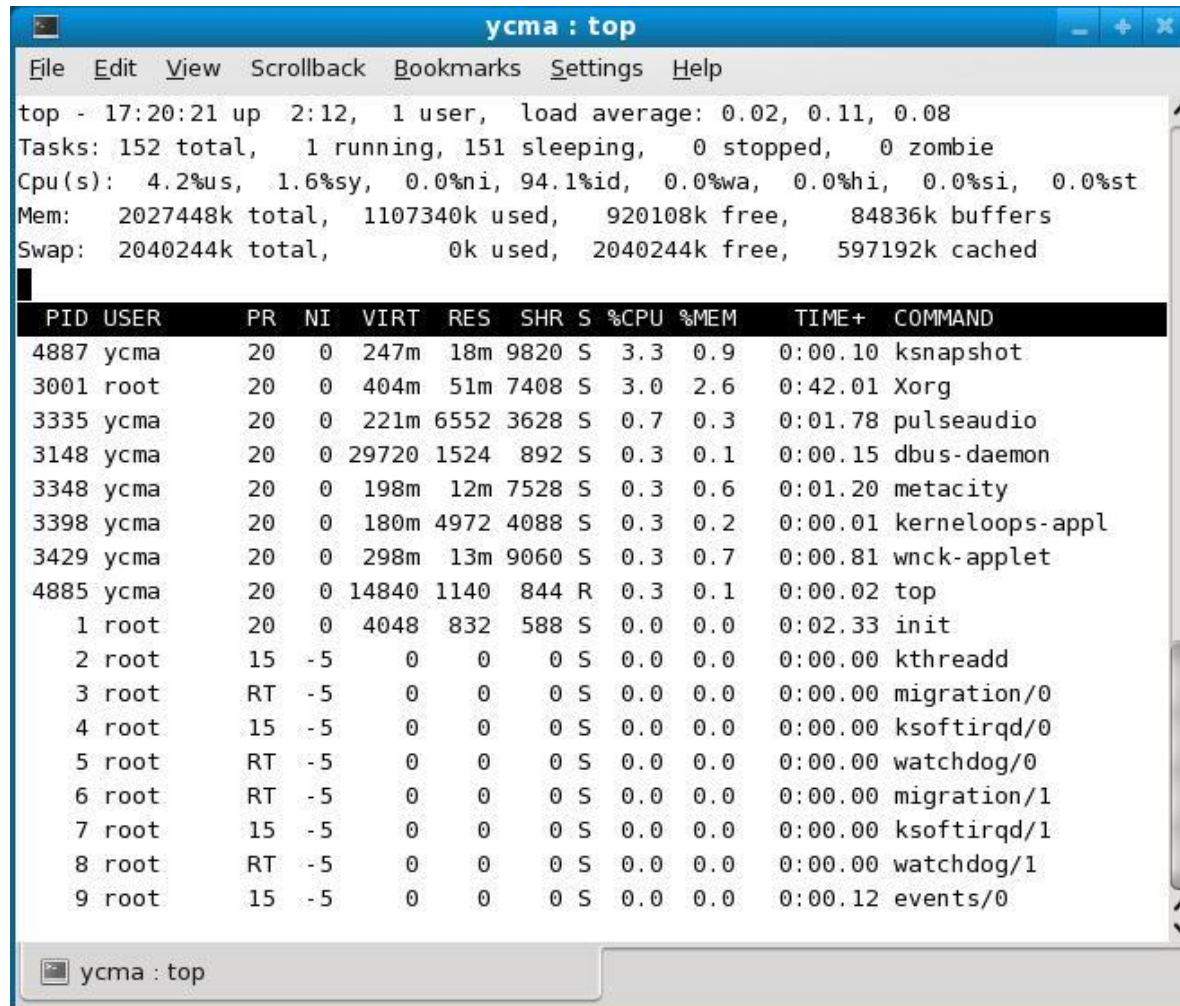




What is a process

- an instance of program been executed
 - process ID
 - it's own virtual memory space
 - files opened, I/O devices accessed, etc.
 - ...and a lot...
- there may be 2 or more processes corresponding to the same program
- Example:
 - run an infinite-loop program
 - find out what a process is in “top”

Attributes of a process



ycma : top

File Edit View Scrollback Bookmarks Settings Help

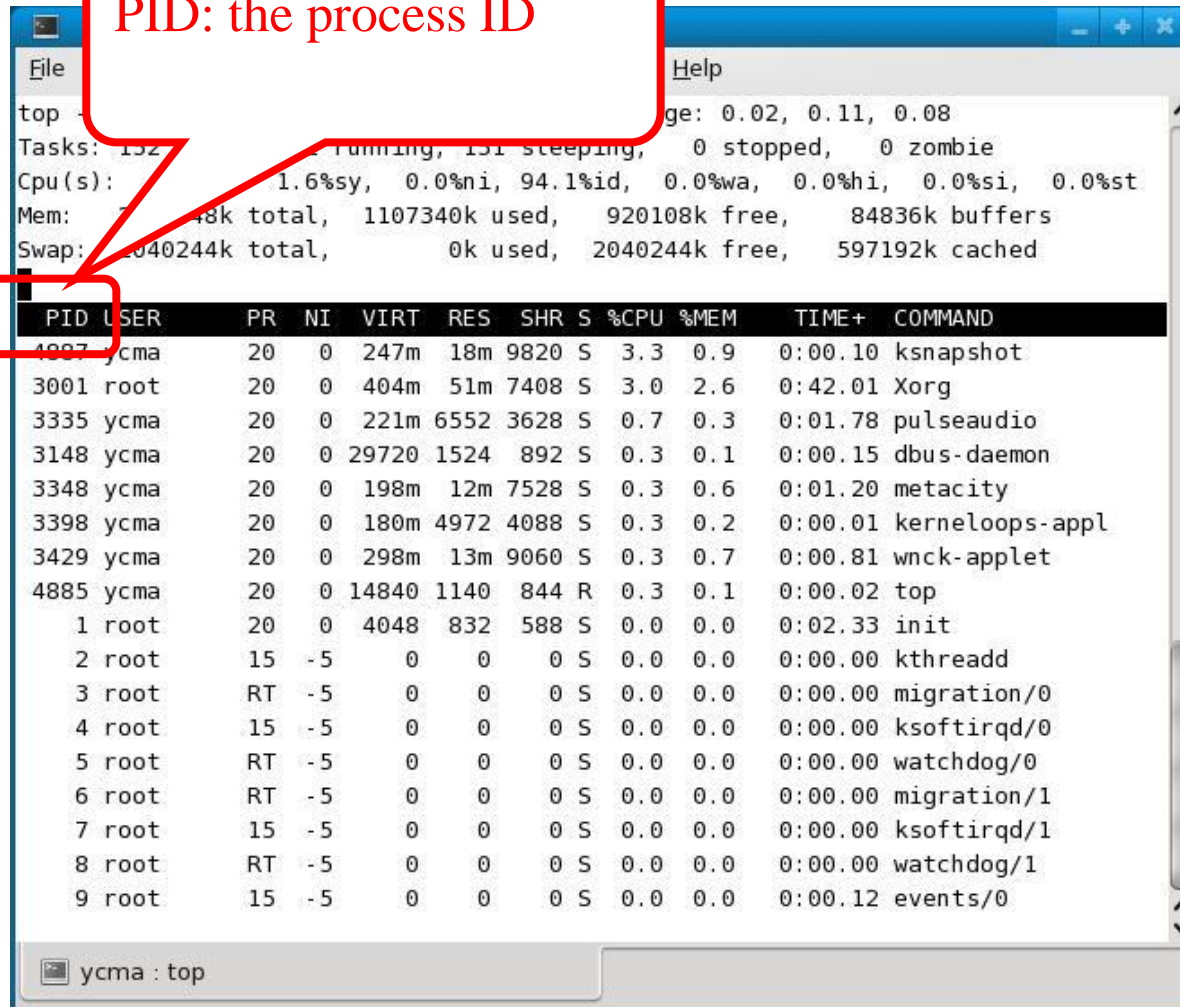
top - 17:20:21 up 2:12, 1 user, load average: 0.02, 0.11, 0.08
Tasks: 152 total, 1 running, 151 sleeping, 0 stopped, 0 zombie
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.1%id, 0.0%wa, 0.0%hi, 0.0%si, 0.0%st
Mem: 2027448k total, 1107340k used, 920108k free, 84836k buffers
Swap: 2040244k total, 0k used, 2040244k free, 597192k cached

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4887	ycma	20	0	247m	18m	9820	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

Attributes of a process

PID: the process ID



top -

Tasks: 152 running, 151 sleeping, 0 stopped, 0 zombie

Cpu(s): 1.6%sy, 0.0%ni, 94.1%id, 0.0%wa, 0.0%hi, 0.0%si, 0.0%st

Mem: 2048k total, 1107340k used, 920108k free, 84836k buffers

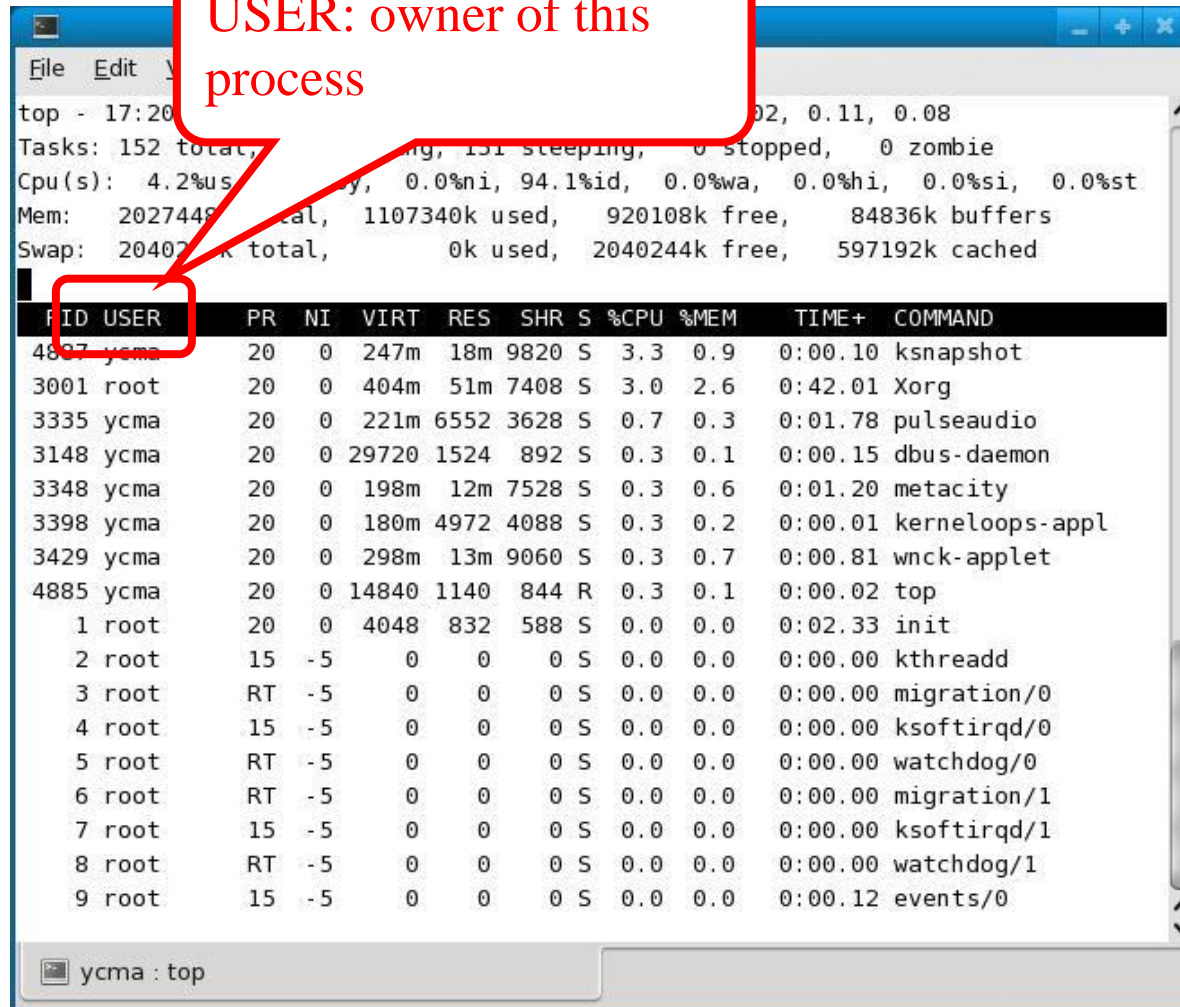
Swap: 2040244k total, 0k used, 2040244k free, 597192k cached

