UNIVERSITY of WEST FLORIDA

COP4634: Systems & Networks I

Course Overview

C++, Unix, Compiling, g++, …

Instructor

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See syllabus for office hours

Expectations

- Read the syllabus and review the semester schedule for topics, assignments, and exams.
- Read the weekly book chapter(s) prior to start of the class.
- Come to class and see me during office hours.
- Participate in classroom discussions.
- Submit homework and project assignments on time.

Class Work

- Projects – complete them in teams of two.
  - upload solution to Dropbox
- Individual homework assignments.
- Readings in textbook required for class.
- Exams:
  - Midterm exams: Sept. 28th & Oct. 26th given via quiz
  - Final exam: Thursday, Dec. 7th given via quiz
- Participation in class.

What is an Operating System?

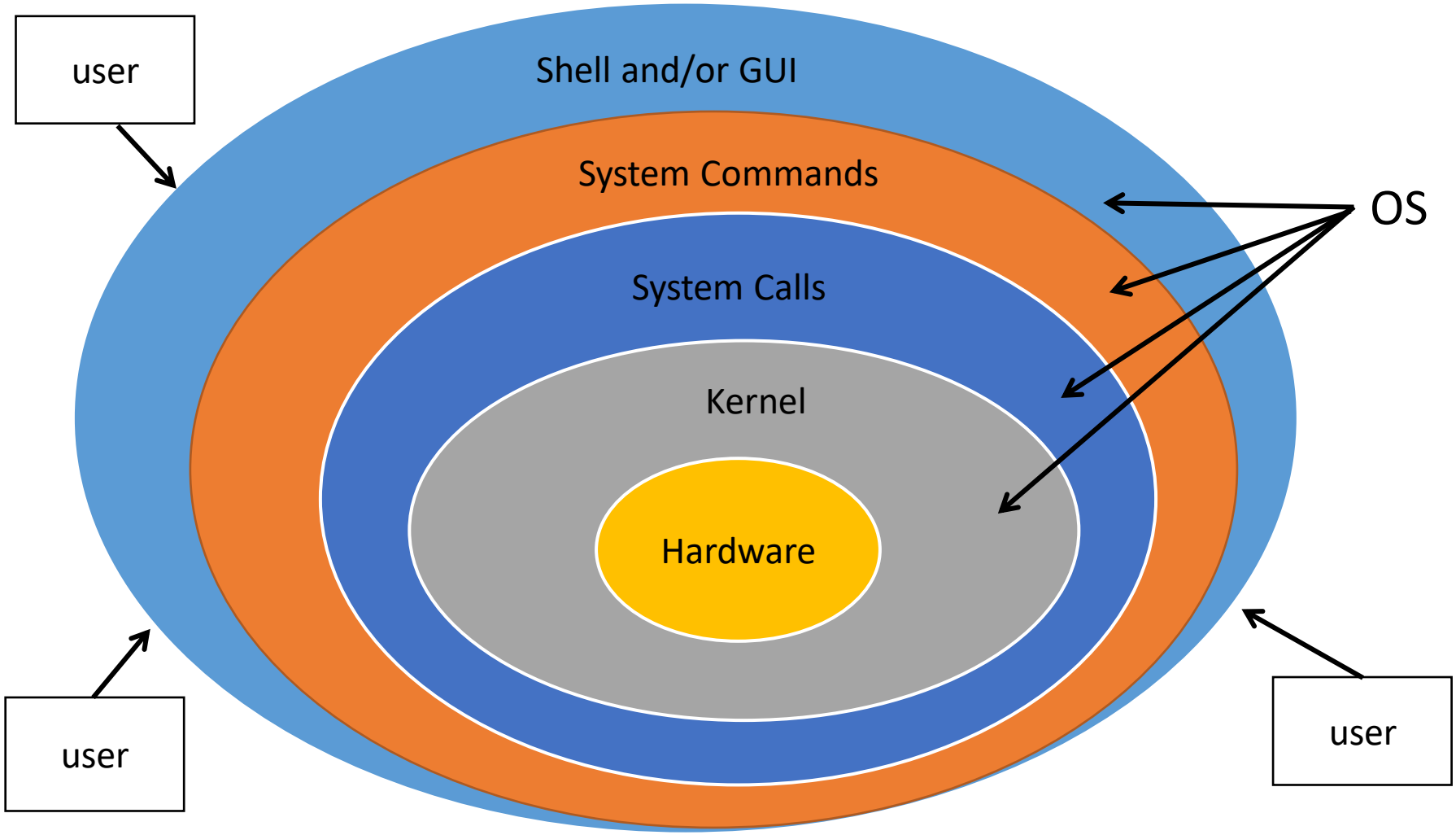
- A software program
  - mediates between hardware resources and user
  - Linux/UNIX Kernel
- A resource allocator.
- A control program.
- Examples: Windows Family, Linux Family, UNIX (Berkeley, ATT Bell Labs)

  (On UNIX see http://www.unix.org/what_is_unix/history_timeline.html)

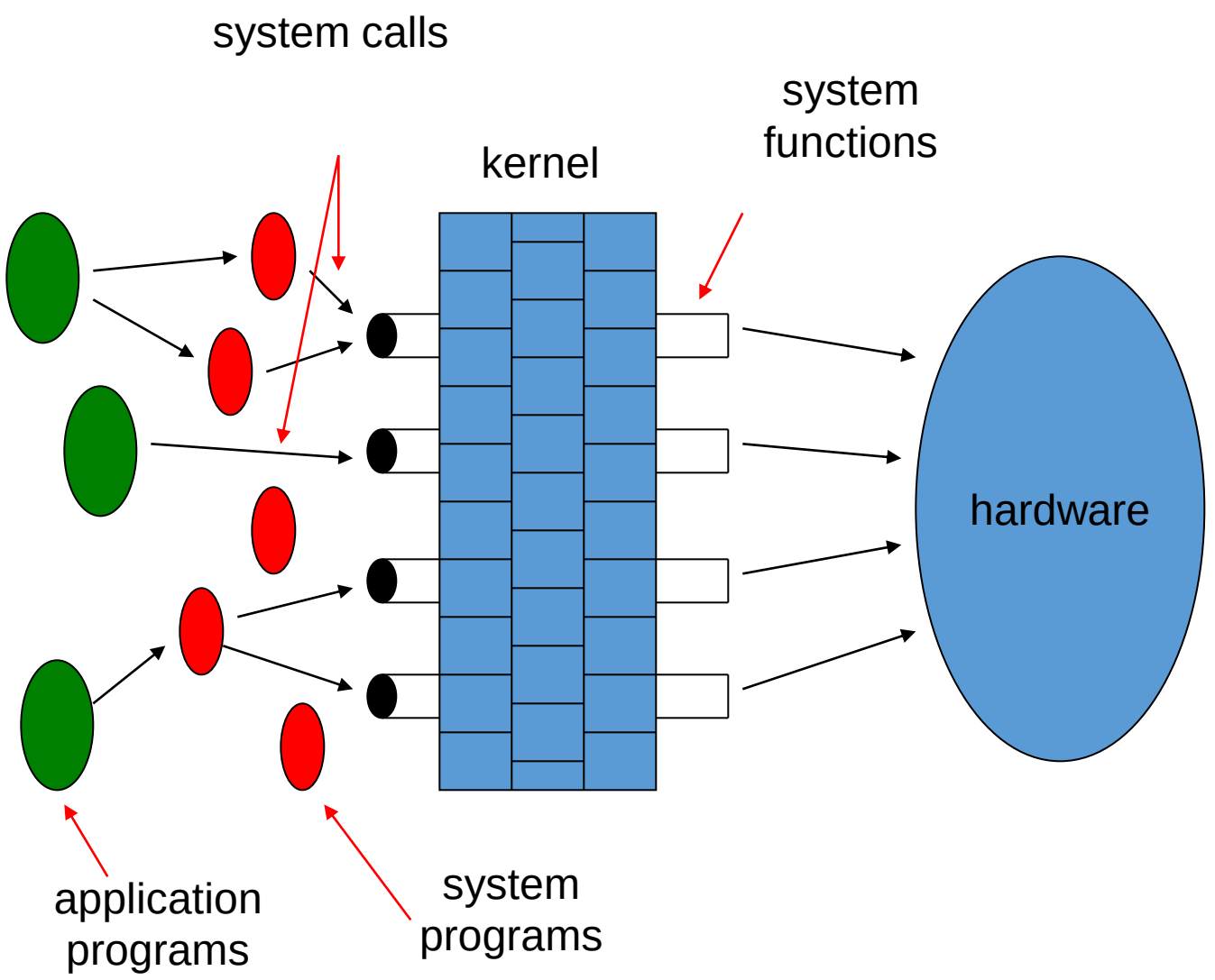
What is the purpose of an OS?

