

# Inter Process Communication (IPC)



# Why IPC

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- 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

# Producer-Consumer Problem

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- 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
  - **bounded-buffer** assumes that there is a fixed buffer size

# Bounded-Buffer – Shared-Memory Solution

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- Shared data

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

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

- Solution is correct, but can only use BUFFER\_SIZE-1 elements

# Bounded-Buffer – Producer

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```
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

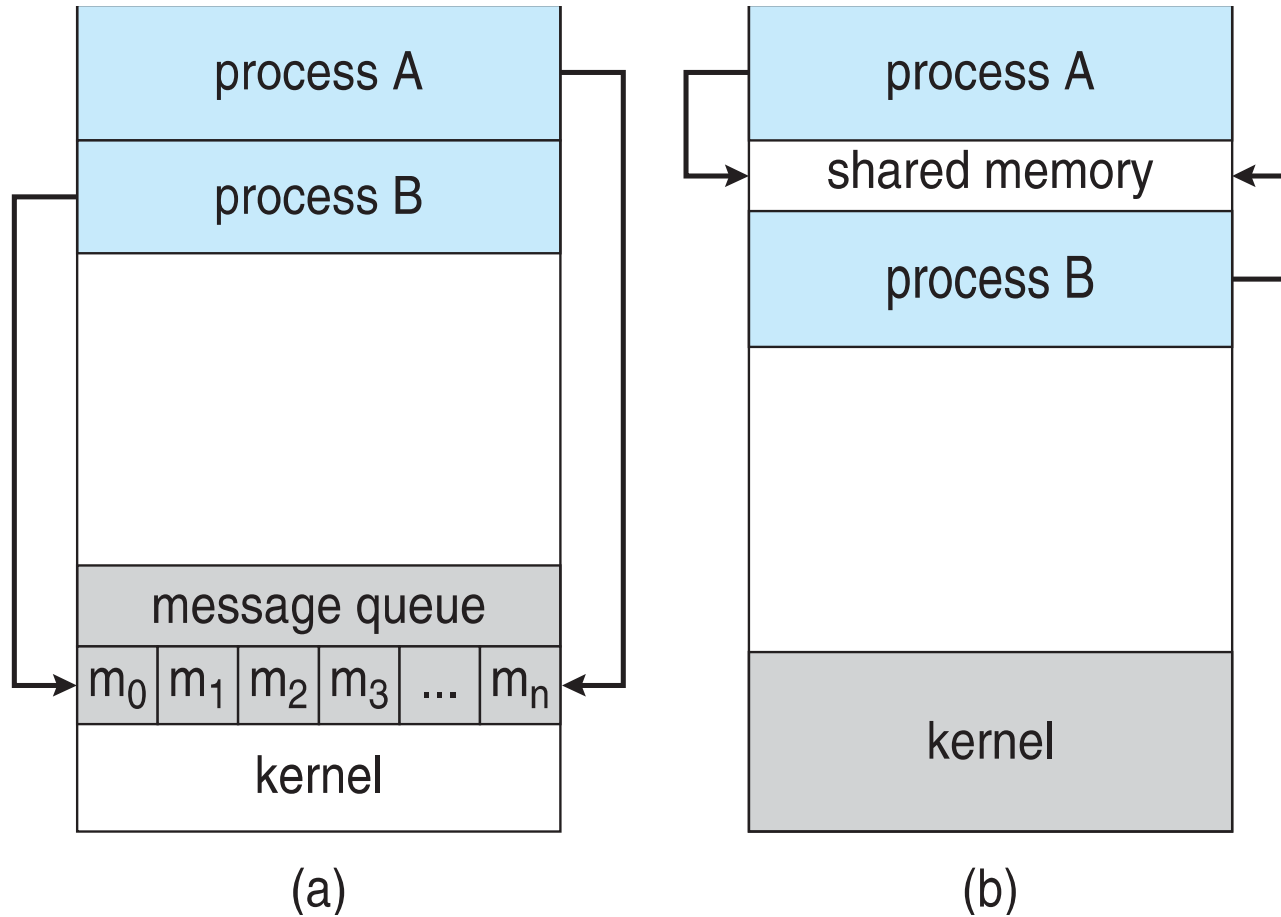
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```
item next_consumed;
while (true) {
    while (in == out)
        ; /* do nothing */
    next_consumed = buffer[out];
    out = (out + 1) % BUFFER_SIZE;