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
1007	ycma	20	0	247m	18m	9820	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

Attributes of a process

USER: owner of this process

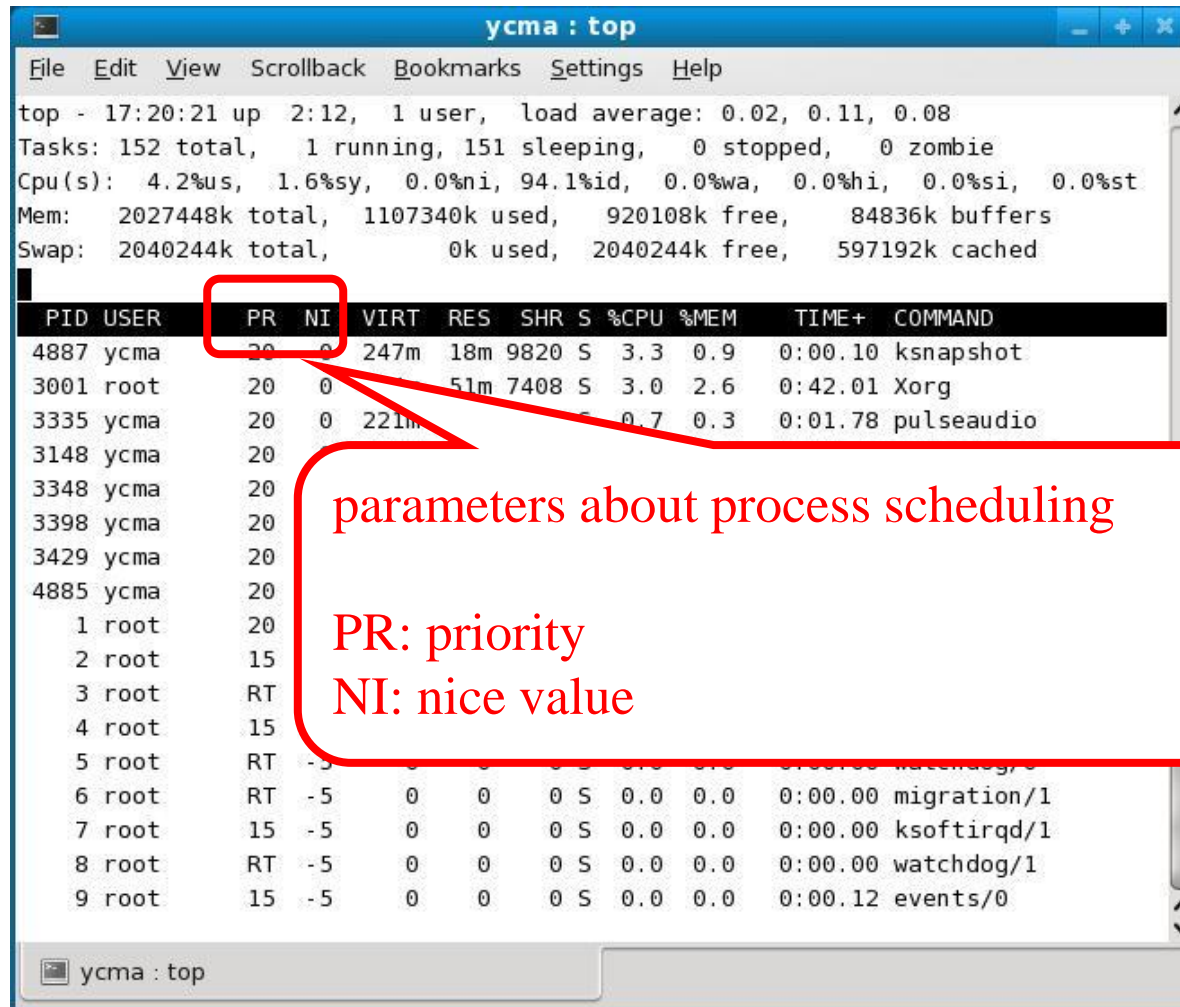


top - 17:20:02, 0.11, 0.08
Tasks: 152 total, 151 sleeping, 0 stopped, 0 zombie
Cpu(s): 4.2%us, 0.0%ni, 94.1%id, 0.0%wa, 0.0%hi, 0.0%si, 0.0%st
Mem: 2027448k total, 1107340k used, 920108k free, 84836k buffers
Swap: 20402k total, 0k used, 204024k free, 597192k cached

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4897	ycma	20	0	247m	18m	9820	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

Attributes of a process



ycma : top

File Edit View Scrollback Bookmarks Settings Help

top - 17:20:21 up 2:12, 1 user, load average: 0.02, 0.11, 0.08
Tasks: 152 total, 1 running, 151 sleeping, 0 stopped, 0 zombie
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.1%id, 0.0%wa, 0.0%hi, 0.0%si, 0.0%st
Mem: 2027448k total, 1107340k used, 920108k free, 84836k buffers
Swap: 2040244k total, 0k used, 2040244k free, 597192k cached

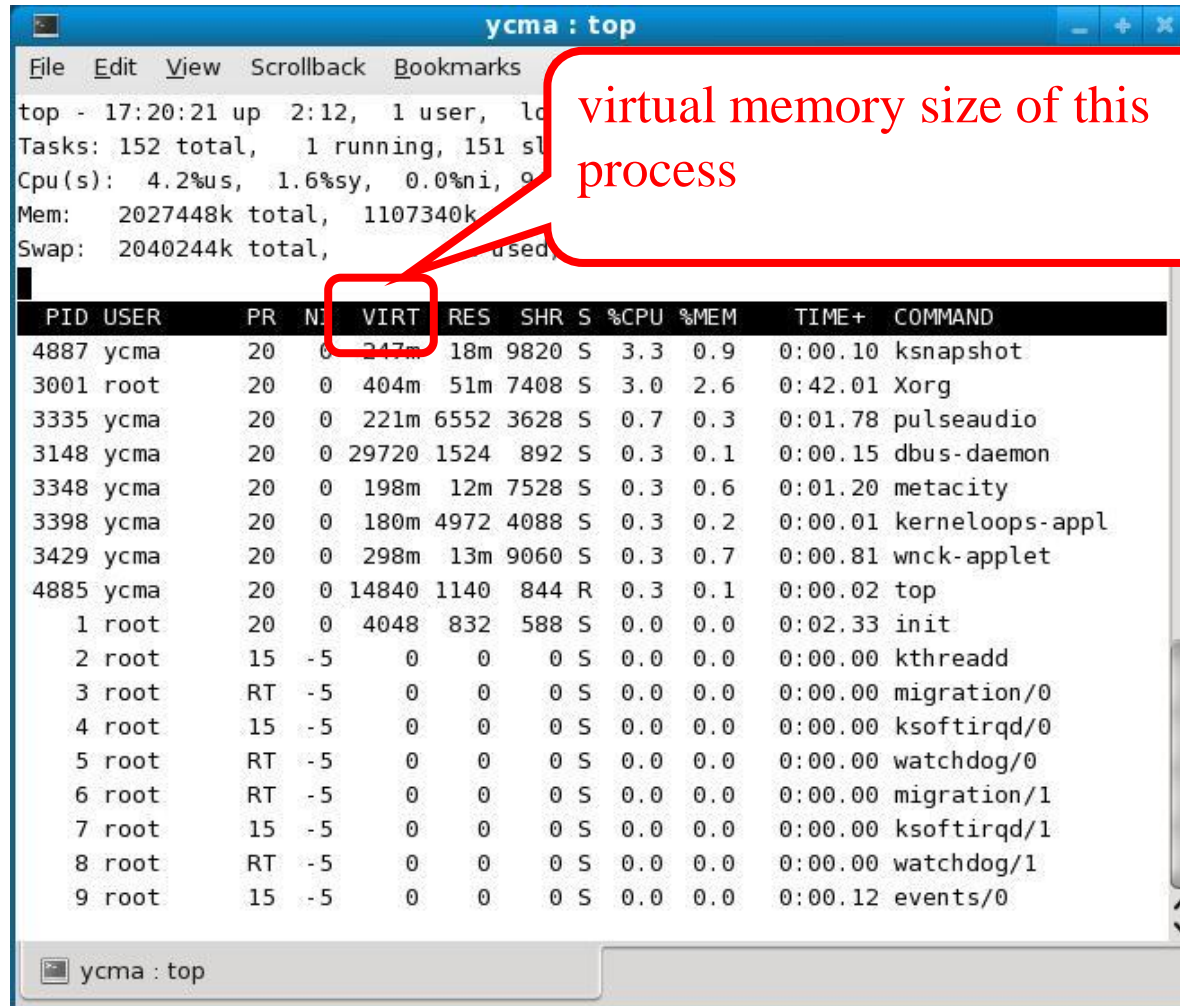
PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4887	ycma	20	0	247m	18m	9820	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	51m	7408	S	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m			S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20									
3348	ycma	20									
3398	ycma	20									
3429	ycma	20									
4885	ycma	20									
1	root	20									
2	root	15									
3	root	RT									
4	root	15									
5	root	RT	-5				S	0.0	0.0	0:00.00	watchdog/1
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

parameters about process scheduling

PR: priority
NI: nice value

ycma : top

Attributes of a process



ycma : top

File Edit View Scrollback Bookmarks

top - 17:20:21 up 2:12, 1 user, 1 load average
Tasks: 152 total, 1 running, 151 sleeping
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.2%id
Mem: 2027448k total, 1107340k used, 920108k free
Swap: 2040244k total, 0k used, 2040244k free

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4887	ycma	20	0	247m	18m	9820	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

