

CS420: Operating Systems

Interprocess Communication

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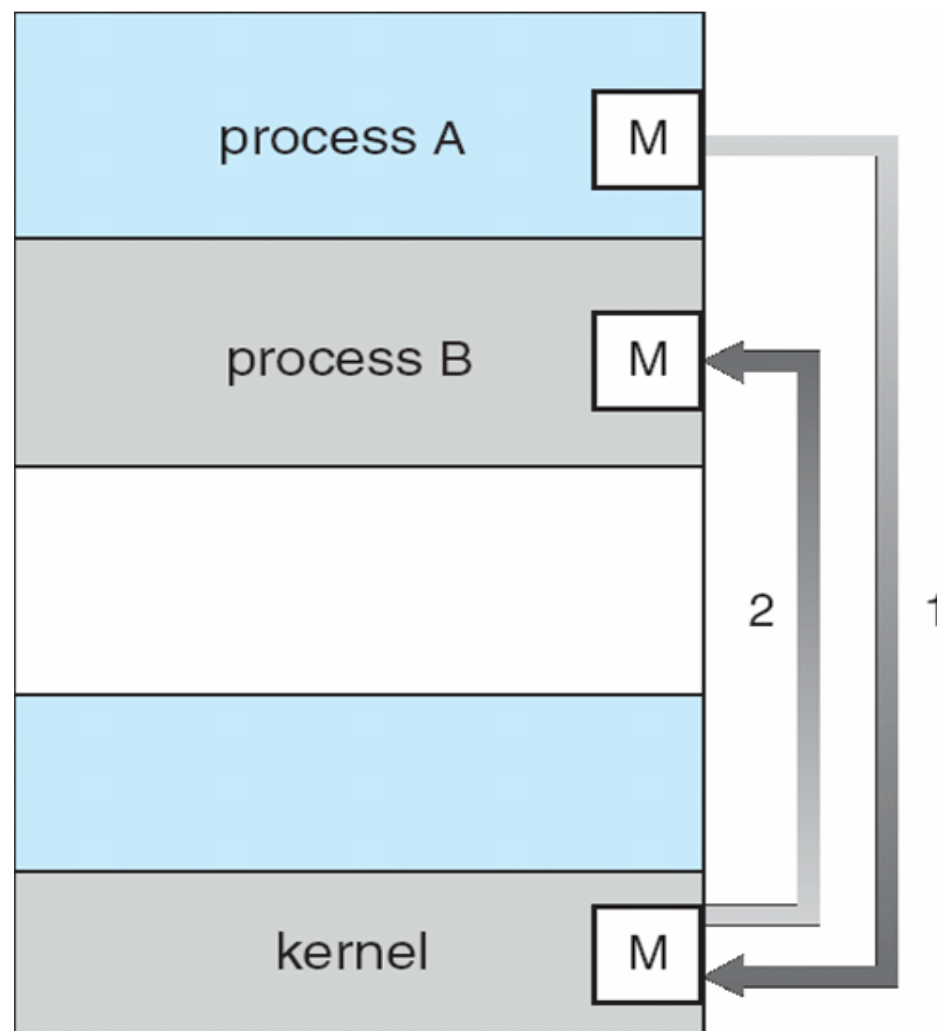
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Interprocess Communication

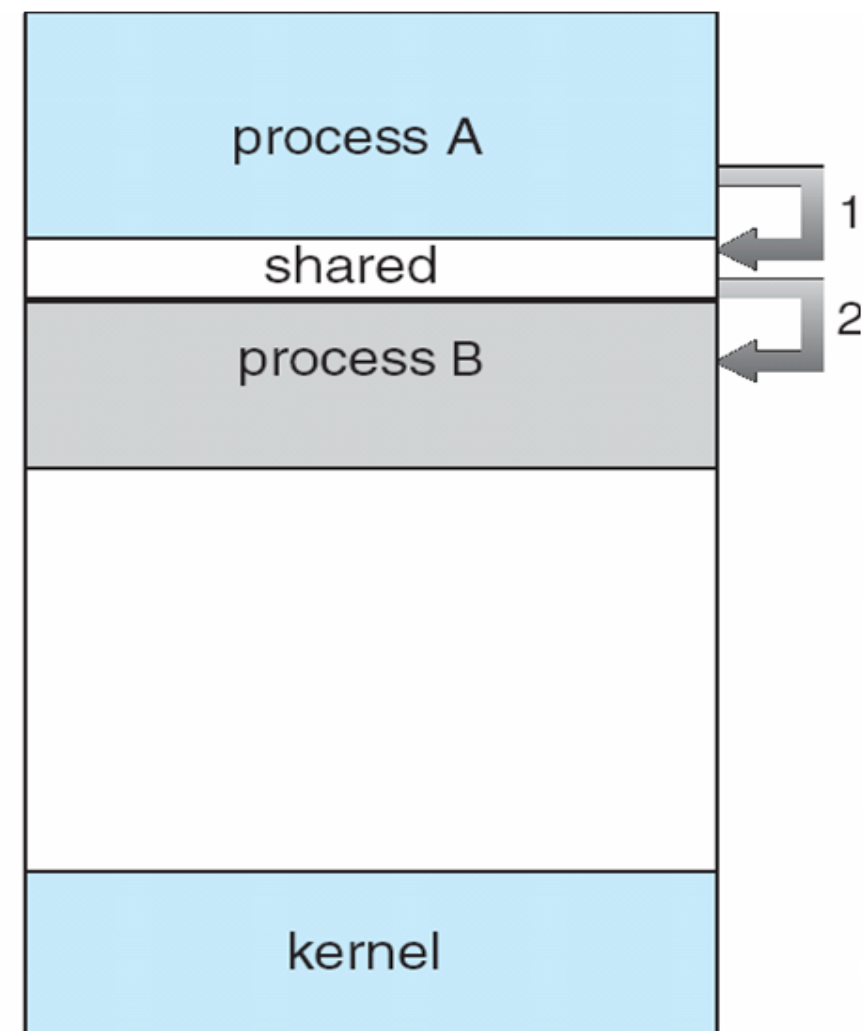
- **Processes within a system may be independent or cooperating**
- **Cooperating processes can affect or be affected by other processes, including sharing data**
- **Reasons for cooperating processes:**
 - Information sharing
 - Computation speedup
 - Modularity
 - Convenience
- **Cooperating processes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