    /* consume the item in next consumed */
}
```

# Communications Models

(a) Message passing. (b) shared memory.



## Interprocess Communication – Shared Memory

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- 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.
- Synchronization is discussed in great details in Chapter 6.



# Interprocess Communication – Message Passing

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- 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.)

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- 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?

### ■ Implementation of communication link

- Physical:

- ▶ Shared memory
- ▶ Hardware bus
- ▶ Network

- Logical:

- ▶ Direct or indirect
- ▶ Synchronous or asynchronous
- ▶ Automatic or explicit buffering

# Direct Communication

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- 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

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- 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

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## ■ 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

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## ■ 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.

# Mailbox owner ship

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## ■ Process owned mailbox

- Destroyed when process is destroyed
- Creator is the owner, but can be changed

## ■ OS owned mailbox

- Exists independently of the process
- OS must provide mechanism of
  - ▶ Creation
  - ▶ Send and receive
  - ▶ Destruction



# Synchronization

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- 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**

# Synchronization (Cont.)

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## ■ 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

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- Queue of messages attached to the link.
- 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

# Examples of IPC Systems - POSIX

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## ■ POSIX Shared Memory

- Process first creates shared memory segment  
`shm_id = shmget(IPC_PRIVATE, size, S_IRUSR | S_IWUSR);`
- Also used to open an existing segment to share it
- Set the size of the object

`ftruncate(shm_id, 4096);`

- Process who wants to use  
`shared_memory = shmat(shm_id, NULL, 0);`
- Now the process could write to the shared memory  
`sprintf(shared_memory, "Writing to shared memory");`

# IPC POSIX Producer

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```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <sys/shm.h>
#include <sys/stat.h>

int main()
{
    /* the size (in bytes) of shared memory object */
    const int SIZE = 4096;
    /* name of the shared memory object */
    const char *name = "OS";
    /* strings written to shared memory */
    const char *message_0 = "Hello";
    const char *message_1 = "World!";

    /* shared memory file descriptor */
    int shm_fd;
    /* pointer to shared memory object */
    void *ptr;

    /* create the shared memory object */
    shm_fd = shm_open(name, O_CREAT | O_RDWR, 0666);

    /* configure the size of the shared memory object */
    ftruncate(shm_fd, SIZE);

    /* memory map the shared memory object */
    ptr = mmap(0, SIZE, PROT_WRITE, MAP_SHARED, shm_fd, 0);

    /* write to the shared memory object */
    sprintf(ptr,"%s",message_0);
    ptr += strlen(message_0);
    sprintf(ptr,"%s",message_1);
    ptr += strlen(message_1);

    return 0;
}
```

# IPC POSIX Consumer

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```
#include <stdio.h>
#include <stdlib.h>
#include <fcntl.h>
#include <sys/shm.h>
#include <sys/stat.h>

int main()
{
    /* the size (in bytes) of shared memory object */
    const int SIZE = 4096;
    /* name of the shared memory object */
    const char *name = "OS";
    /* shared memory file descriptor */
    int shm_fd;
    /* pointer to shared memory object */
    void *ptr;

    /* open the shared memory object */
    shm_fd = shm_open(name, O_RDONLY, 0666);

    /* memory map the shared memory object */
    ptr = mmap(0, SIZE, PROT_READ, MAP_SHARED, shm_fd, 0);

    /* read from the shared memory object */
    printf("%s", (char *)ptr);

    /* remove the shared memory object */
    shm_unlink(name);