- Facilitates program execution.
- Supports program development.
- Makes computer system easy to use for users.
- Uses computer resources efficiently.

System Layers



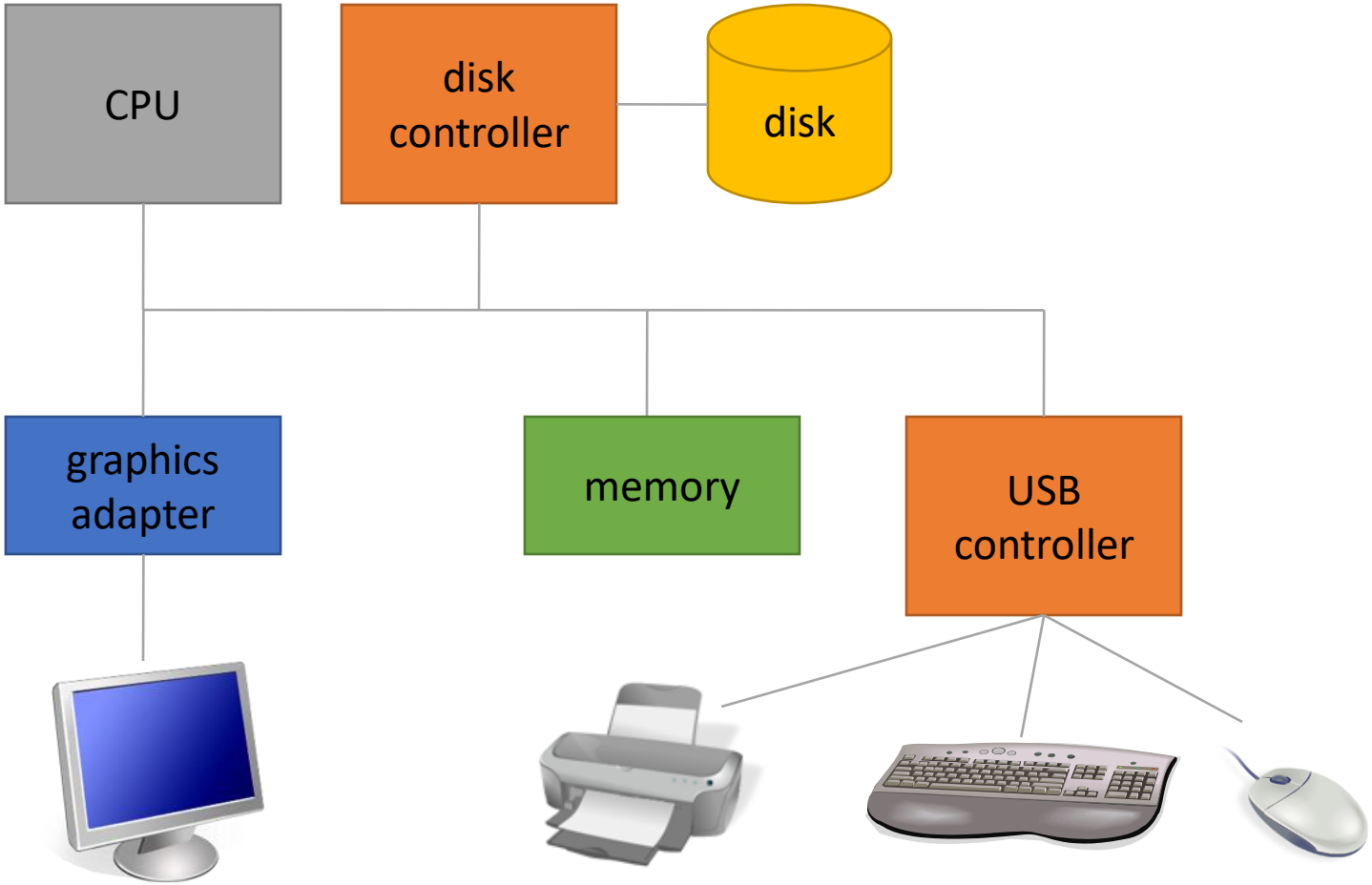
System Layers



Computer System Components

- Hardware:
  - CPU, Memory
- Operating system:
  - device driver
  - interrupt handler
  - scheduler
  - …
- Application programs:
  - use system resources (e.g. libraries)
  - provide interfaces to access system resources

