Processes

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(partly based on slides of Le Thanh Van)

Outline

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What is a process ?

The textbook

A process is a program in execution

Oxford dictionary

A process is a series of actions or steps taken in order to achieve a particular end

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A process is a series of actions or steps taken in order to achieve a particular end

- process execution must progress in sequential fashion
- job and process are used interchangeably

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  - process (generic)

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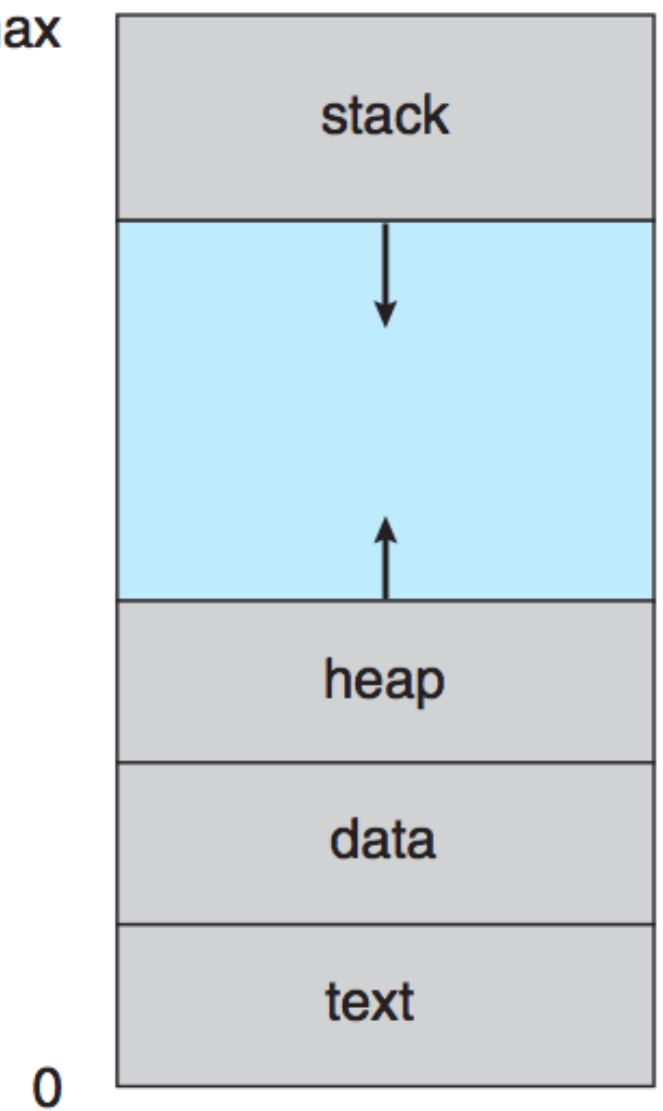
J. Brisendine *(writer)*