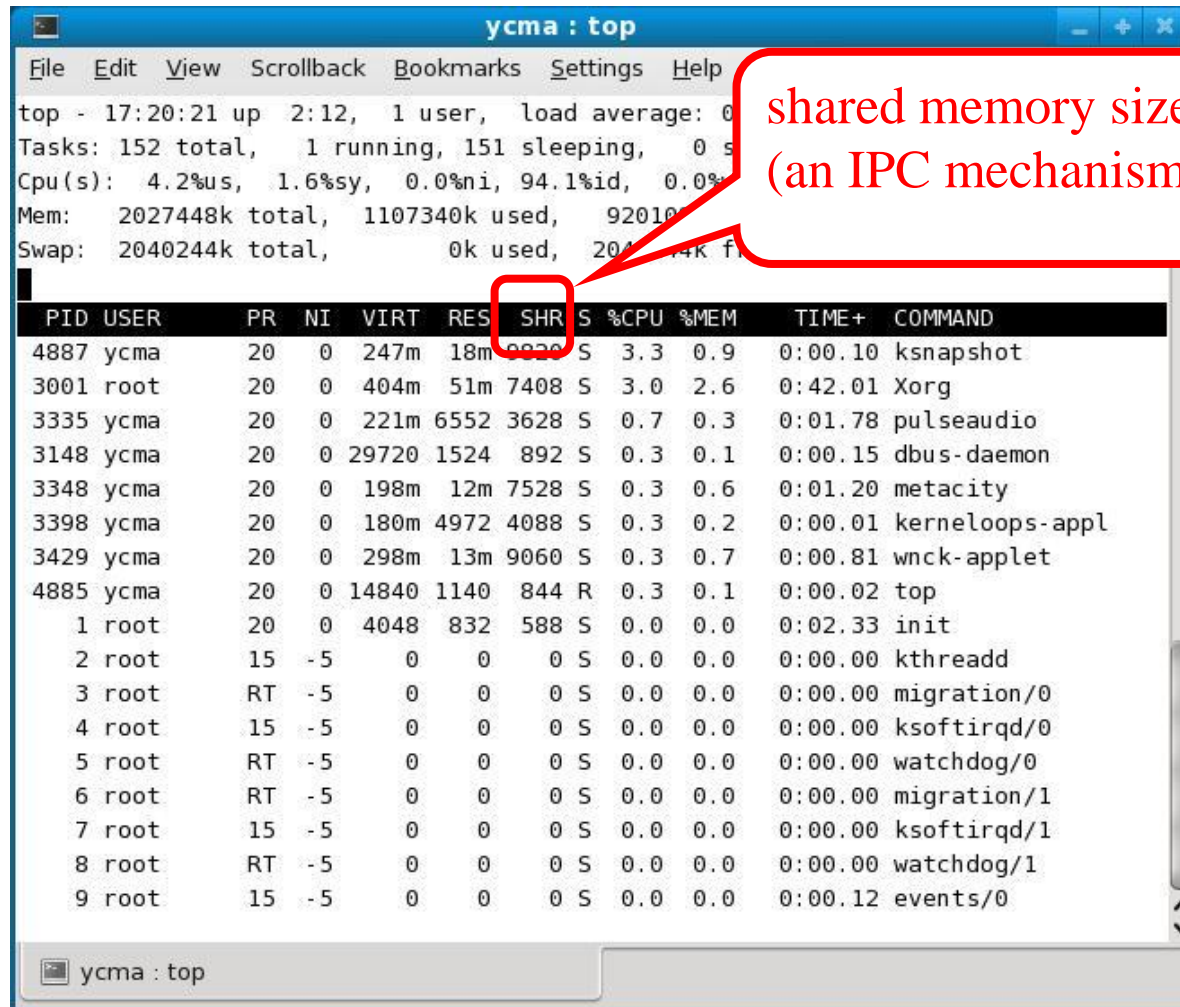
Attributes of a process

```
ycma : top
File Edit View Scrollback Bookmarks Settings
top - 17:20:21 up 2:12, 1 user, load aver
Tasks: 152 total, 1 running, 151 sleeping,
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.1%id
Mem: 2027448k total, 1107340k used,
Swap: 2040244k total, 0k used, 2040k free

  PID USER      PR  NI  VIRT  RES  SHR  S  %CPU  %MEM    TIME+  COMMAND
 4887 ycma        20   0 247m 18m 9820 S   3.3   0.9   0:00.10 ksnapshot
 3001 root         20   0 404m 51m 7408 S   3.0   2.6   0:42.01 Xorg
 3335 ycma        20   0 221m 6552 3628 S   0.7   0.3   0:01.78 pulseaudio
 3148 ycma        20   0 29720 1524 892 S   0.3   0.1   0:00.15 dbus-daemon
 3348 ycma        20   0 198m 12m 7528 S   0.3   0.6   0:01.20 metacity
 3398 ycma        20   0 180m 4972 4088 S   0.3   0.2   0:00.01 kerneloops-appl
 3429 ycma        20   0 298m 13m 9060 S   0.3   0.7   0:00.81 wnck-applet
 4885 ycma        20   0 14840 1140 844 R   0.3   0.1   0:00.02 top
    1 root         20   0 4048 832 588 S   0.0   0.0   0:02.33 init
    2 root        15  -5     0     0     0 S   0.0   0.0   0:00.00 kthreadd
    3 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 migration/0
    4 root        15  -5     0     0     0 S   0.0   0.0   0:00.00 ksoftirqd/0
    5 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 watchdog/0
    6 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 migration/1
    7 root        15  -5     0     0     0 S   0.0   0.0   0:00.00 ksoftirqd/1
    8 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 watchdog/1
    9 root        15  -5     0     0     0 S   0.0   0.0   0:00.12 events/0
```

size of physical memory used
by this process

Attributes of a process



ycma : top

File Edit View Scrollback Bookmarks Settings Help

top - 17:20:21 up 2:12, 1 user, load average: 0.00, 0.01, 0.05
Tasks: 152 total, 1 running, 151 sleeping, 0 stopped
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.1%id, 0.0%wa, 0.0%st, 0.0%hi, 0.0%si
Mem: 2027448k total, 1107340k used, 920108k free, 0k buffers
Swap: 2040244k total, 0k used, 2040244k free

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4887	ycma	20	0	247m	18m	9920	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

Attributes of a process

ycma : top

File Edit View Scrollback Bookmarks Settings Help

top - 17:20:21 up 2:12, 1 user, load average: 0.00, 0.00, 0.00
Tasks: 152 total, 1 running, 151 sleeping, 0 stopped
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.1%id, 0.0%wa
Mem: 2027448k total, 1107340k used, 920108k free
Swap: 2040244k total, 0k used, 2040244k free

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4887	ycma	20	0	247m	18m	9820	S	0.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

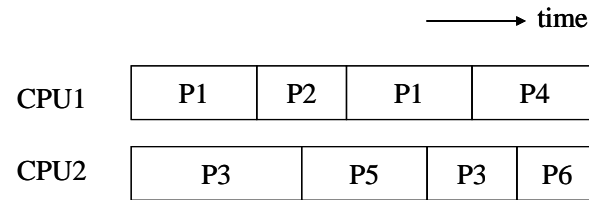


Process scheduling and management of CPUs (1)

what the OS textbook tells you

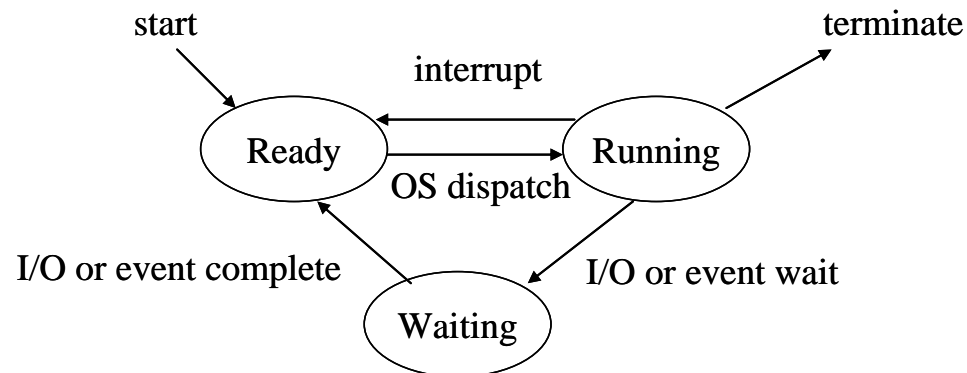
What the OS does to manage your CPUs and processes

- executing processes with **time-sharing** scheme



processes alive: P1, P2, ..., P6

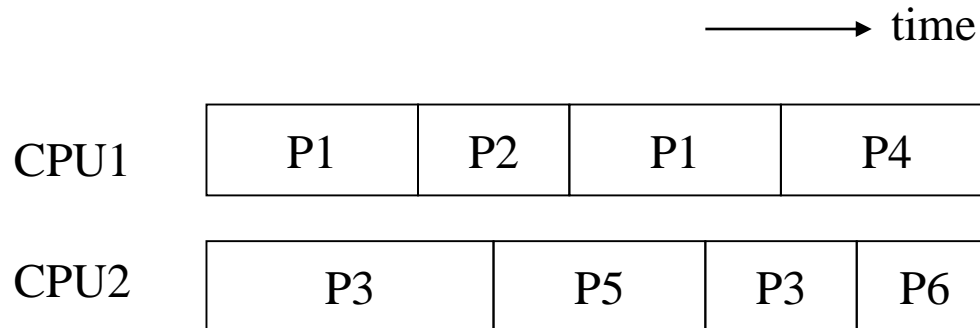
- a process may be in one of these states





Time sharing

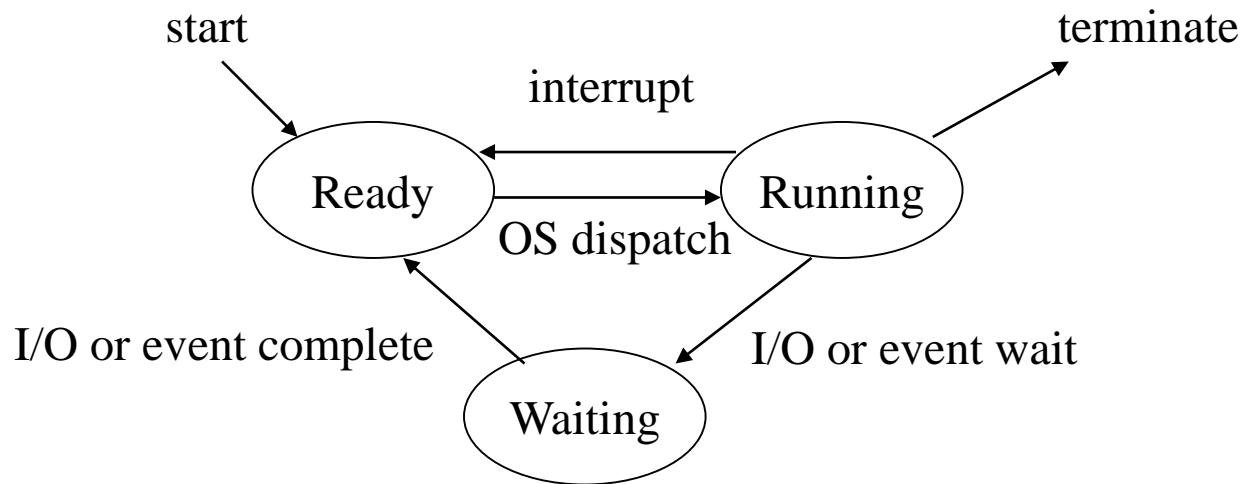
- the OS schedules a set of processes to run on CPUs
- at any time, only one process is running on an CPU