System Architecture



I/O Operation

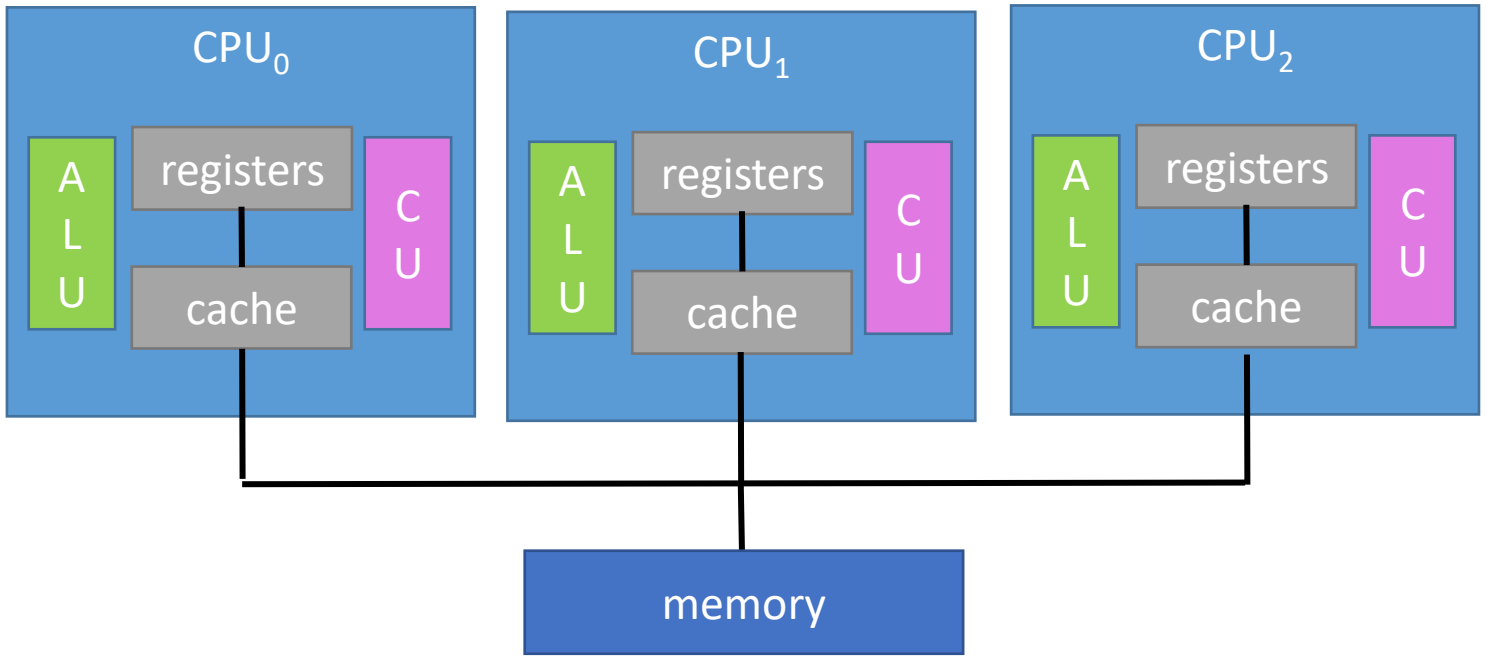
- CPU and I/O devices may operate concurrently.

http://techwiseuk.com/wp-content/uploads/2012/09/CPU.jpg

www.uptechnologysolutions.com

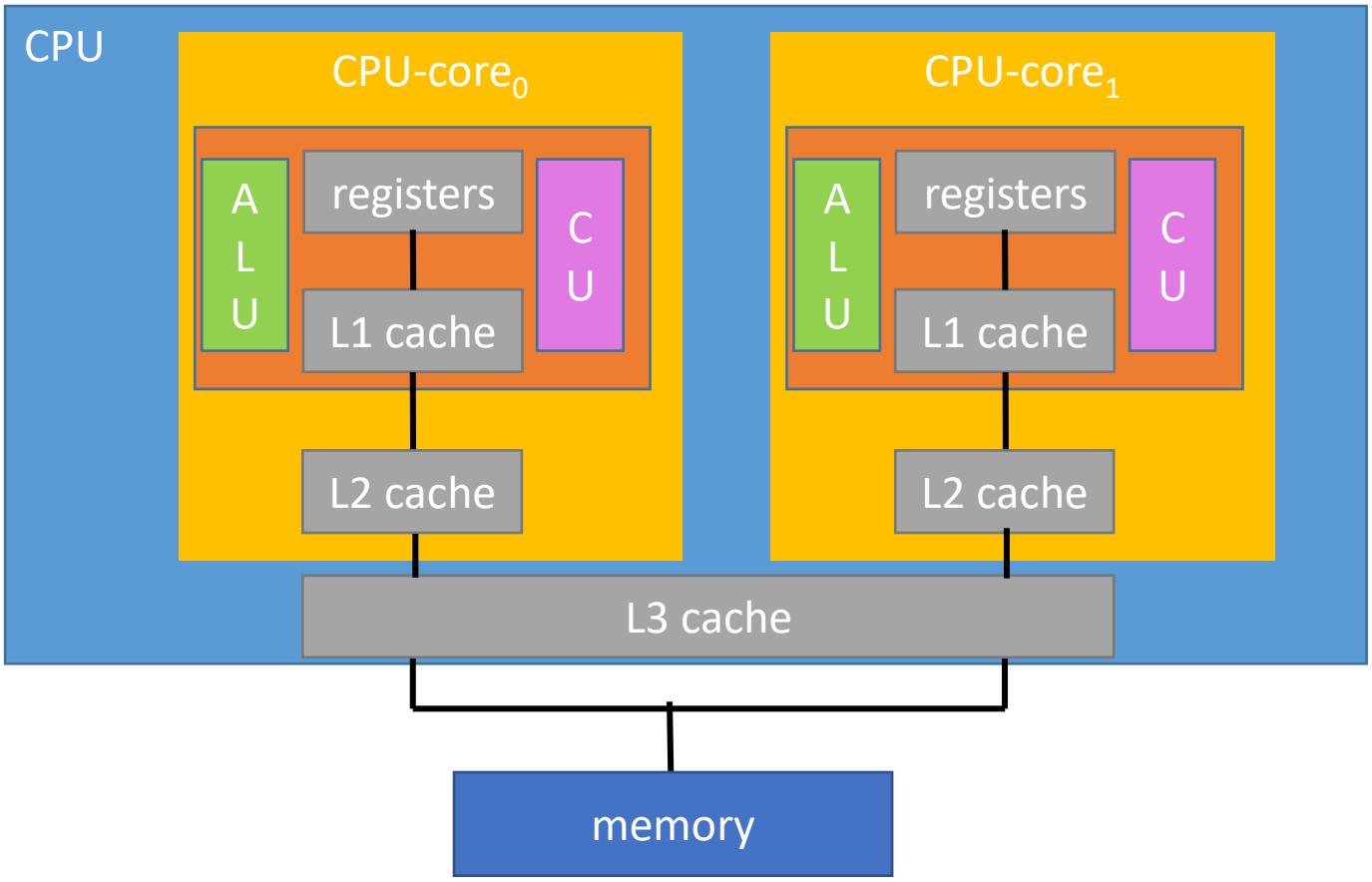
- A device controller operates a device.
  - has local buffer for data exchange
  - uses interrupt to alert CPU
- CPU or DMA perform data exchange.

Multiprocessor System



- Symmetric: all processors execute all functions of the OS
- Asymmetric: master processor controls system, all other processors execute assigned job

Dual-core Processor

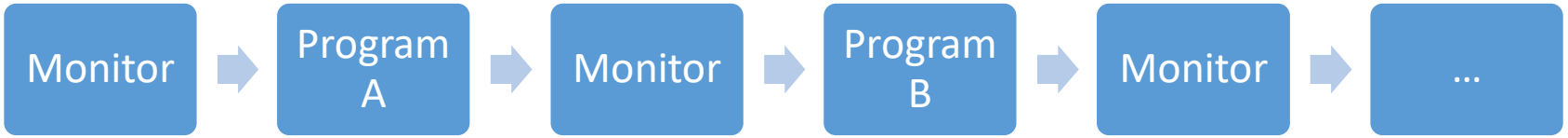


- Cores execute all system functions.
- Cores may share cache.