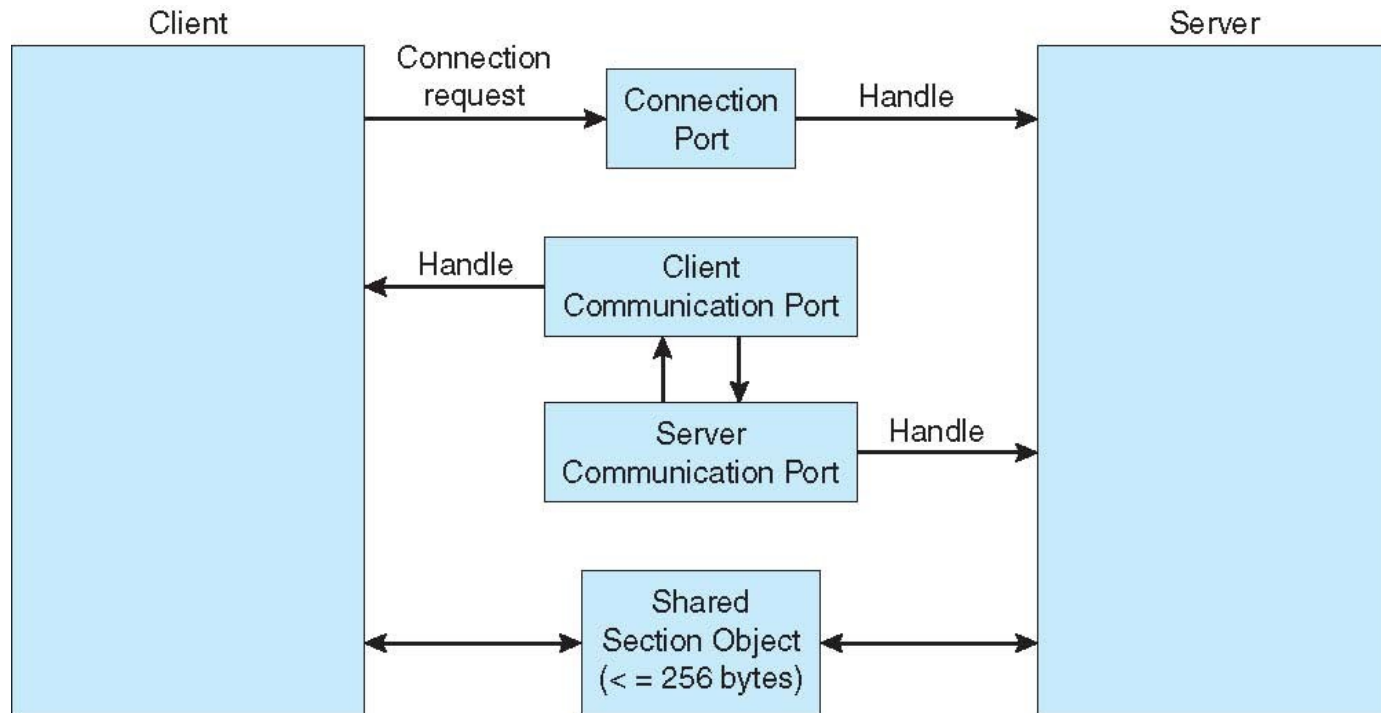
    return 0;
}
```

# Examples of IPC Systems – Windows

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- Message-passing centric via **advanced local procedure call (LPC)** facility
  - Only works between processes on the same system
  - Uses ports (like mailboxes) to establish and maintain communication channels
  - Communication works as follows:
    - ▶ The client opens a handle to the subsystem's **connection port** object.
    - ▶ The client sends a connection request.
    - ▶ The server creates two private **communication ports** and returns the handle to one of them to the client.
    - ▶ The client and server use the corresponding port handle to send messages or callbacks and to listen for replies.

# Local Procedure Calls in Windows





# Communications in Client-Server Systems

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- Sockets
- Remote Procedure Calls
- Pipes
- Remote Method Invocation (Java)

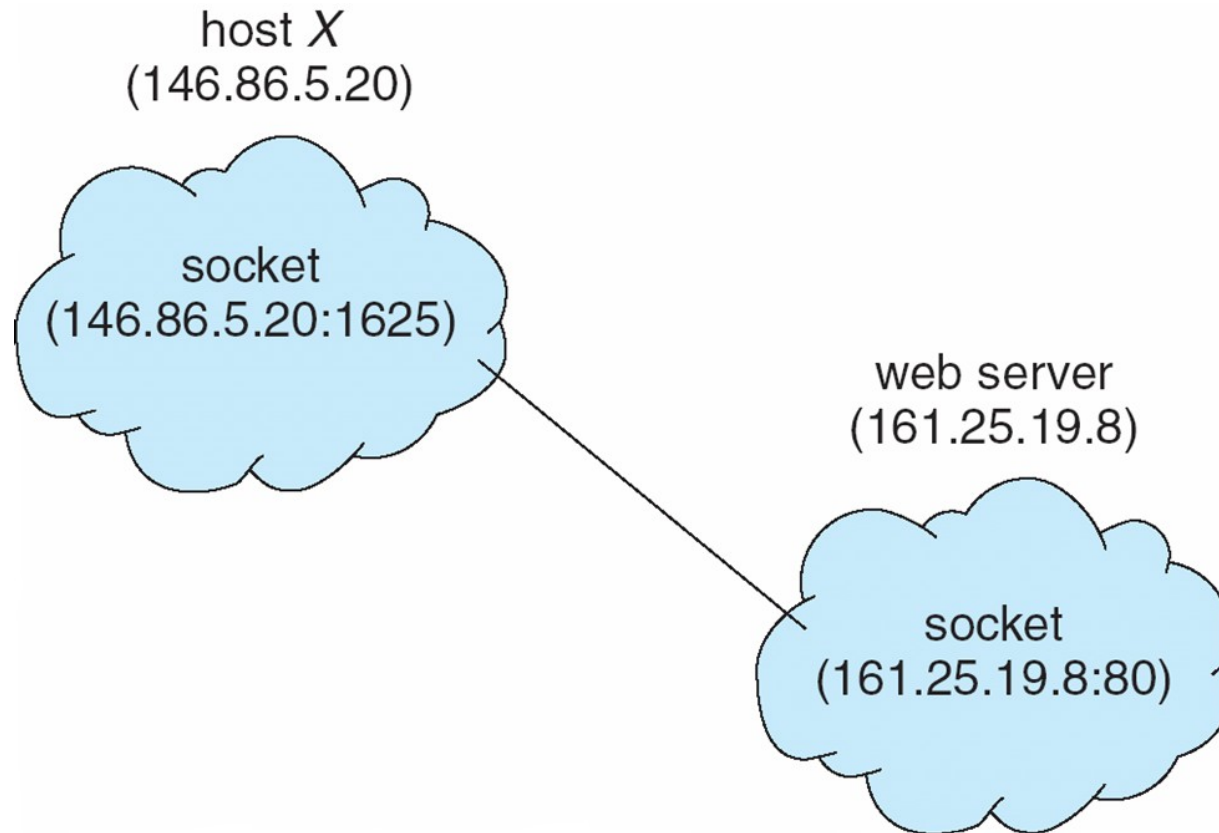
# Sockets

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- A **socket** is defined as an endpoint for communication
- Concatenation of IP address and **port** – a number included at start of message packet to differentiate network services on a host
- The socket **161.25.19.8:1625** refers to port **1625** on host **161.25.19.8**
- Communication consists between a pair of sockets
- All ports below 1024 are ***well known***, used for standard services
- Special IP address 127.0.0.1 (**loopback**) to refer to system on which process is running

# Socket Communication

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# Sockets in Java

- Three types of sockets
  - **Connection-oriented (TCP)**
  - **Connectionless (UDP)**
  - **MulticastSocket class**— data can be sent to multiple recipients