processes alive: P1, P2, ..., P6

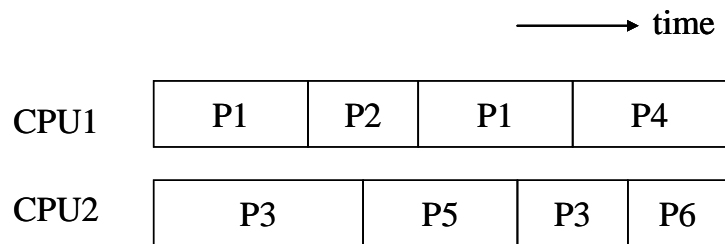


States of a process

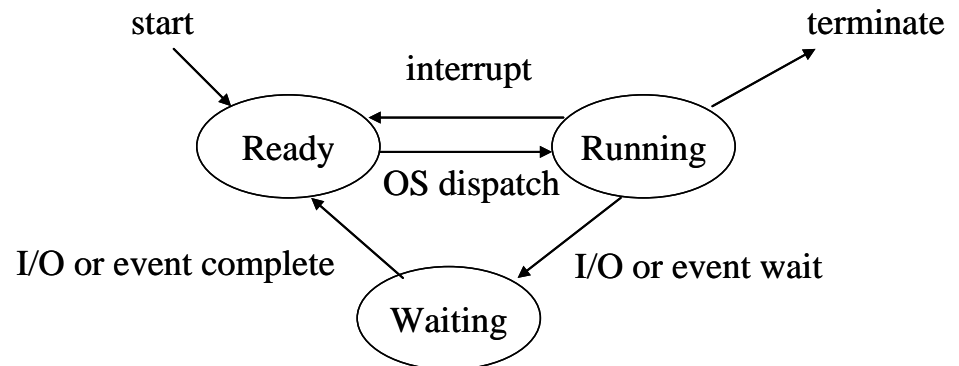


Process scheduling with states

- Consider process P1

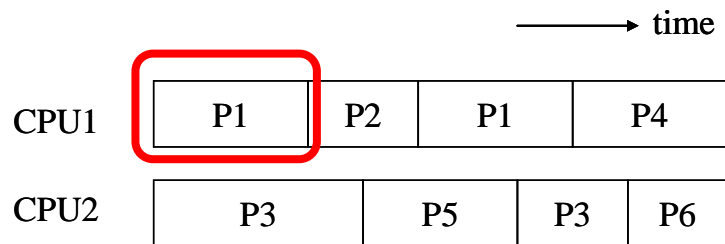


processes alive: P1, P2, ..., P6

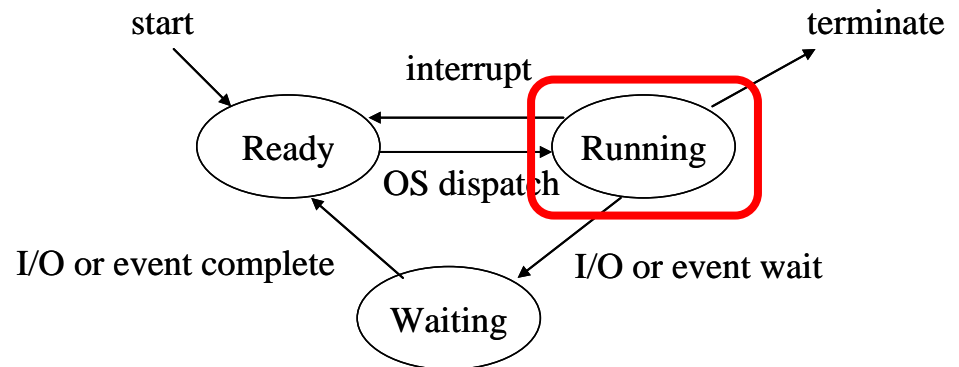


Process scheduling with states

- P1 in running state and occupies a CPU

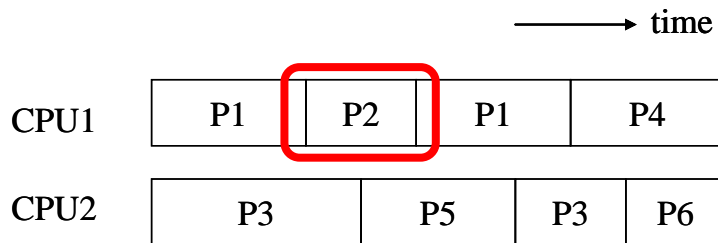


processes alive: P1, P2, ..., P6

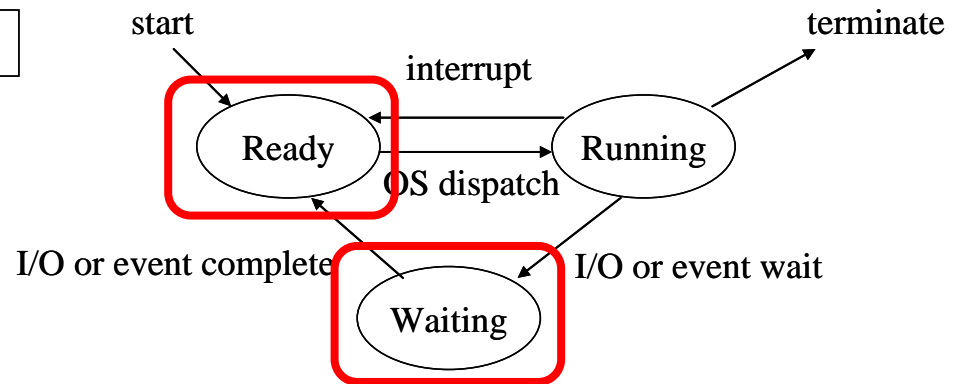


Process scheduling with states

- P1 enters Waiting/Ready state due to
 - OS schedules, or
 - waiting for an I/O

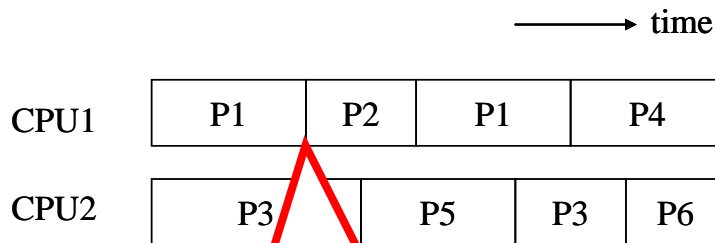


processes alive: P1, P2, ..., P6

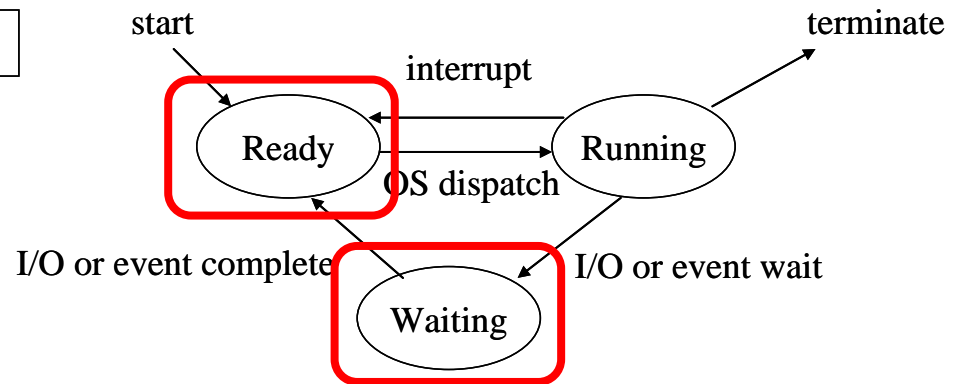


Process scheduling with states

- P1 enters Waiting/Ready state due to
 - OS schedules, or
 - waiting for an I/O

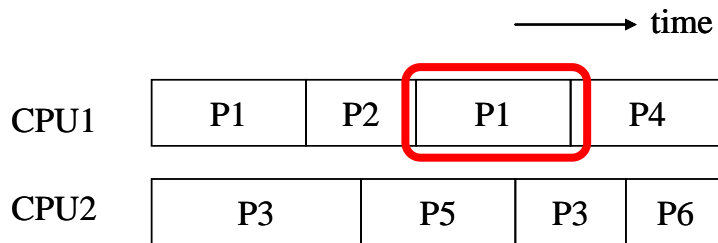


Preemptive

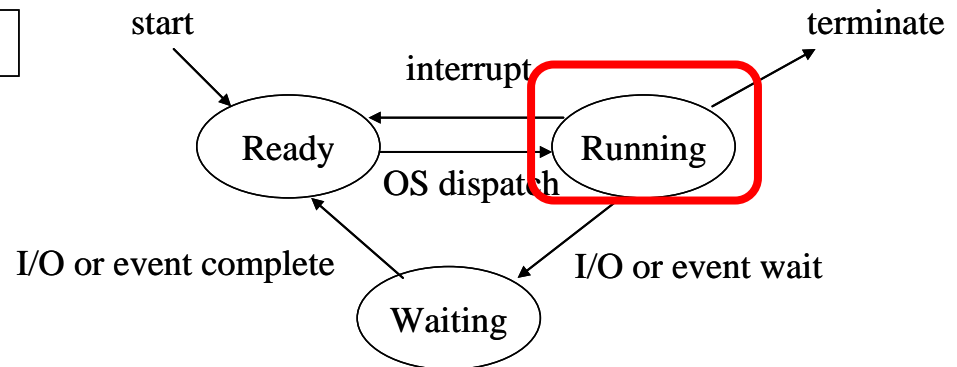


Process scheduling with states

- P1 re-gains the CPU due to
 - OS schedules, or
 - waiting for an I/O



processes alive: P1, P2, ..., P6





Process scheduling and management of CPUs (2)

Let's see a concrete example on
Linux

Example program

- Let's trace how the process state transfers with this program

```
#include <stdio.h>
```

```
main ()
```

```
{
```

```
    int d;
```

```
    printf ("input an integer: ");
```

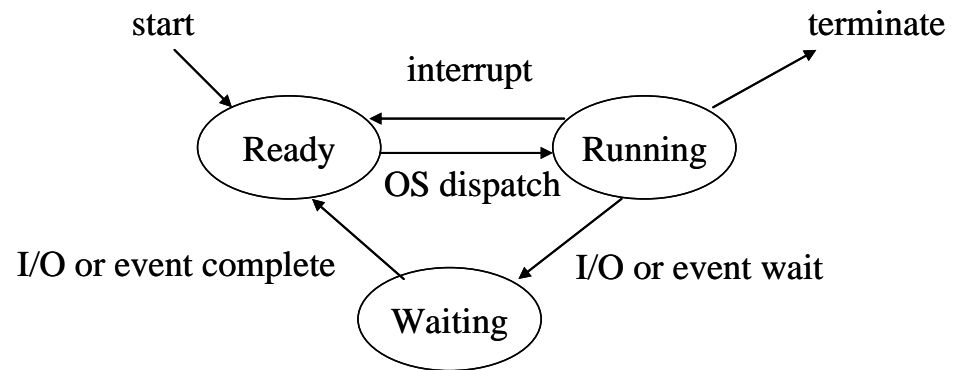
```
    scanf ("%d", &d);
```

```
    printf ("entering infinite loop\n");
```

```
    while (1);
```

```
    return 0;
```

```
}//main()
```