Early Mainframe Systems

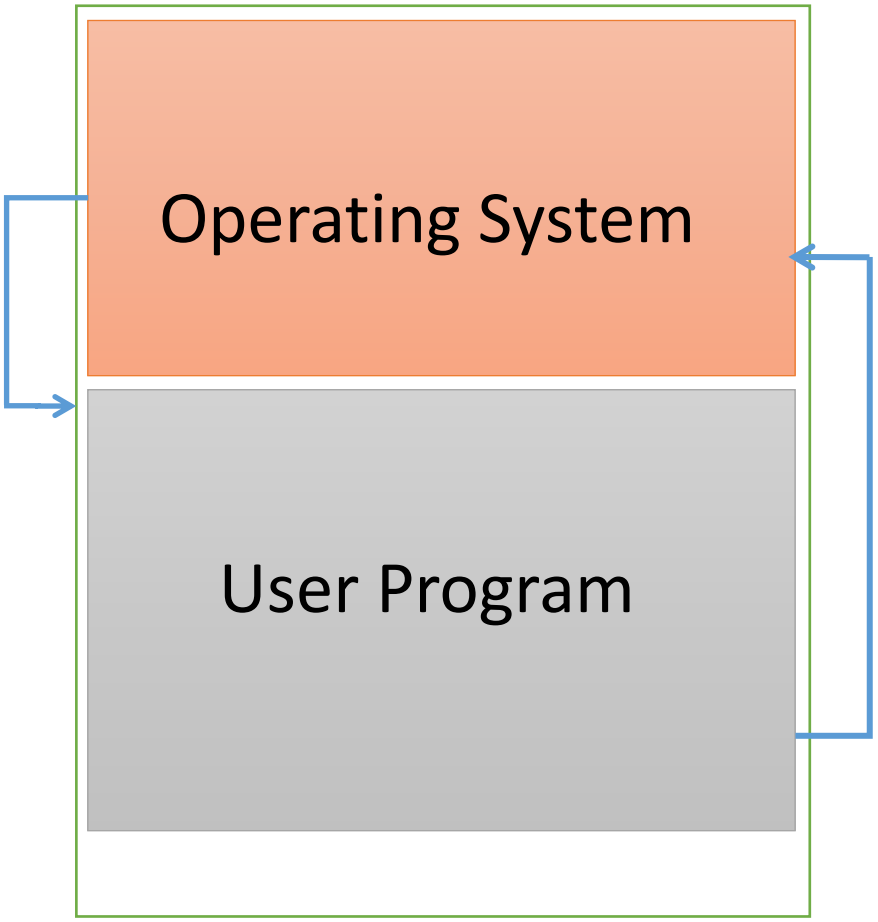
http://blog.softlayer.com/tag/mainframe/

- Executes a single user program, a.k.a. job, at a given time.
- Perform automatic job sequencing (basic scheduler)



Memory Layout Batch System

1. OS loads user program into memory
2. OS starts user program.
3. User program terminates.
4. OS resumes operation.
5. OS loads next user program into memory.
6. …

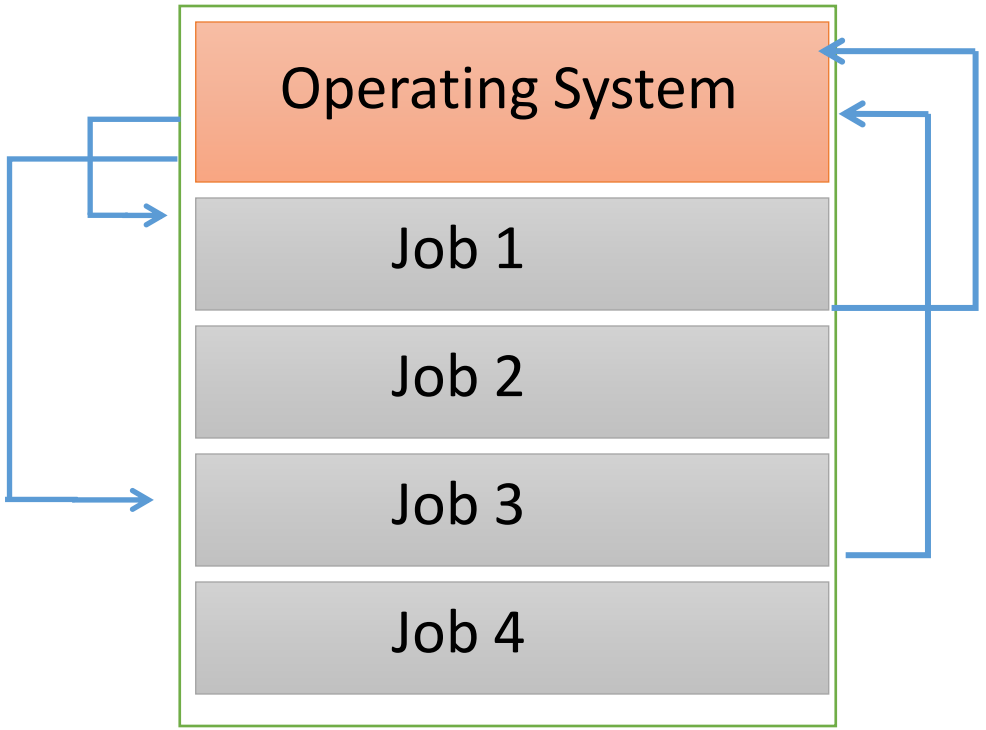


Multiprogrammed Batch System

- Several jobs exist in memory.
- CPU is multiplexed among them.

1. OS selects a job in memory for execution.
2. OS starts user program.
3. User program terminates or performs IO.
4. OS resumes operation.
5. OS selects next job for execution.
6. …

OS loads new jobs into memory

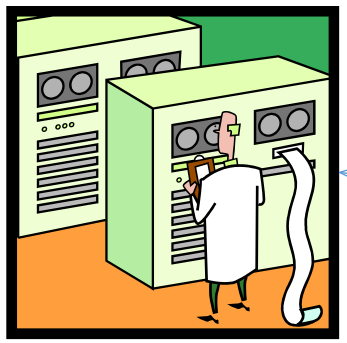


Requirements for Multi-Program Batch System

- I/O routine must be provided by OS.
- System must manage memory
  (discussed in details later)
- CPU scheduling
  (discussed in details later)
- OS must manage I/O devices.

Interactive Time-Sharing System

- CPU is multiplexed among several jobs.
- Jobs may be swapped in and out of memory.
- Interactive communication between user and system.