Life is a process, not a thing

Process in memory



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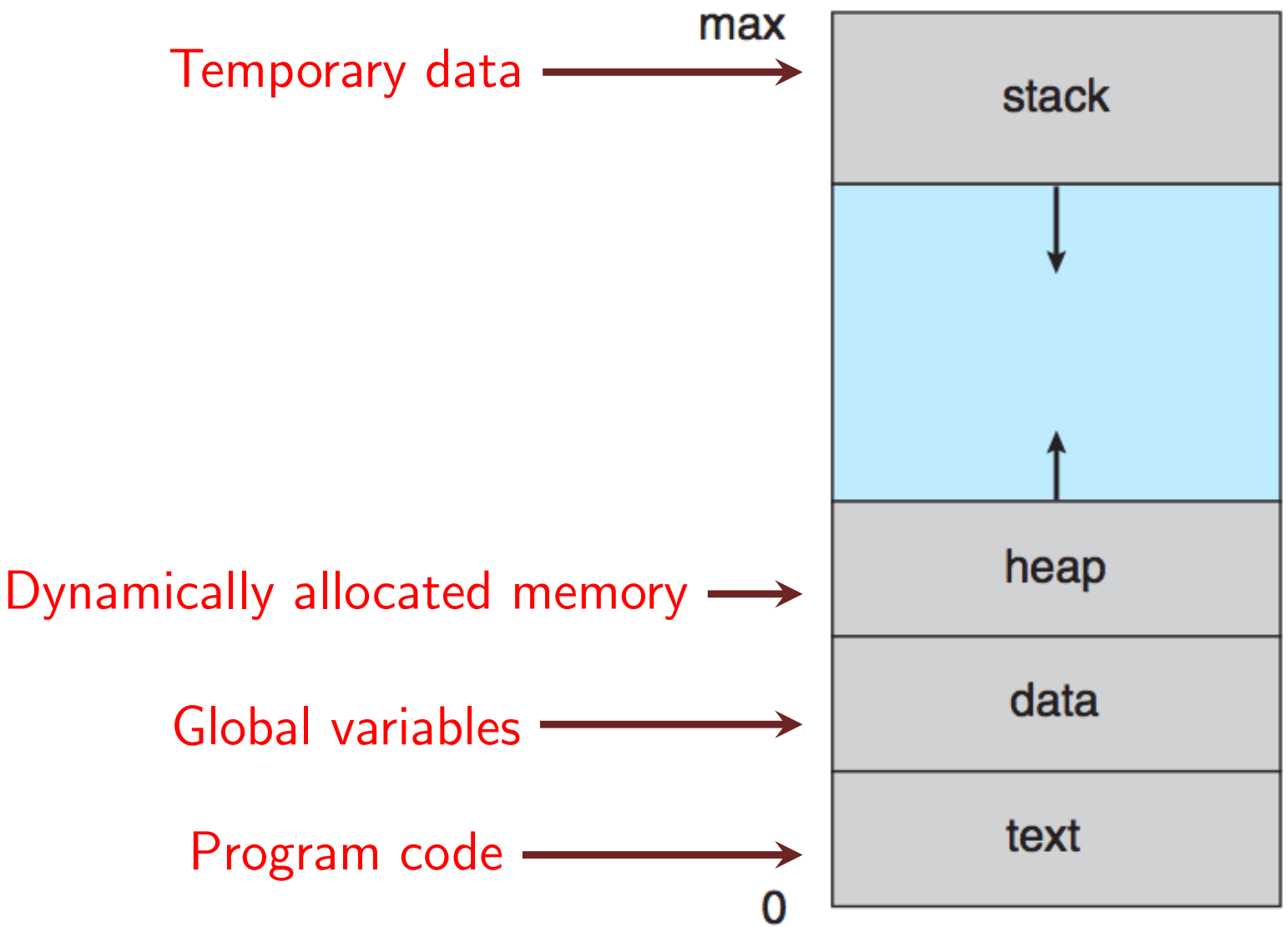
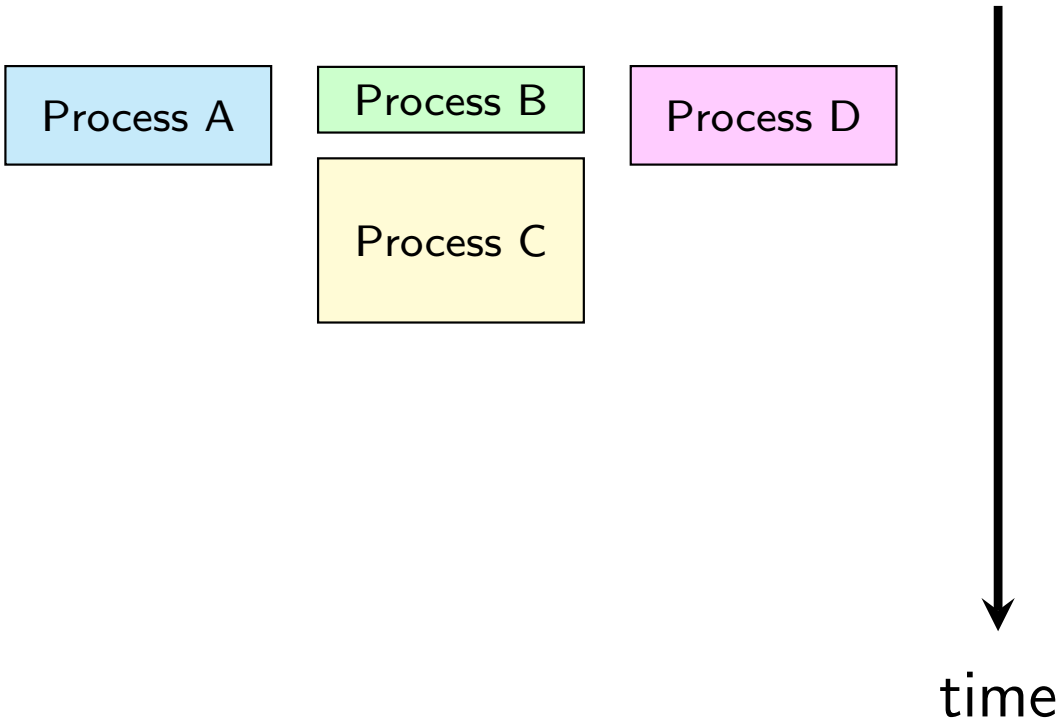