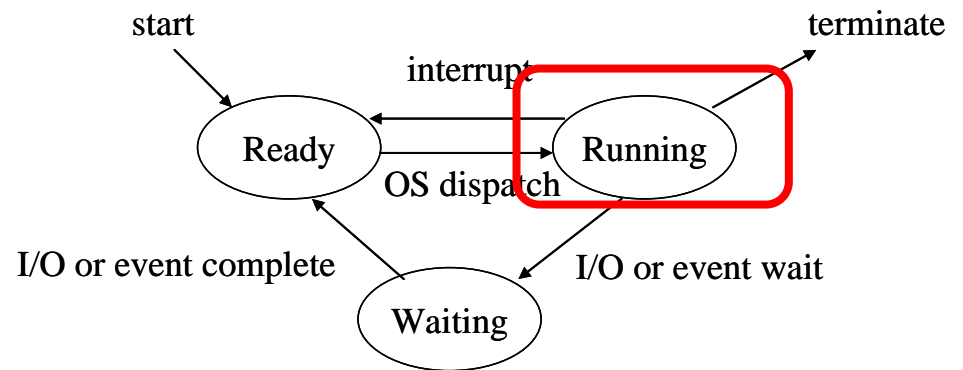


Example program

(1) At initial, the process is running

```
#include <stdio.h>

main ()
{
    int d;
    printf ("input an integer: ");
    scanf ("%d", &d);
    printf ("entering infinite loop\n");
    while (1);
    return 0;
} //main()
```



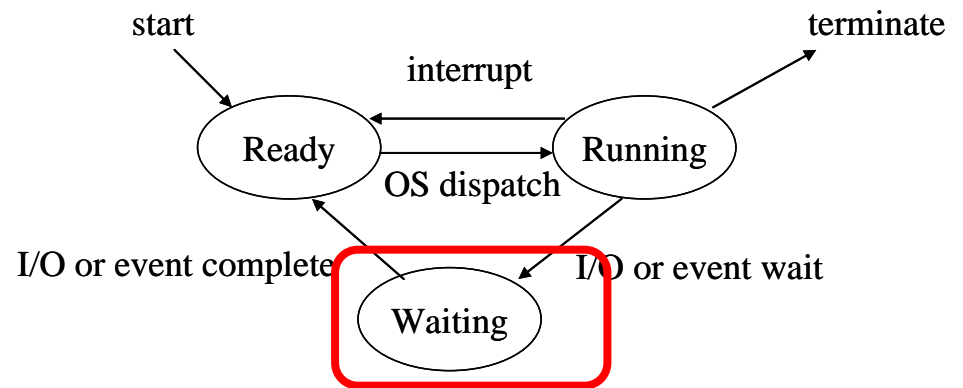
Example program

(2) Transfer to waiting state while waiting the user input from the keyboard

```
#include <stdio.h>

main ()
{
    int d;

    printf ("input an integer: ");
    scanf ("%d", &d);
    printf ("entering infinite loop\n");
    while (1);
    return 0;
} //main()
```



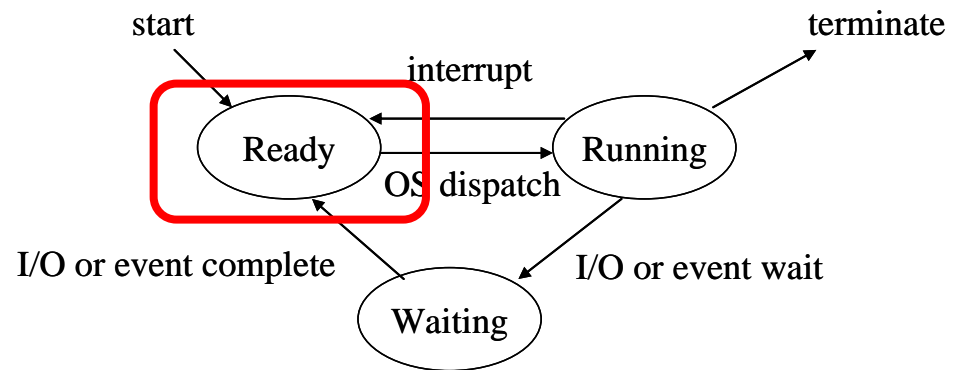
Example program

(3) Transfer to Ready state after the user inputs something from the keyboard

```
#include <stdio.h>

main ()
{
    int d;

    printf ("input an integer: ");
    scanf ("%d", &d);
    printf ("entering infinite loop\n");
    while (1);
    return 0;
} //main()
```



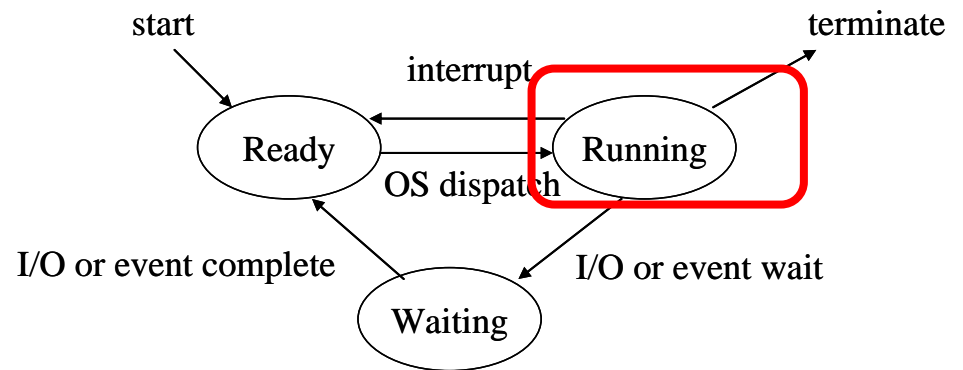
Example program

(4) Regain the CPU after the OS picks it up

```
#include <stdio.h>

main ()
{
    int d;

    printf ("input an integer: ");
    scanf ("%d", &d);
    printf ("entering infinite loop\n");
    while (1);
    return 0;
} //main()
```



Example program

- Let's have a trial on Linux
 - demo/infinite_loop/demo2.c

```
#include <stdio.h>
```

```
main ()
```

```
{
```

```
    int d;
```

```
    printf ("input an integer: ");
```

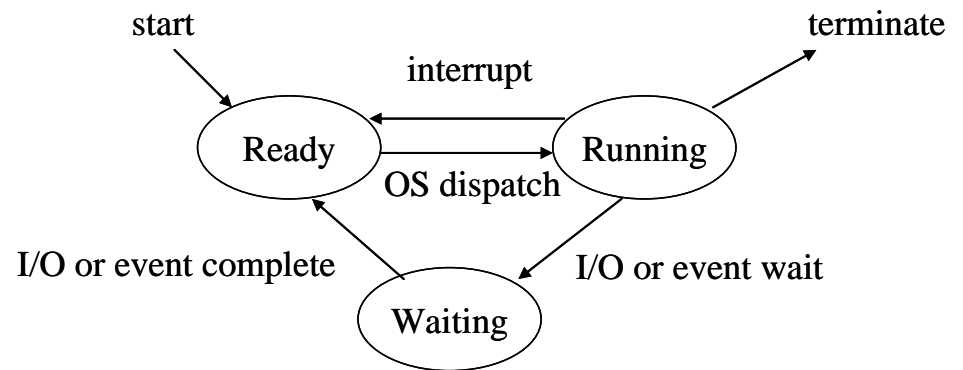
```
    scanf ("%d", &d);
```

```
    printf ("entering infinite loop\n");
```

```
    while (1);
```

```
    return 0;
```

```
}//main()
```





More on the process

- inter-process communication
- process creation

Let's explain other services of OS first

How the OS manages memory and storage devices



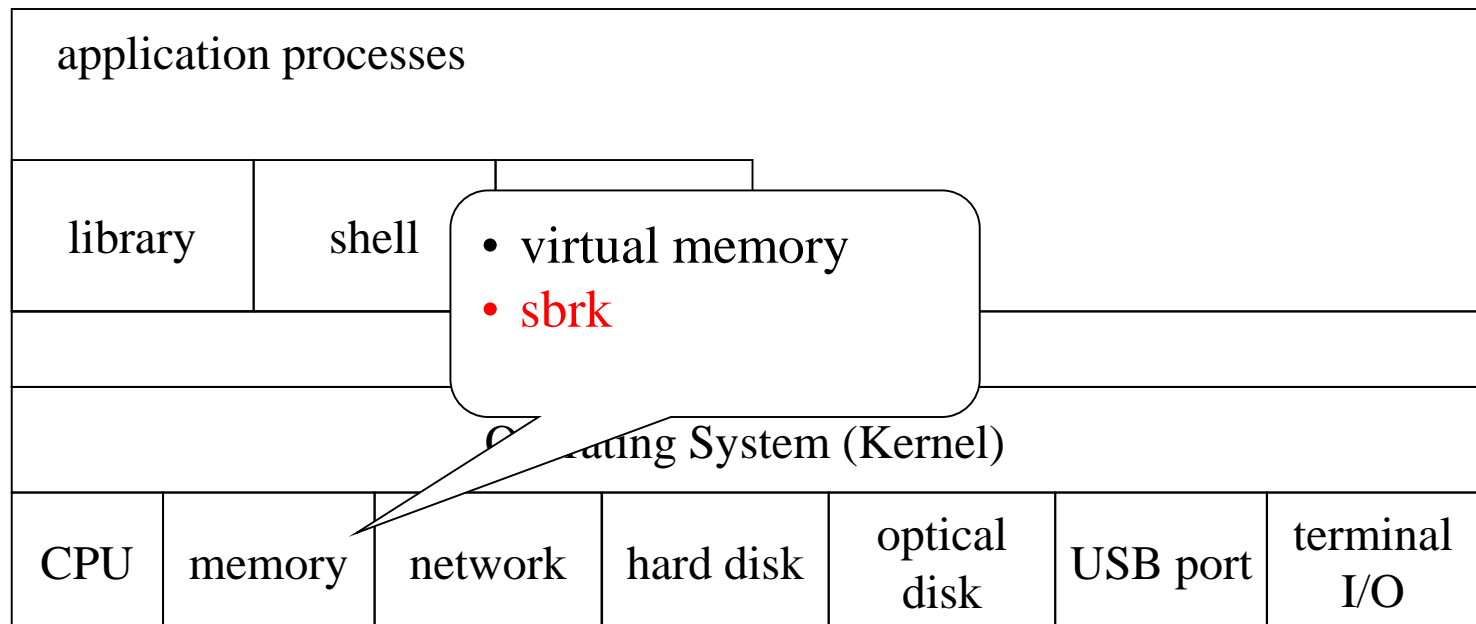


What an OS should provides?