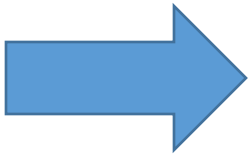
one mainframe

many terminals

http://www.youtube.com/watch?v=Anxxe8SdX78

System Control

- OS assigns CPU to the next job in memory.
  - program uses IO devices during execution
  - program relinquishes CPU at completion or when a program error occurs



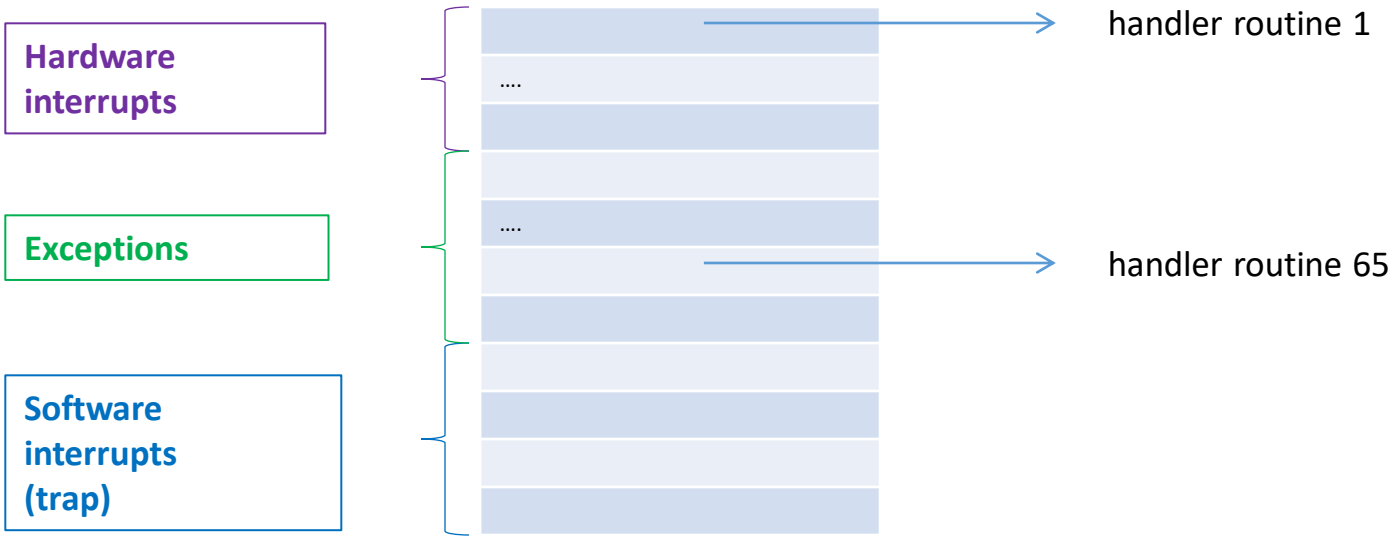
Loss of Control for OS

- What mechanisms exist for the OS to regain control of the CPU?

  Answer: Software and hardware interrupts.

Hardware & Software Interrupts

- Interrupt transfers control to interrupt service routine
  - interrupt vector vs. interrupt service routines

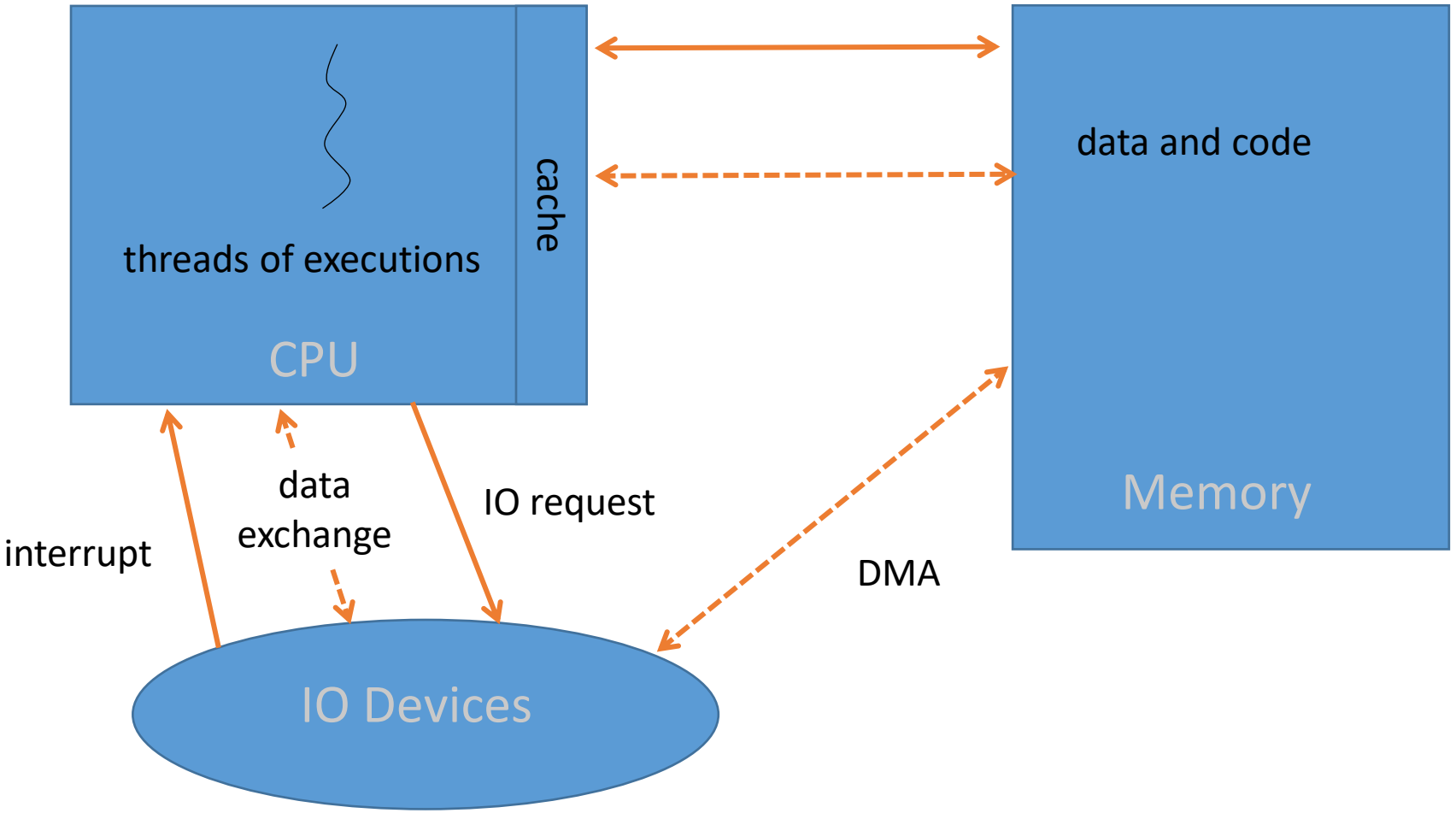


- When interrupt occurs:
  - save address of instruction being interrupted
  - disallow all or most interrupts

Who triggers an interrupt?