Process in execution

Conceptual model of process execution



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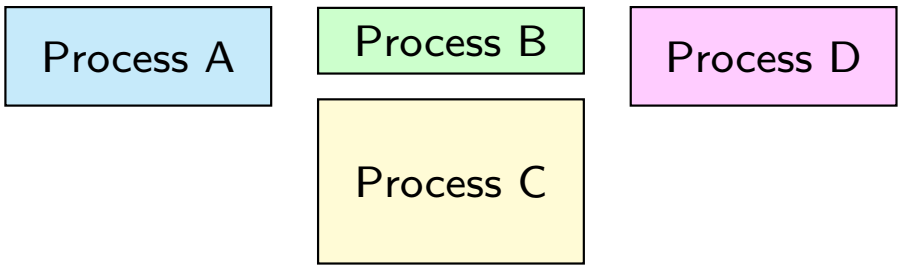
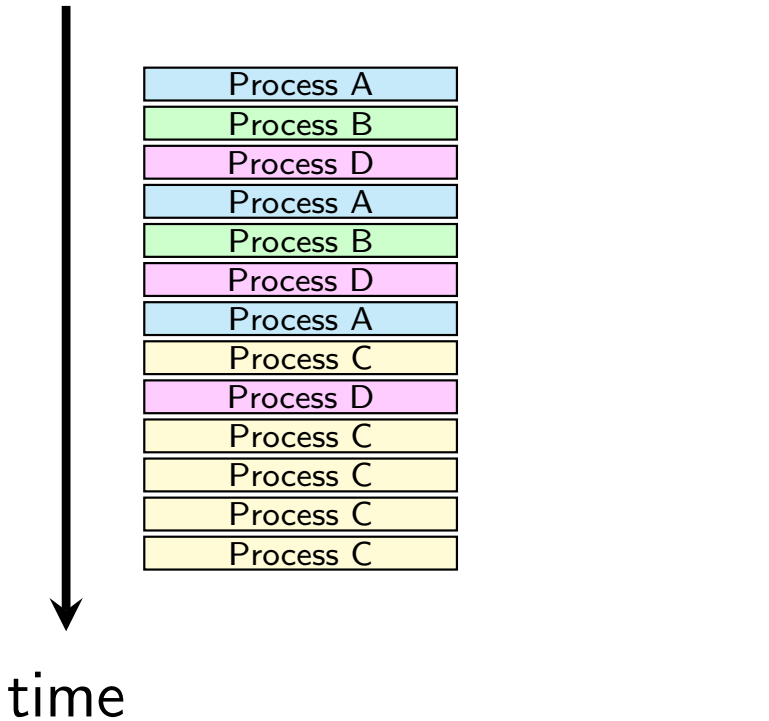


