OPERATING SYSTEMS

IPC - Shared Memory & Message Passing

Suresh Jamadagni
Department of Computer Science

OPERATING SYSTEMS

Slides Credits for all the PPTs of this course

- The slides/diagrams in this course are an **adaptation**, **combination**, and **enhancement** of material from the following resources and persons:

1. Slides of Operating System Concepts, Abraham Silberschatz, Peter Baer Galvin, Greg Gagne - 9th edition 2013 and some slides from 10th edition 2018
2. Some conceptual text and diagram from Operating Systems - Internals and Design Principles, William Stallings, 9th edition 2018
3. Some presentation transcripts from A. Frank – P. Weisberg
4. Some conceptual text from Operating Systems: Three Easy Pieces, Remzi Arpaci-Dusseau, Andrea Arpaci Dusseau

OPERATING SYSTEMS

IPC - Shared Memory and Message Passing

Suresh Jamadagni
Department of Computer Science

Interprocess Communication

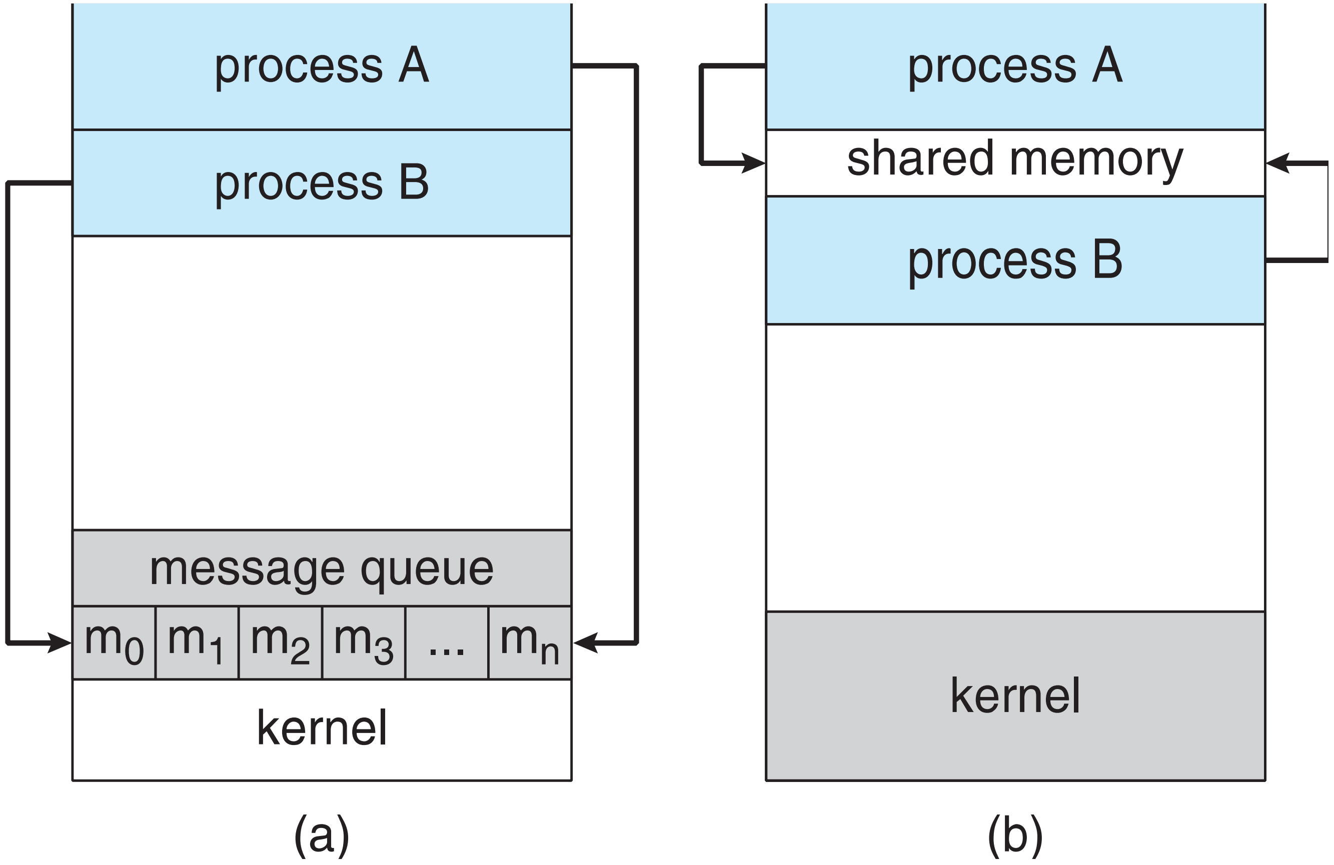
- Processes within a system may be ***independent*** or ***cooperating***
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **interprocess communication** (**IPC**)
- Two models of IPC
  - **Shared memory**
  - **Message passing**