```
import java.net.*;
import java.io.*;

public class DateServer
{
    public static void main(String[] args) {
        try {
            ServerSocket sock = new ServerSocket(6013);

            /* now listen for connections */
            while (true) {
                Socket client = sock.accept();

                PrintWriter pout = new
                    PrintWriter(client.getOutputStream(), true);

                /* write the Date to the socket */
                pout.println(new java.util.Date().toString());

                /* close the socket and resume */
                /* listening for connections */
                client.close();
            }
        }
        catch (IOException ioe) {
            System.err.println(ioe);
        }
    }
}
```

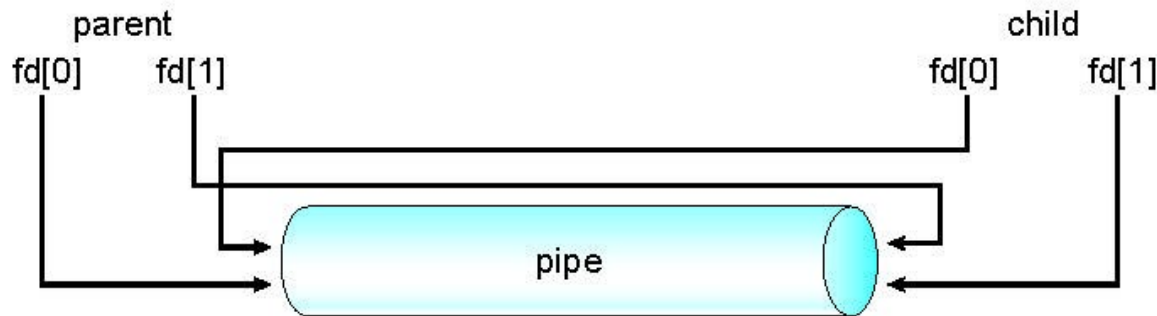
# Pipes

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- Acts as a conduit allowing two processes to communicate
- Issues:
  - Is communication unidirectional or bidirectional?
  - In the case of two-way communication, is it half or full-duplex?
  - Must there exist a relationship (i.e., ***parent-child***) between the communicating processes?
  - Can the pipes be used over a network?
- Ordinary pipes – cannot be accessed from outside the process that created it. Typically, a parent process creates a pipe and uses it to communicate with a child process that it created.
- Named pipes – can be accessed without a parent-child relationship.

# Ordinary Pipes

- Ordinary Pipes allow communication in standard producer-consumer style
- Producer writes to one end (the **write-end** of the pipe)
- Consumer reads from the other end (the **read-end** of the pipe)
- Ordinary pipes are therefore unidirectional
- Require parent-child relationship between communicating processes



- Windows calls these **anonymous pipes**
- See Unix and Windows code samples in textbook

# Named Pipes

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- Named Pipes are more powerful than ordinary pipes
- Communication is bidirectional
- No parent-child relationship is necessary between the communicating processes
- Several processes can use the named pipe for communication
- Provided on both UNIX and Windows systems