Actual interleaved execution of the processes



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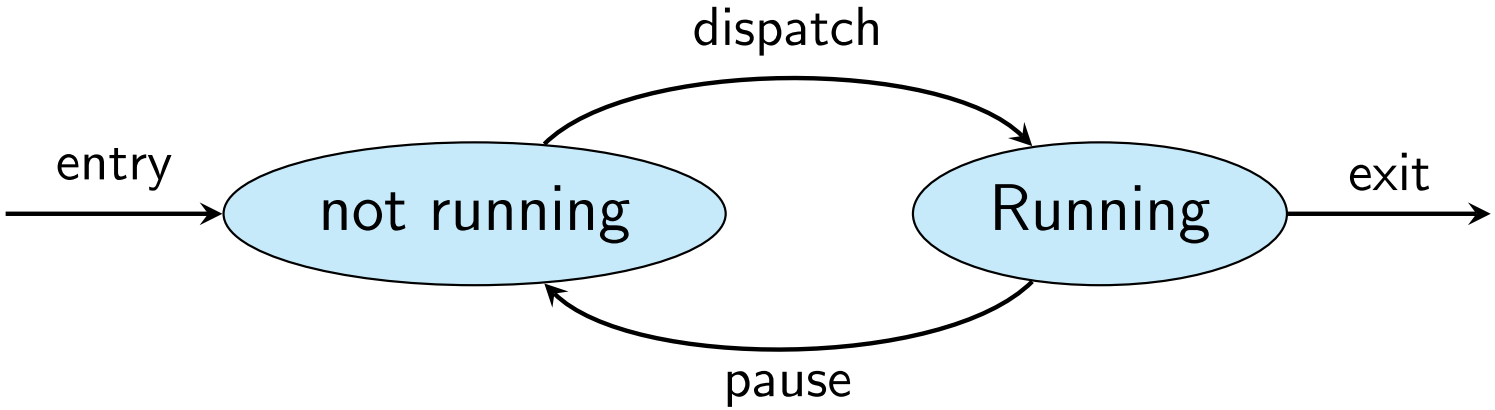

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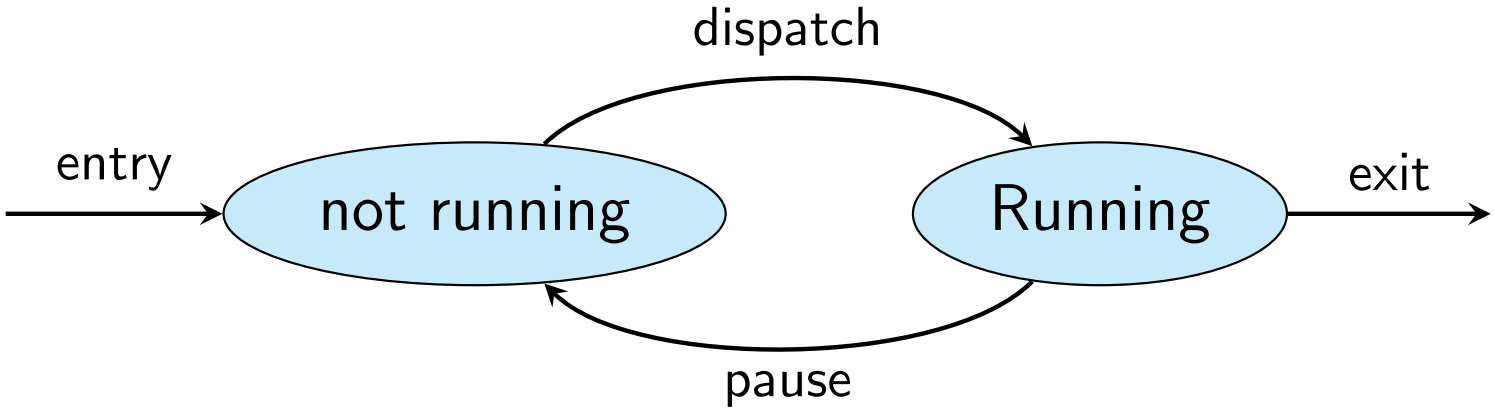
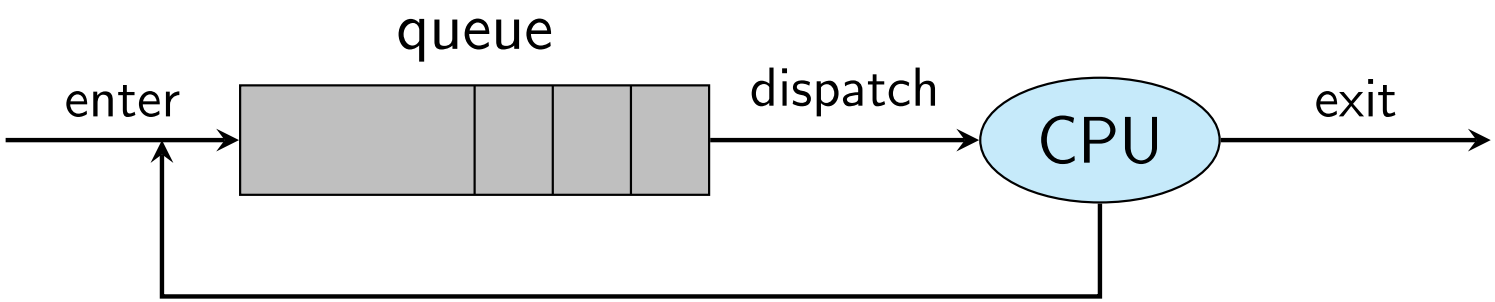