- for general users: ease to use application programs
- for programmers: ease of programming over all hardware resources
 - manage CPUs and processes/threads scheduling
 - memory and storage devices management (e.g. virtual memory, file system, etc.)
 - API (application programmer interfaces) to I/O devices
- security and users protection



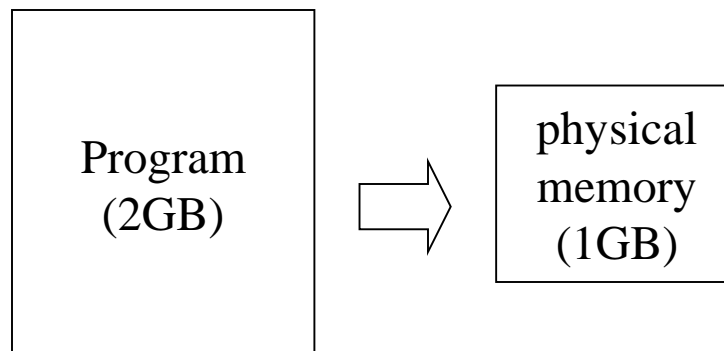
What services UNIX provides





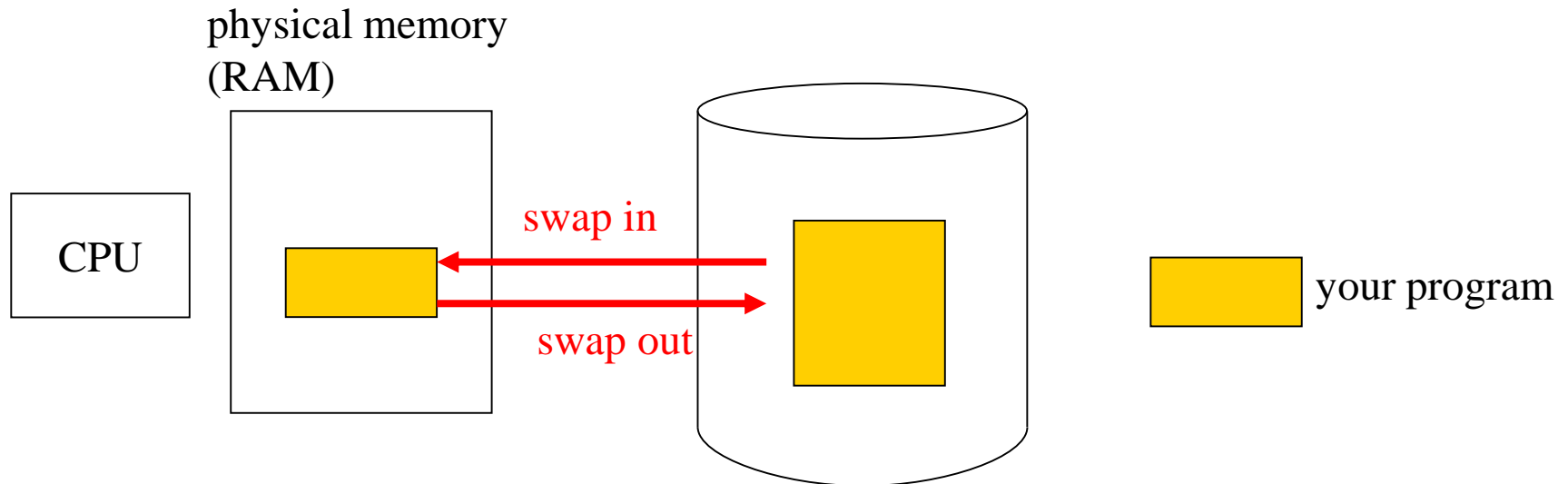
What is virtual memory

- a mechanism provided by OS+CPU
- Purpose:
 - let a program has individual memory space, not interfere with others
 - let you write a program larger than the size of physical memory



The magic of virtual memory

- use RAM + hard disk to run your program
 - RAM + hard disk > program size
- swap in currently required part
- swap out currently not required part





Check the virtual memory setup of your Linux

- try command “*top*”
- you can setup the size of swap space at install (setup disk partition)

Check the virtual memory setup of your Linux

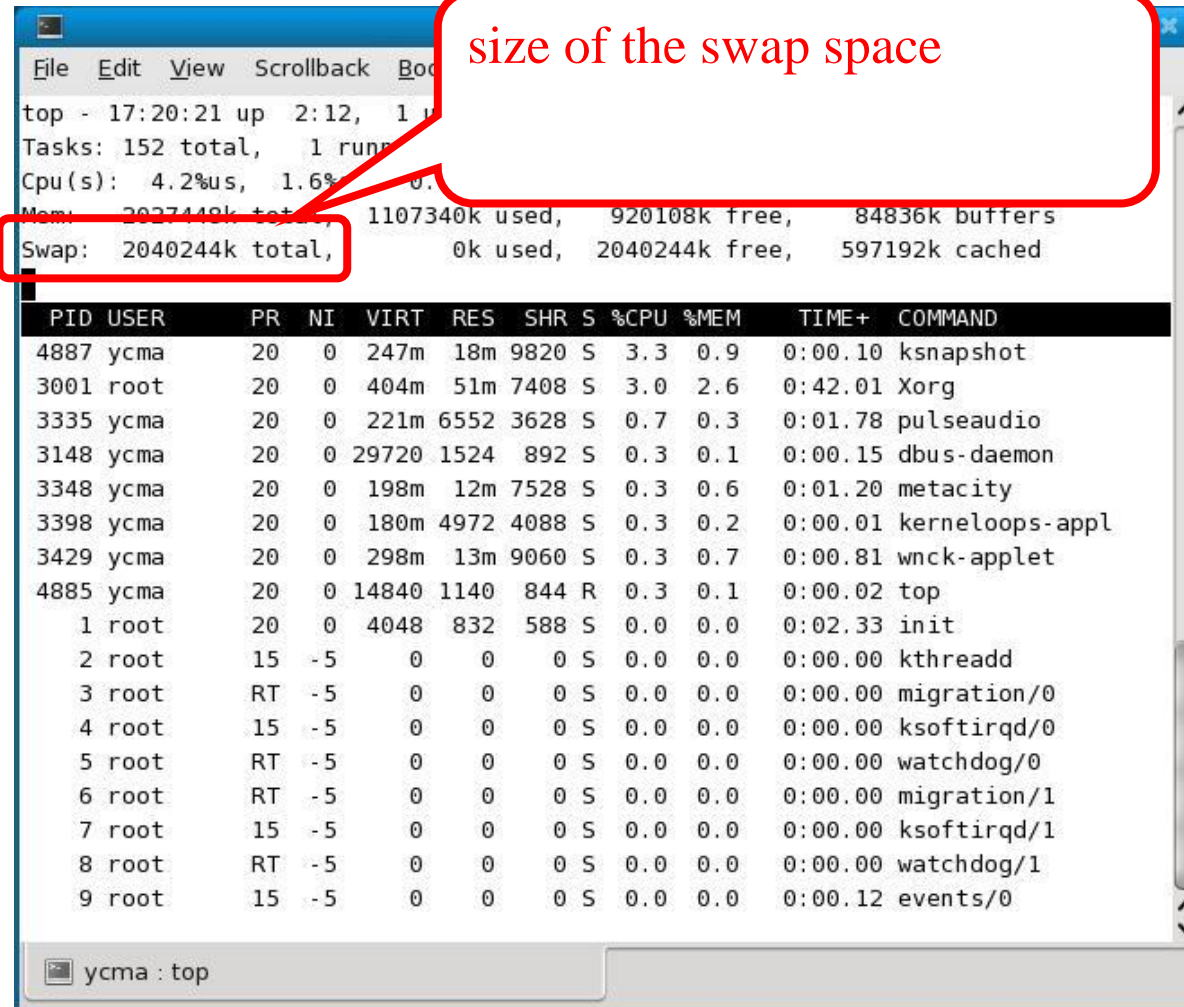
size of the physical memory

```
File Edit View Scrollback Bookmarks
top - 17:20:21 up 2:12, 1 user, load averages: 0.00, 0.01, 0.05
Tasks: 152 total, 1 running, 151 sleeping, 0 stopped, 0 zombie
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.1%id, 0.0%wa, 0.0%hi, 0.0%si, 0.0%st
Mem: 2027448k total, 1107340k used, 920108k free, 84836k buffers
Swap: 2040244k total, 0k used, 2040244k free, 597192k cached
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4887	ycma	20	0	247m	18m	9820	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

Check the virtual memory setup of your Linux

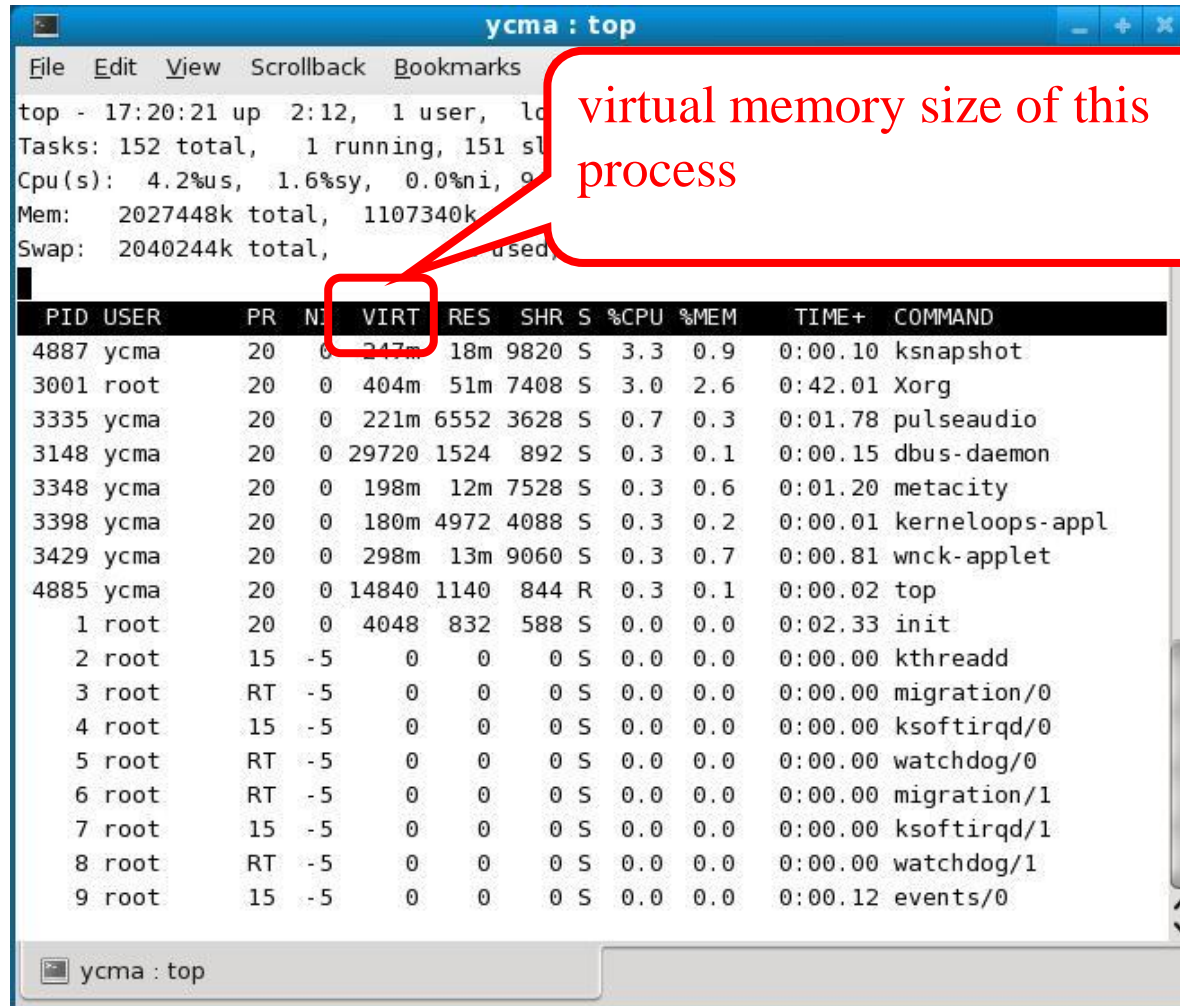


```
File Edit View Scrollback Boo
top - 17:20:21 up 2:12, 1 u
Tasks: 152 total, 1 runn
Cpu(s): 4.2%us, 1.6%
Mem: 2037448k total, 1107340k used, 920108k free, 84836k buffers
Swap: 2040244k total, 0k used, 2040244k free, 597192k cached