- IO device such as
  - keyboard
  - mouse
  - network card
  - …
- Timer when the time slice has expired to return control back to the OS.
- Programs when
  - a system call is executed
  - a run-time error occurs

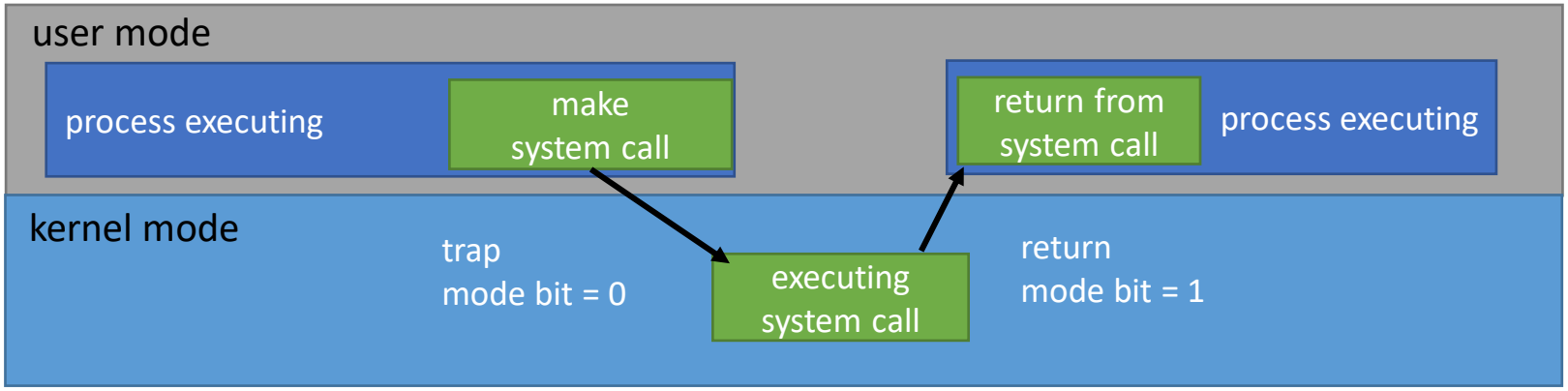
System Operation: The Big Picture



Dual-Mode Protection

- System must ensure that malicious or incorrect code cannot cause other programs to malfunction.

- Hardware provides support for two modes of operation:
  - user mode – execution done on behalf of user
  - kernel mode – execution done on behalf of operating system



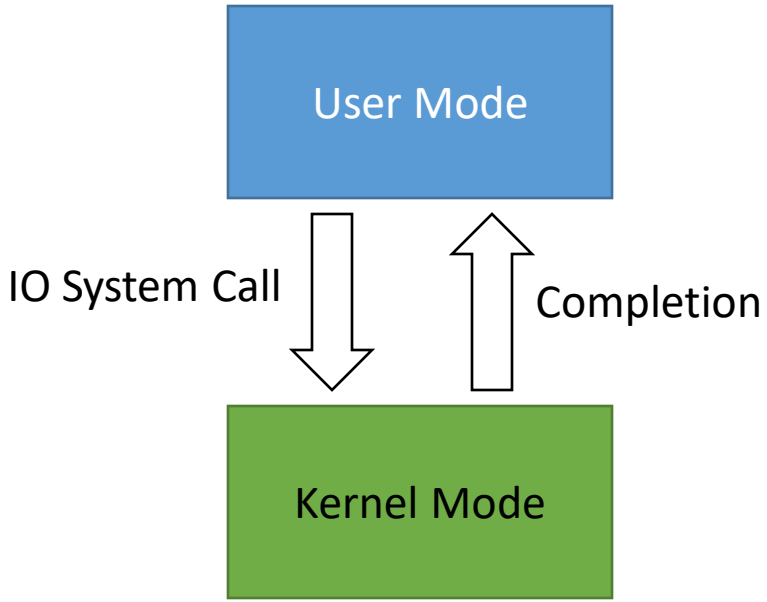
Dual-Mode Protection

- Mode bit indicates operation mode.
  - 0 for kernel mode
  - 1 for user mode
- An interrupt triggers a change of mode.
- OS sets user mode bit to switch back to user mode.

Privileged instructions only execute in kernel mode.

I/O Protection

- All I/O operations are privileged instructions that must be executed in kernel mode.

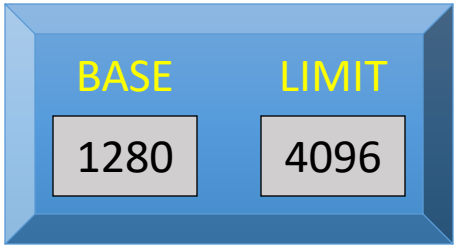


Upon completion, kernel jumps back to user program.

Memory Protection

- When more than one program resides in memory, memory protection is needed.
- Two hardware registers specify range of legal address space for program:

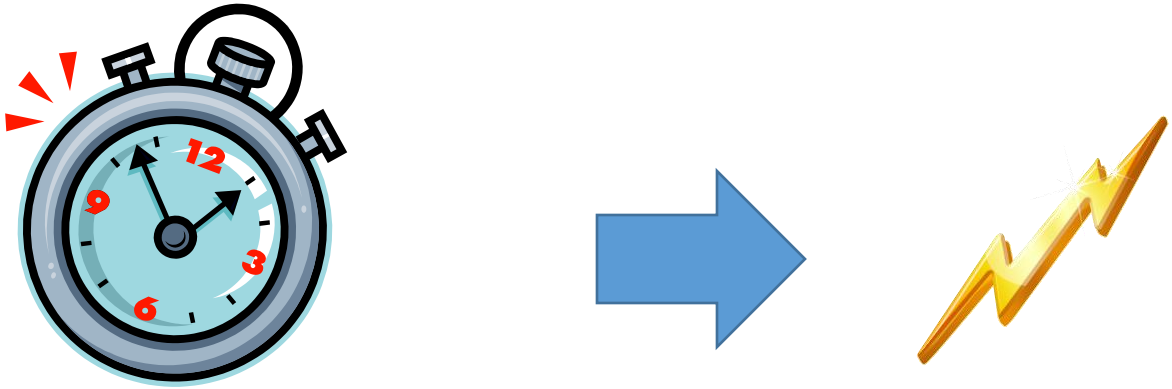
Memory Management Unit (MMU)



- A program that accesses memory outside the legal address space causes an interrupt.

