CS420: Operating Systems

Interprocess Communication

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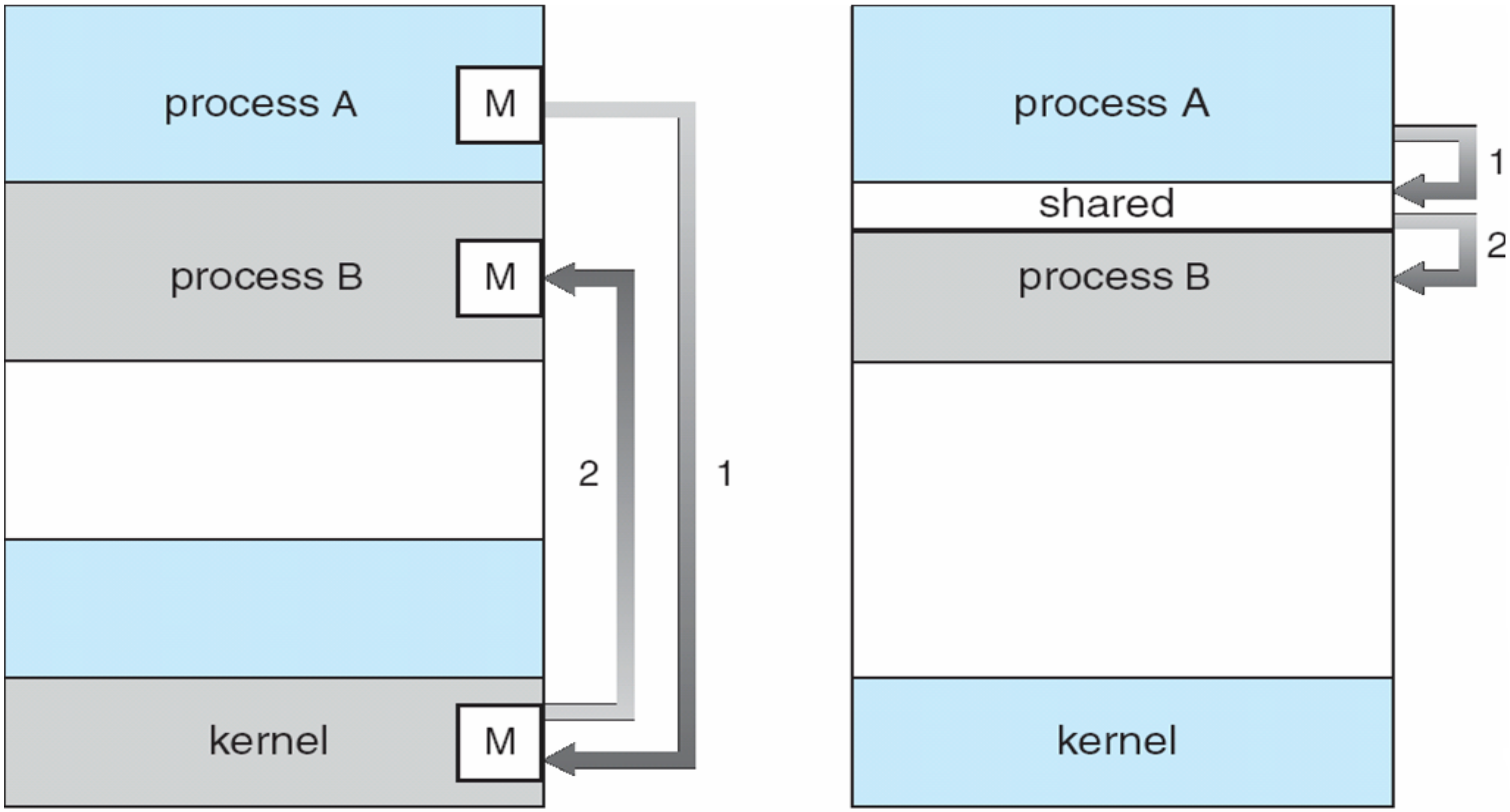
Interprocess Communication

- **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)

(b)

Message passing

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;
int out = 0;
```

- **This implementation can only use `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;
    return item;
}
```

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( )`