Cooperating Processes

- ***Independent*** process cannot affect or be affected by the execution of another process
- ***Cooperating*** process can affect or be affected by the execution of another process
- Advantages of process cooperation
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

Communication Models

- Two models of IPC
  - a) **Message passing**
  - b) **Shared memory**



- Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process
  - **unbounded-buffer** places no practical limit on the size of the buffer
    - Consumer may have to wait for new items, but the producer can always produce new items
  - **bounded-buffer** assumes that there is a fixed buffer size
    - Consumer must wait if the buffer is empty; producer must wait if the buffer is full

Bounded-Buffer – Producer Consumer

- Shared data

```
#define BUFFER_SIZE 10
typedef struct {
    . . .
} item;

item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```

- Shared buffer is implemented as a circular array with 2 logical pointers: **in** and **out**
- Buffer is empty when **in == out;** buffer is full when ((**in** + 1) % BUFFER_SIZE) == **out**
- Variable **in** points to the next free position in the buffer; **out** points to the first full position in the buffer
- Solution is correct, but can only use BUFFER_SIZE-1 elements

Bounded-Buffer – Producer

```
item next_produced;
while (true) {
        /* produce an item in next_produced */
        while (((in + 1) % BUFFER_SIZE) == out)
                ; /* do nothing */
        buffer[in] = next_produced;
        in = (in + 1) % BUFFER_SIZE;
}
```

Bounded-Buffer – Consumer

```
item next_consumed;

while (true) {
        while (in == out)

                ; /* do nothing */
        next_consumed = buffer[out];

        out = (out + 1) % BUFFER_SIZE;