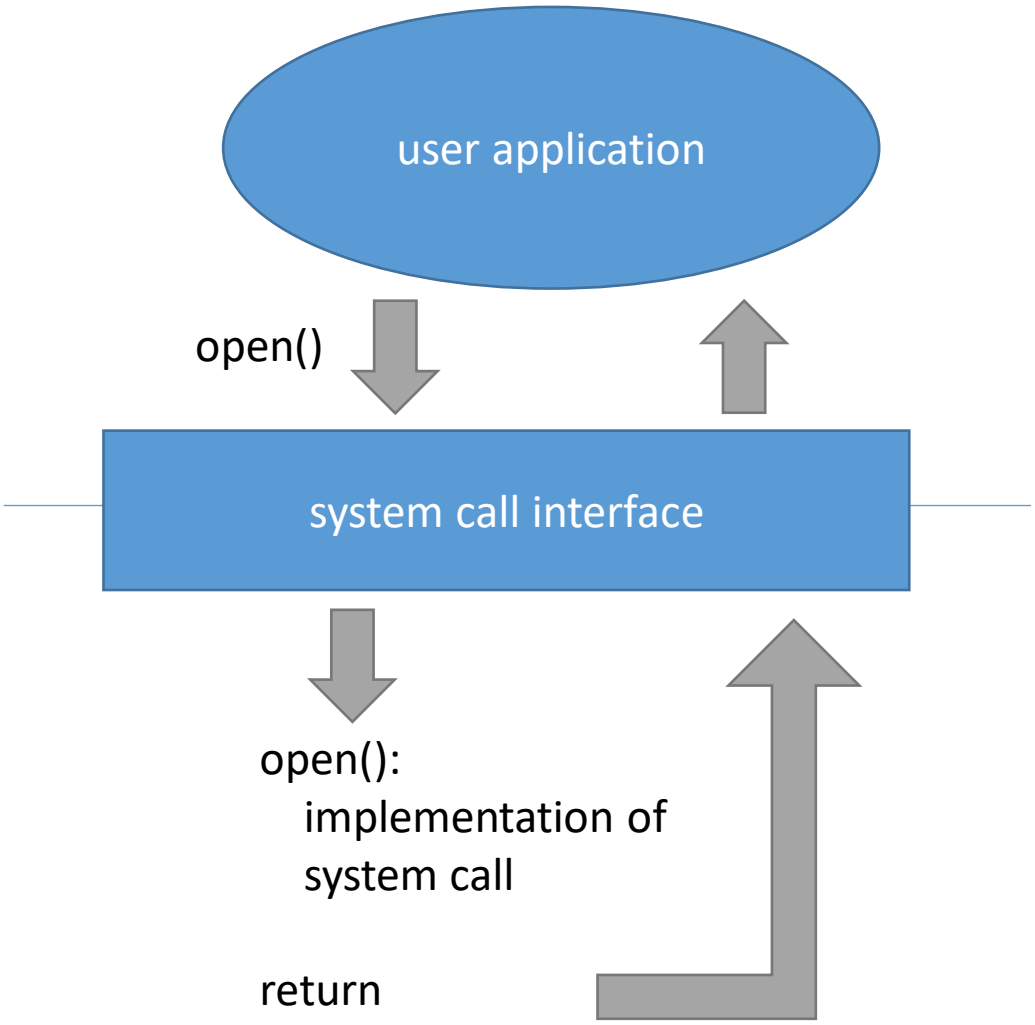
CPU Protection

- CPU must be available to all programs for execution.
- Timer generates interrupt after specified period, to ensure OS regains control.



- Timer is used to implement time-sharing systems.

System Call



Types of System Call

- process control
- file operations
- device operations
- communication
- …

System Call Examples

- exit()
- fork()
- allocate() / free()
- open() / close() / write() / read()

Metric System (Powers of 10)

Nano	10^{-9}	1/1000000000	Billionth	n
Micro	10^{-6}	1/1000000	Millionth	μ (mu)
Milli	10^{-3}	1/1000	Thousandth	m
Kilo	10^{3}	1000	Thousand	k
Mega	10^{6}	1000000	Million	M
Giga	10^{9}	1000000000	Billion	G
Tera	10^{12}	1000000000000	Trillion	T
Peta	10^{15}	1000000000000000	Quadrillion	P

Computer System (Powers of 2)

Kilobyte	10 bits	2^{10}	1024	KB
Megabyte	20 bits	2^{20}	1048576	MB
Gigabyte	30 bits	2^{30}	1073741824	GB
Terabyte	40 bits	2^{40}	1099511627776	TB
Petabyte	50 bits	2^{50}	1125899906842620	PB

External References

- Website for C/C++ programming

  http://www.cprogramming.com

  http://www.stroustrup.com/C++.html

- C++ Programming in UNIX Systems

  https://www.usna.edu/Users/cs/choi/ic210/lab/l01/lab.html

  https://see.stanford.edu/materials/icsppcs107/08-Unix-Development.pdf

- Internet Forums

  StackOverlow

Common Unix Commands

`man`	Display a page of the on-line manual
`ls`	List the contents of a directory
`cd`	Change the current working directory
`pwd`	Display the current working directory
`mkdir`	Make a new directory
`rmdir`	Remove a directory
`rm`	Remove a file or directory
`cp`	Copy a file
`mv`	Move or rename a file or directory

More Unix Commands

`cat`	Display the contents of a file on the screen
`more`	Like cat, but a page at a time
`less`	Like more, but more of it
`grep`	Search for a pattern in files
`ps`	List the status of processes in the system
`uname`	Print system information
`gzip`	Compress (decompress) a file
`tar`	Manipulates files in an archive

Still More Unix Commands

`lpr`	Print a file
`ispell`	Spell check a text file
`cal`	Display a calendar
`diff`	Compare two files and display the differences
`vi`	One of many text-based editors
`emacs`	One of many GUI-based editors
`gcc`	GNU C compiler
`gdb`	GNU debugger