  PID USER      PR  NI  VIRT  RES  SHR  S  %CPU  %MEM    TIME+  COMMAND
 4887 ycma      20   0 247m  18m 9820  S   3.3   0.9   0:00.10 ksnapshot
 3001 root       20   0 404m  51m 7408  S   3.0   2.6   0:42.01 Xorg
 3335 ycma      20   0 221m 6552 3628  S   0.7   0.3   0:01.78 pulseaudio
 3148 ycma      20   0 29720 1524 892   S   0.3   0.1   0:00.15 dbus-daemon
 3348 ycma      20   0 198m  12m 7528  S   0.3   0.6   0:01.20 metacity
 3398 ycma      20   0 180m 4972 4088  S   0.3   0.2   0:00.01 kerneloops-appl
 3429 ycma      20   0 298m  13m 9060  S   0.3   0.7   0:00.81 wnck-applet
 4885 ycma      20   0 14840 1140 844   R   0.3   0.1   0:00.02 top
    1 root      20   0 4048   832 588   S   0.0   0.0   0:02.33 init
    2 root      15  -5     0     0    0   S   0.0   0.0   0:00.00 kthreadd
    3 root      RT  -5     0     0    0   S   0.0   0.0   0:00.00 migration/0
    4 root      15  -5     0     0    0   S   0.0   0.0   0:00.00 ksoftirqd/0
    5 root      RT  -5     0     0    0   S   0.0   0.0   0:00.00 watchdog/0
    6 root      RT  -5     0     0    0   S   0.0   0.0   0:00.00 migration/1
    7 root      15  -5     0     0    0   S   0.0   0.0   0:00.00 ksoftirqd/1
    8 root      RT  -5     0     0    0   S   0.0   0.0   0:00.00 watchdog/1
    9 root      15  -5     0     0    0   S   0.0   0.0   0:00.12 events/0
```

ycma : top

Attributes of a process



ycma : top

File Edit View Scrollback Bookmarks

top - 17:20:21 up 2:12, 1 user, 1 load average
Tasks: 152 total, 1 running, 151 sleeping
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.2%id
Mem: 2027448k total, 1107340k used, 920108k free
Swap: 2040244k total, 0k used, 2040244k free

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
4887	ycma	20	0	247m	18m	9820	S	3.3	0.9	0:00.10	ksnapshot
3001	root	20	0	404m	51m	7408	S	3.0	2.6	0:42.01	Xorg
3335	ycma	20	0	221m	6552	3628	S	0.7	0.3	0:01.78	pulseaudio
3148	ycma	20	0	29720	1524	892	S	0.3	0.1	0:00.15	dbus-daemon
3348	ycma	20	0	198m	12m	7528	S	0.3	0.6	0:01.20	metacity
3398	ycma	20	0	180m	4972	4088	S	0.3	0.2	0:00.01	kerneloops-appl
3429	ycma	20	0	298m	13m	9060	S	0.3	0.7	0:00.81	wnck-applet
4885	ycma	20	0	14840	1140	844	R	0.3	0.1	0:00.02	top
1	root	20	0	4048	832	588	S	0.0	0.0	0:02.33	init
2	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	kthreadd
3	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/0
4	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/0
5	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/0
6	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	migration/1
7	root	15	-5	0	0	0	S	0.0	0.0	0:00.00	ksoftirqd/1
8	root	RT	-5	0	0	0	S	0.0	0.0	0:00.00	watchdog/1
9	root	15	-5	0	0	0	S	0.0	0.0	0:00.12	events/0

ycma : top

Attributes of a process

```
ycma : top
File Edit View Scrollback Bookmarks Settings
top - 17:20:21 up 2:12, 1 user, load aver
Tasks: 152 total, 1 running, 151 sleeping,
Cpu(s): 4.2%us, 1.6%sy, 0.0%ni, 94.1%id
Mem: 2027448k total, 1107340k used,
Swap: 2040244k total, 0k used, 2040244k free