Communication Models



(a)

Message passing



(b)

Shared Memory

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

Producer-Consumer Problem

- **Producer-consumer problem is a common paradigm for cooperating processes**
- ***Producer* process produces information that is consumed by a *consumer* process**
 - One solution is to use shared memory for the two processes to communicate
 - Useful to have a buffer that can be filled by the producer and emptied by the consumer if they are to run concurrently
 - **Unbounded-buffer** places no practical limit on the size of the buffer
 - **Bounded-buffer** assumes that there is a fixed buffer size

Bounded-Buffer – Shared-Memory Approach

- **The following information is in shared memory and is available to both the producer and the consumer**

```
#define BUFFER_SIZE 10

typedef struct {
    /* info to be passed */
} item;

item buffer[BUFFER_SIZE]; /* circular buffer */
int in = 0; /* updated by producer */
int out = 0; /* updated by consumer */
```

- **This implementation can only use $\text{BUFFER_SIZE}-1$ elements**

Bounded-Buffer – Producer

```
while (true) {  
    /* Produce an item */  
  
    while ( ((in + 1) % BUFFER_SIZE) == out)  
        ; /* do nothing -- no free buffers */  
  
    buffer[in] = item; /* buffer not full, add item */  
  
    in = (in + 1) % BUFFER_SIZE;  
  
}
```

Bounded Buffer – Consumer

```
while (true) {  
    while (in == out)  
        ; /* do nothing -- nothing to consume */  
  
    // remove an item from the buffer  
  
    item = buffer[out];  
  
    out = (out + 1) % BUFFER_SIZE;  
  
    /* consume/process item retrieved from buffer */  
  
}
```


Interprocess Communication – Message Passing

- **Message passing** – 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 two processes want to communicate, they need to:**
 - Establish a **communication link** between them
 - Exchange messages via send/receive

Interprocess Communication – Message Passing

- **Communication link can be implemented in variety of ways (including shared memory)**
- **There are several choices when implementing the communication link**
 - **Direct** or **indirect** communication
 - **Synchronous** or **asynchronous** communication
 - **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 direct communication link**
 - Links are established automatically between the two processes
 - 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 indirect communication link**
 - Link established only if processes share a common mailbox
 - A link may be associated with more than two 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
- 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 - consider the following ...**

- P_1 , P_2 , and P_3 share mailbox A
- P_1 sends; P_2 and P_3 receive
- Who gets the message?

- **Possible solutions to avoid unpredictable behavior**

- 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 arbitrarily select 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

- **Regardless of how messages are exchanged between processes, messages are queued**
- **Queueing can be implemented in one of three ways**
 - (1) **Zero capacity** – queue has maximum length of 0
Sender must wait (or block) until the receiver gets the message
 - (2) **Bounded capacity** – queue has finite length of n messages
Sender must wait if link full
 - (3) **Unbounded capacity** – queue has ‘infinite’ length
Sender never waits

Examples of IPC Systems - POSIX

- **POSIX Shared Memory**

- Process first creates shared memory segment

```
segment_id = shmget(IPC_PRIVATE, size, S_IRUSR | S_IWUSR);
```

- Any process wanting access to that shared memory must attach to it

```
shared_memory = (char *) shmat(segment_id, NULL, 0);
```

- Now the process could write to the shared memory

```
sprintf(shared_memory, "Writing to shared memory");
```

- When done a process can detach the shared memory from its address space

```
shmdt(shared_memory);
```

- When the shared memory space is no longer needed, free it

```
shmctl(segment_id, IPC_RMID, NULL);
```

Examples of IPC Systems - Mach

- **Mach communication is message based**
 - Even system calls are messages
 - Each task gets two mailboxes at creation - *Kernel* and *Notify*
 - *Kernel* mailbox is used by the kernel to communicate with the process
 - *Notify* mailbox is used by the kernel to send notifications of events to the process
 - Only three system calls needed for message transfer
`msg_send()`, `msg_receive()`, `msg_rpc()`
 - Mailboxes needed for communication, created via:
`port_allocate()`