        /* consume the item in next_consumed */

}
```

Interprocess Communication – Shared Memory

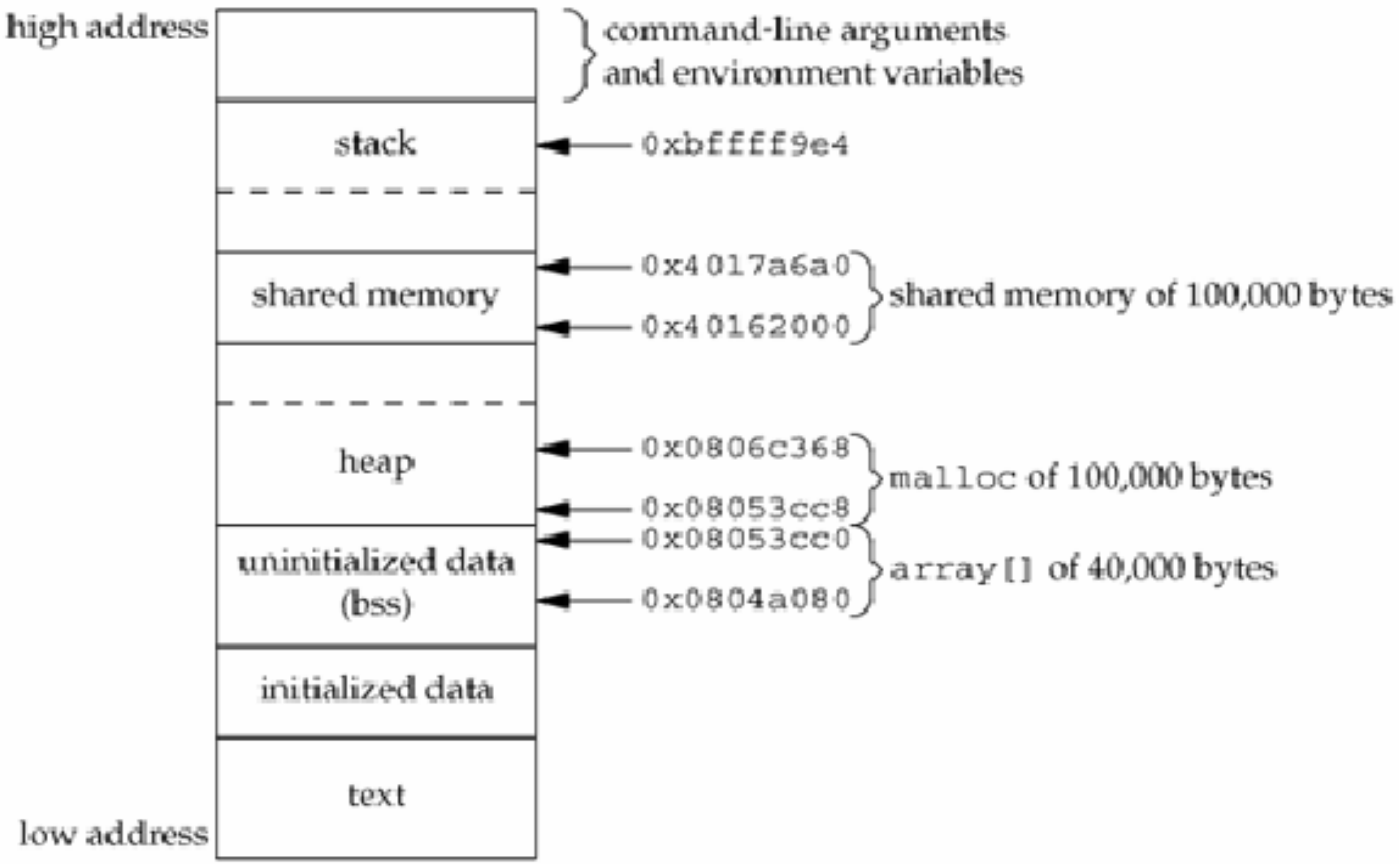
- An area of memory shared among the processes that wish to communicate
- The communication is under the control of the users processes not the operating system.
- Major issues is to provide mechanism that will allow the user processes to synchronize their actions when they access shared memory.

Shared Memory (Cont.)

- Shared memory allows two or more processes to share a given region of memory.
- Shared memory is the fastest form of IPC, because the data does not need to be copied between the client and the server.
- The only trick in using shared memory is synchronizing access to a given region among multiple processes.
- If the server is placing data into a shared memory region, the client shouldn't try to access the data until the server is done.
- Often, semaphores are used to synchronize shared memory access. (record locking can also be used.)

Shared Memory (Cont.)

Memory layout on an Intel-based Linux system



Interprocess Communication – Message Passing

- 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*)
  - **receive**(*message*)
- The *message* size is either fixed or variable

Message Passing (Cont.)

- If processes *P* and *Q* wish to communicate, they need to:
  - Establish a ***communication link*** between them
  - Exchange messages via send/receive
- Implementation issues:
  - 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?

Message Passing (Cont.)

- Implementation of communication link
  - Physical:
    - Shared memory
    - Hardware bus
    - Network
  - Logical:
    - Direct or indirect
    - Synchronous or asynchronous
    - Automatic or explicit buffering

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 (Cont.)

- Operations
  - create a new mailbox (port)
  - 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 (Cont.)

- 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.

Message Passing - Synchronization

- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** -- the sender is blocked until the message is received
  - **Blocking receive** -- the receiver is blocked until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking send** -- the sender sends the message and continue
  - **Non-blocking receive** -- the receiver receives:
    - A valid message, or
    - Null message
- Different combinations possible
  - If both send and receive are blocking, we have a **rendezvous** between the sender and the receiver

Message Passing - Synchronization (Cont.)

- Producer-consumer becomes trivial

```
message next_produced;
while (true) {
   /* produce an item in next_produced */
send(next_produced);
}
```

```
message next_consumed;
while (true) {
  receive(next_consumed);

  /* consume the item in next_consumed */
}
```

Buffering

- Queue of messages attached to the link (direct or indirect); messages reside in a temporary queue.
- Queues can be implemented in one of three ways
  1. Zero capacity – no messages are queued on a link.
     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
- Zero-capacity case is sometimes referred to as a message system with no buffering; other cases are referred to as systems with automatic buffering

THANK YOU

Suresh Jamadagni
Department of Computer Science Engineering

sureshjamadagni@pes.edu