  PID USER      PR  NI  VIRT  RES  SHR  S  %CPU  %MEM    TIME+  COMMAND
 4887 ycma        20   0 247m 18m 9820 S   3.3   0.9   0:00.10 ksnapshot
 3001 root         20   0 404m 51m 7408 S   3.0   2.6   0:42.01 Xorg
 3335 ycma        20   0 221m 6552 3628 S   0.7   0.3   0:01.78 pulseaudio
 3148 ycma        20   0 29720 1524 892 S   0.3   0.1   0:00.15 dbus-daemon
 3348 ycma        20   0 198m 12m 7528 S   0.3   0.6   0:01.20 metacity
 3398 ycma        20   0 180m 4972 4088 S   0.3   0.2   0:00.01 kerneloops-appl
 3429 ycma        20   0 298m 13m 9060 S   0.3   0.7   0:00.81 wnck-applet
 4885 ycma        20   0 14840 1140 844 R   0.3   0.1   0:00.02 top
    1 root         20   0 4048 832 588 S   0.0   0.0   0:02.33 init
    2 root        15  -5     0     0     0 S   0.0   0.0   0:00.00 kthreadd
    3 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 migration/0
    4 root        15  -5     0     0     0 S   0.0   0.0   0:00.00 ksoftirqd/0
    5 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 watchdog/0
    6 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 migration/1
    7 root        15  -5     0     0     0 S   0.0   0.0   0:00.00 ksoftirqd/1
    8 root         RT  -5     0     0     0 S   0.0   0.0   0:00.00 watchdog/1
    9 root        15  -5     0     0     0 S   0.0   0.0   0:00.12 events/0
```

size of physical memory used
by this process



Example program for virtual memory

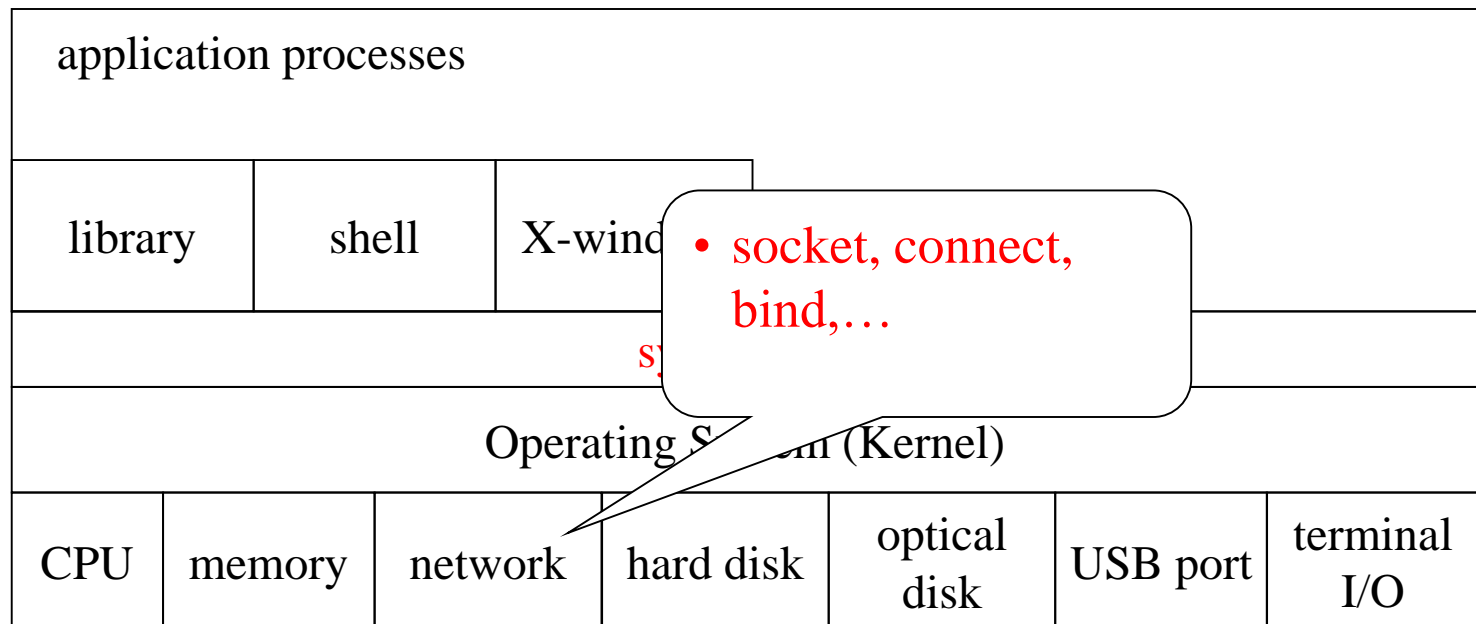
- `demo/infinite_loop/vmem.c`
 - a program accessing an array of 2GB size
 - to execute on my laptop with only 1GB RAM

How UNIX manages networking and I/O devices



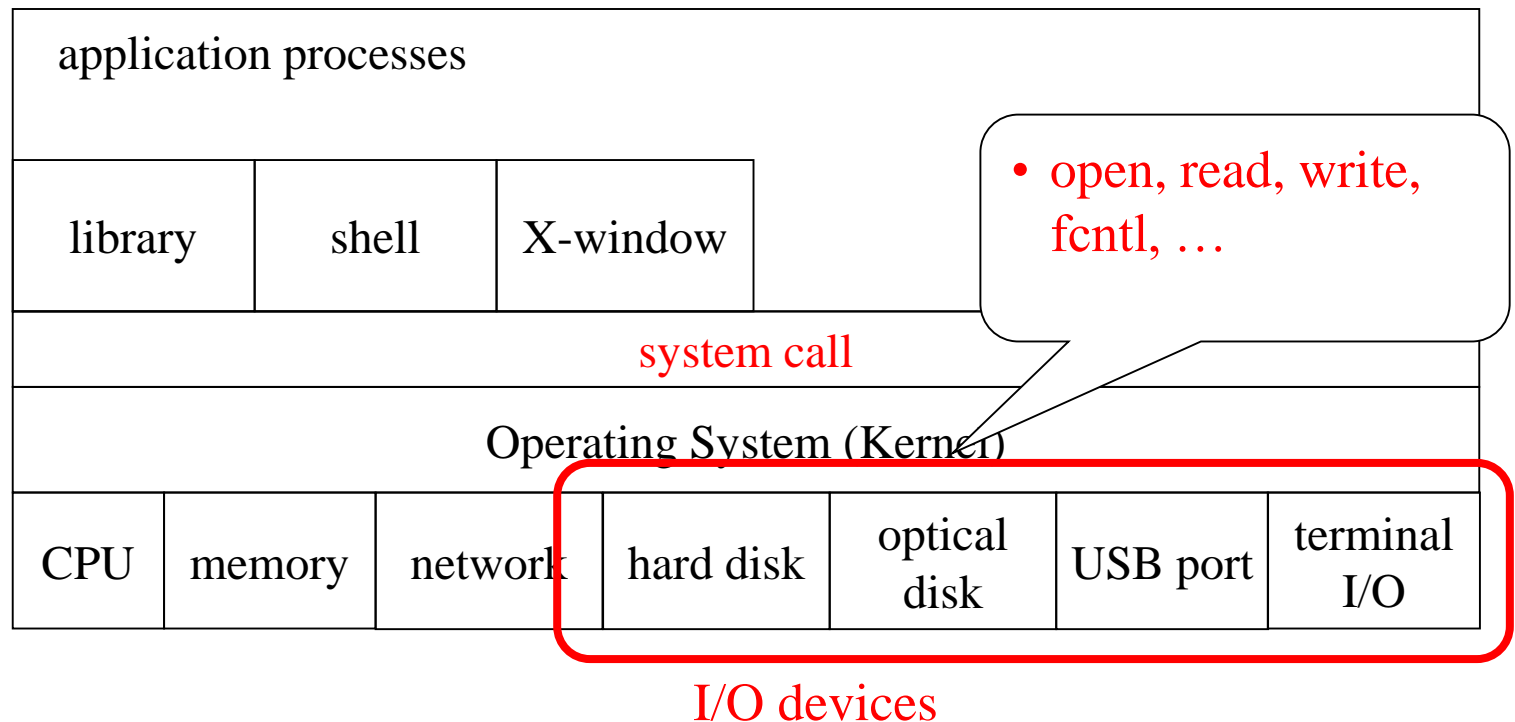


What services UNIX provides



What services UNIX provides

- I/O devices are accessed like files



How the OS provides security and protection





What an OS should provides?

- for general users: ease to use application programs
- for programmers: ease of programming over all hardware resources
- security and users protection
 - access permission for files, I/O devices for multi-users
 - network security

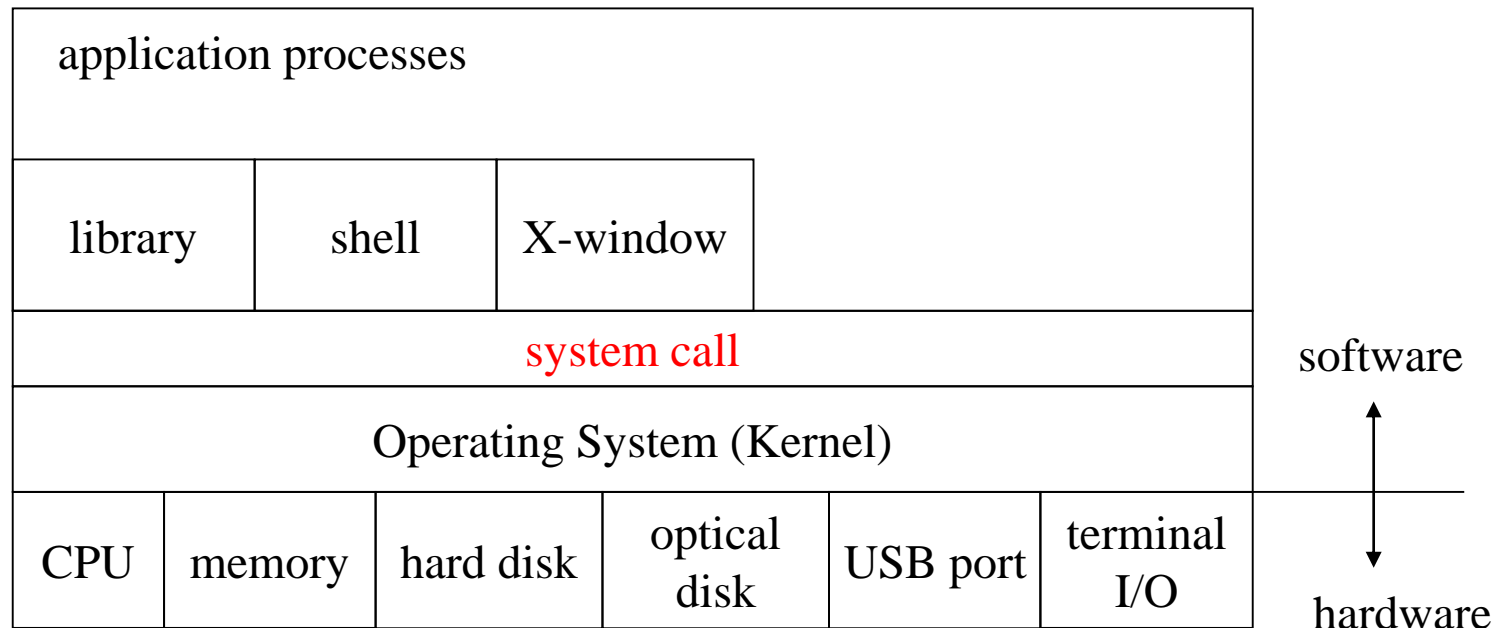


Example of security and protection

- trying to access other ones file
 - check the file permission

UNIX provides protection through *system call*

- system call: a special function call provided by OS
- all hardware resources can only be accessed through system calls
- the system call checks for access permission



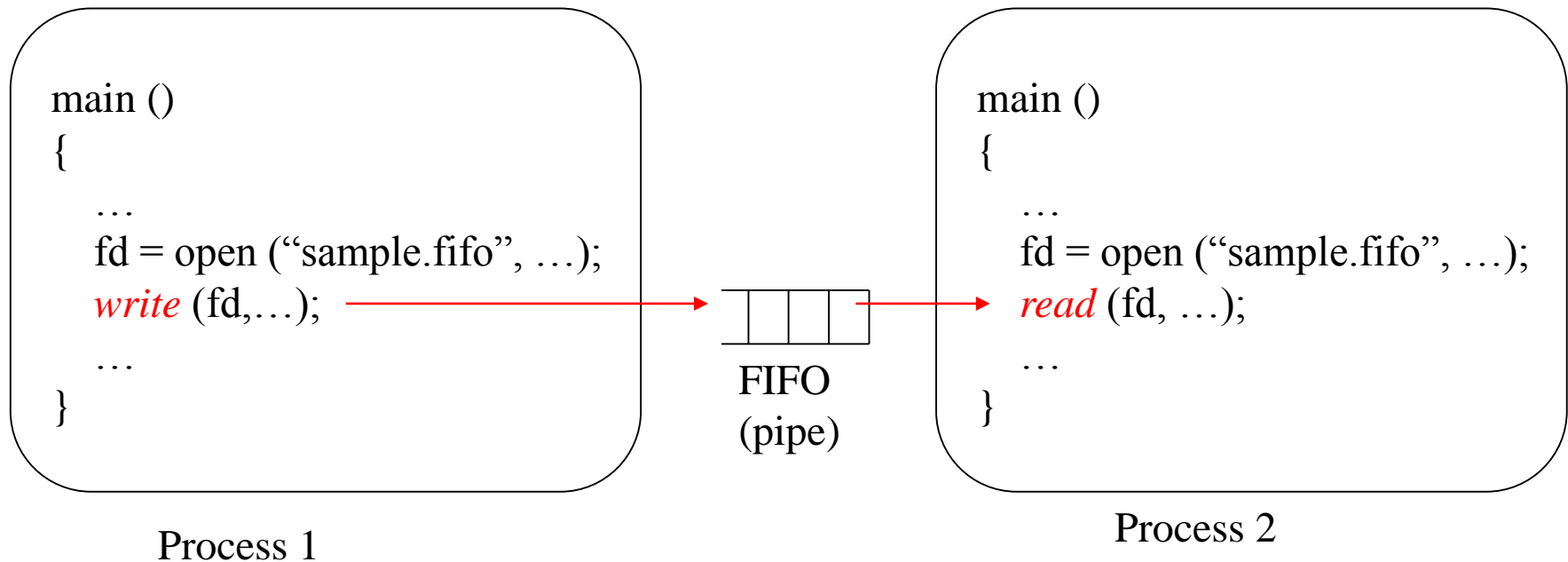


More on process

How to create a new process and execute a program

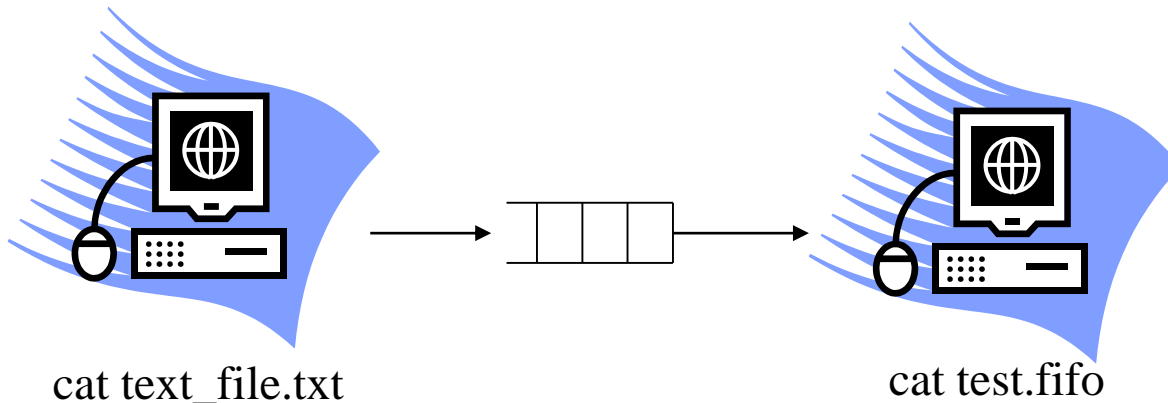
The IPC (inter-process communication)

Processes may also communicate like accessing files



A simple exercise on using FIFO

- Step 1: execute command
`mkfifo test.fifo`
- Step 2: open a terminal and execute command
`cat test.fifo`
- Step 3: open another terminal and execute command
`cat text_file.txt > test.fifo`





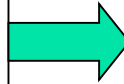
How to create a new process?

- *fork* and generate a process with identical content

Parent Process

```
pid = fork ();  
if (pid==0) { //child process  
    execlp (filename, filename, (void*)0);  
    printf ("Error if you see this line\n");  
}  
else { //parent process  
    printf ("This is in parent process\n");  
}
```

fork



Child Process

```
pid = fork ();  
if (pid==0) { //child process  
    execlp (filename, filename, (void*)0);  
    printf ("Error if you see this line\n");  
}  
else { //parent process  
    printf ("This is in parent process\n");  
}
```

identical copy to the parent process

How to create a new process?

(cont'd)

- But different PID results in different execution path

Parent Process

```
pid = fork ();  
if (pid==0) { //child process  
    execlp (filename, filename, (void*)0);  
    printf ("Error if you see this line\n");  
}  
else { //parent process  
→ printf ("This is in parent process\n");  
}
```

Child Process

```
pid = fork ();  
if (pid==0) { //child process  
→ execlp (filename, filename, (void*)0);  
    printf ("Error if you see this line\n");  
}  
else { //parent process  
    printf ("This is in parent process\n");  
}
```

→ Program Counter

How to create a new process?

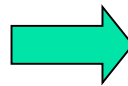
(cont'd)

- The child process executes an *exec()* system call to refill its content

Child Process

```
pid = fork ();  
if (pid==0) { //child process  
    execlp (filename, filename, (void*)0);  
    printf ("Error if you see this line\n");  
}  
else { //parent process  
    printf ("This is in parent process\n");  
}
```

exec



```
main(){  
    printf ("I am the new program\n");  
    return 0;  
}
```



A simple exercise

- What will happen?

```
while (1) {  
    fork ();  
}
```



Next Lecture

- Basic file operations
 - Chap. 3 of [Stevens]
- Remark: History of UNIX skipped (Chap. 2)
 - various versions of UNIX and compatibility issues
 - in simple words: see *man* before you use a function/command/system call



Open Problem

- Does an embedded device (e.g. cell phone) need a protected-mode OS?
- Trend on embedded OS (RTOS) research
 - embedded Linux
 - uCOS
 - TinyOS (UC-Berkeley)