Command-Line

To run a program w/o options

```
> ls
```

To run a program found in the current directory

```
> ./parse
```

Sending output to a file (redirecting output)

```
> ./parse > parse_out.txt
```

Common argument format (`-?`)

```
> ./parse -d > parse_debug.txt
```

Online Manual

`man`

`man -k` *search-word*

`man -s` *section specific-name*

Sections

1 User commands

2 System calls

3 Standard library functions

4 Interface libraries

5 Headers

6 Games and demos

7 Devices

8 Maintenance commands and file formats

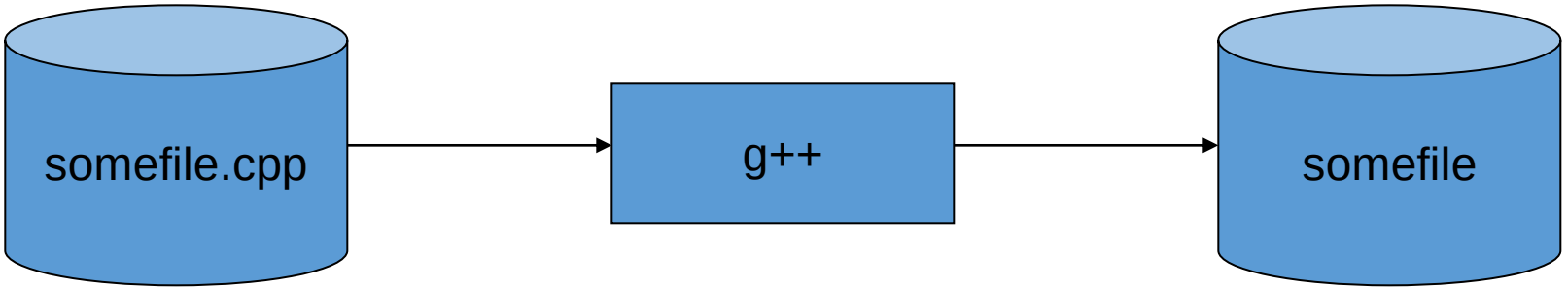
9 Kernel functions for drivers

n Miscellaneous libraries

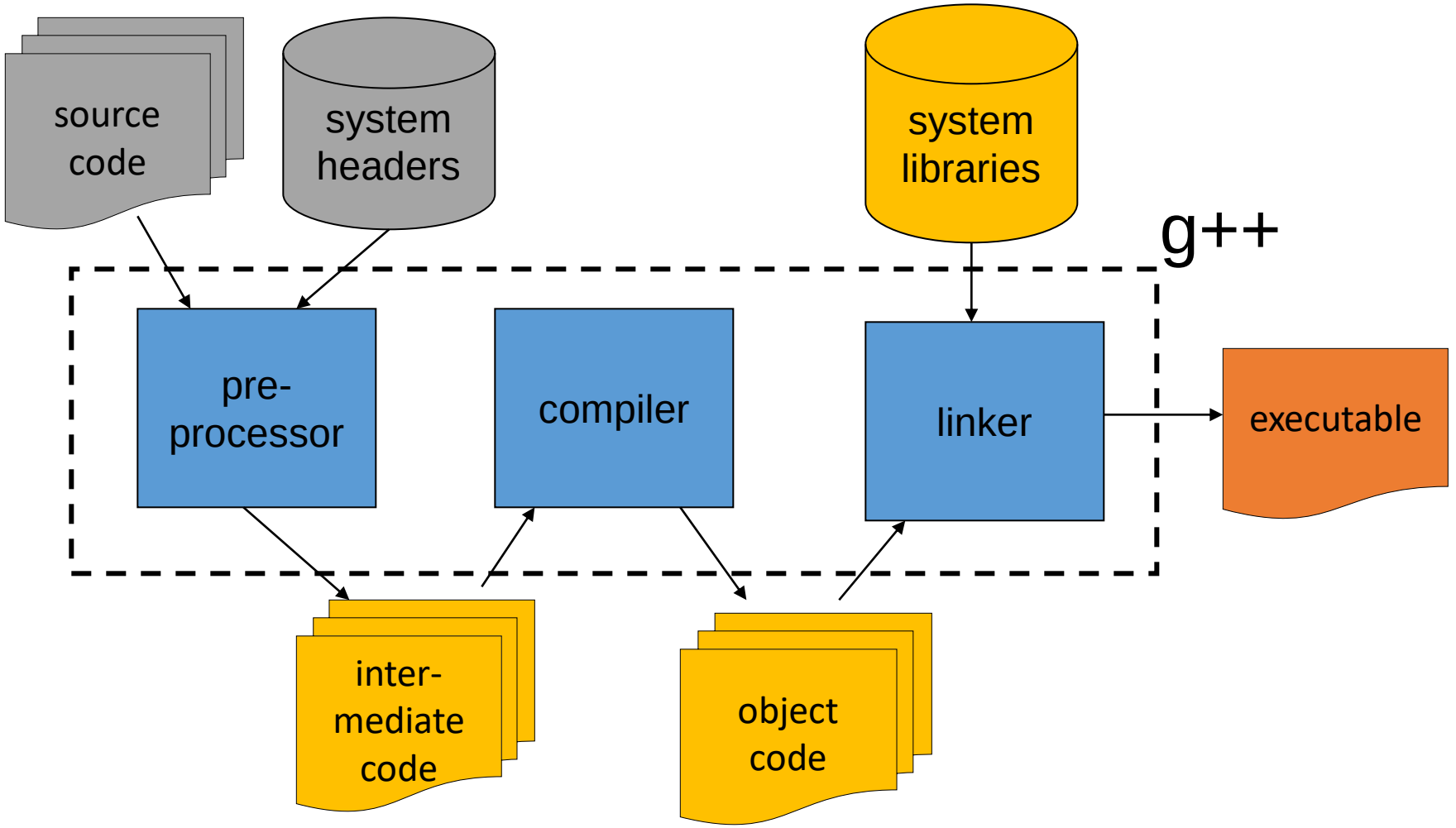
Compilation (simplified)

```
g++ -g -Wall somefile.cpp -o somefile
```

- `g++` — GNU C++ Compiler
- `-g` — produce debugging information
- `-Wall` — enable all warning messages
- *somefile*`.cpp` — source C++ file
- `-o` — send the output to…
- *somefile* — executable output file



Compilation (more details)



Common Sequence

1 Create/edit your program

```
> vim prog1.cpp
```

2 Compile your program into an executable

```
> g++ -g -Wall prog1.cpp -o prog1
```

3 If warnings/errors, go back to step 1

4 Execute program with simple test case

```
> ./prog1
```

5 If errors/output incorrect, go back to step 1

6 Execute program with more complex test case

7 If errors/output incorrect, go to step 1

8 Go to step 6

Command-Line Arguments

```
int main( int argc, char **argv )
```

`argc` – number of arguments on the command-line

`argv` – array of arguments (strings) entered on the command-line (arrays coming soon)

```
> ls -l helloMe.cpp
```

argc == 3

argv[0] == "`ls`"

argv[1] == "`-l`"

argv[2] == "`helloMe.cpp`"

Standard Program Layout

`#include` directives

`#define` directives

Namespace directives

Class definitions

`main()` definition

Makefiles - Introduction

- Automate compile process.
  - why?
  - where?

- System program: *make*
  - a rule interpreter
  - executes instructions to compile and link a program
  - instructions are written in a Makefile

Makefile Rules

- Rules describe dependencies.
  - helps *make* to decide what must be recompiled
- Format of rules:

```
target : prerequisites
        command
…
```

target: a name of a file or program to be built or an action to be carried out.
command: an instruction to be executed.
prerequisites: a list of files on which the target depends.

Makefiles Examples

1. Compiles a program consisting of a single source code file (*hello.c*) and no header files.

```
hello : hello.cpp
	g++ -o hello hello.cpp
```

2. Compiles a program consisting of two source code files (*hello.cpp*) and a header file (*sort.hpp*).

```
test : test.o sort.o
	g++ -o test test.o sort.o

test.o : test.cpp sort.hpp
	g++ -c test.cpp
sort.o : sort.cpp sort.hpp
	g++ -c sort.cpp

clean :
	rm test test.o sort.o
```

Makefiles Examples (cont.)

3. The previous Makefile with variables to reference all object files.

```
objects = test.o sort.o

test : $(objects)
	g++ -o test $(objects)

test.o : test.cpp sort.hpp
	g++ -c test.cpp
sort.o : sort.cpp sort.hpp
	g++ -c sort.cpp

clean :
	rm test $(objects)
```

Makefiles Examples (cont.)

3. Letting make deduce the commands using an implicit rule for updating .o files.

```
objects = test.o sort.o

test : $(objects)
	g++ -o test $(objects)

test.o : test.cpp sort.hpp
sort.o : sort.cpp sort.hpp

.PHONY : clean
clean :
	rm test $(objects)
```

Key take-away

- First-generation operating systems on mainframes consist of a simple monitor program.
- System calls provide access to the kernel's services.
- Hardware and software interrupts transfer control to service routines in the kernel.
- Modern OS offers two mode operation.
- Supported by hardware, the OS provides various protection mechanisms for user programs to run.