- Queueing diagram



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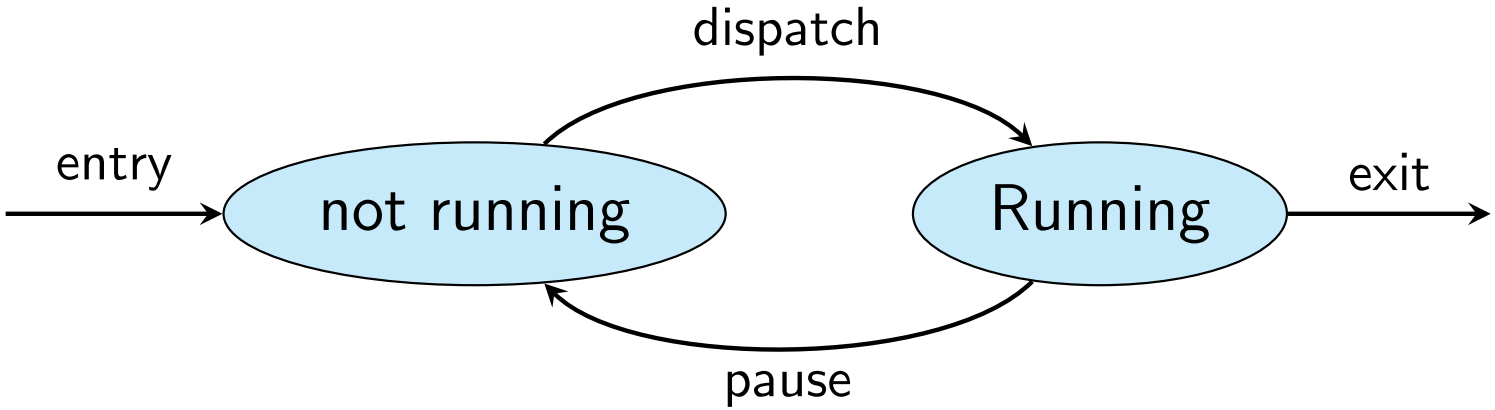

- Queueing diagram

queue

Weakness

2-state model cannot deal with I/O operations.

Process state

As a process executes, it changes state

- new: the process is being created
- running: its instructions are being executed
- waiting: the process is waiting for some event to occur
- ready: the process is waiting to be assigned to CPU
- terminated: the process has finished execution

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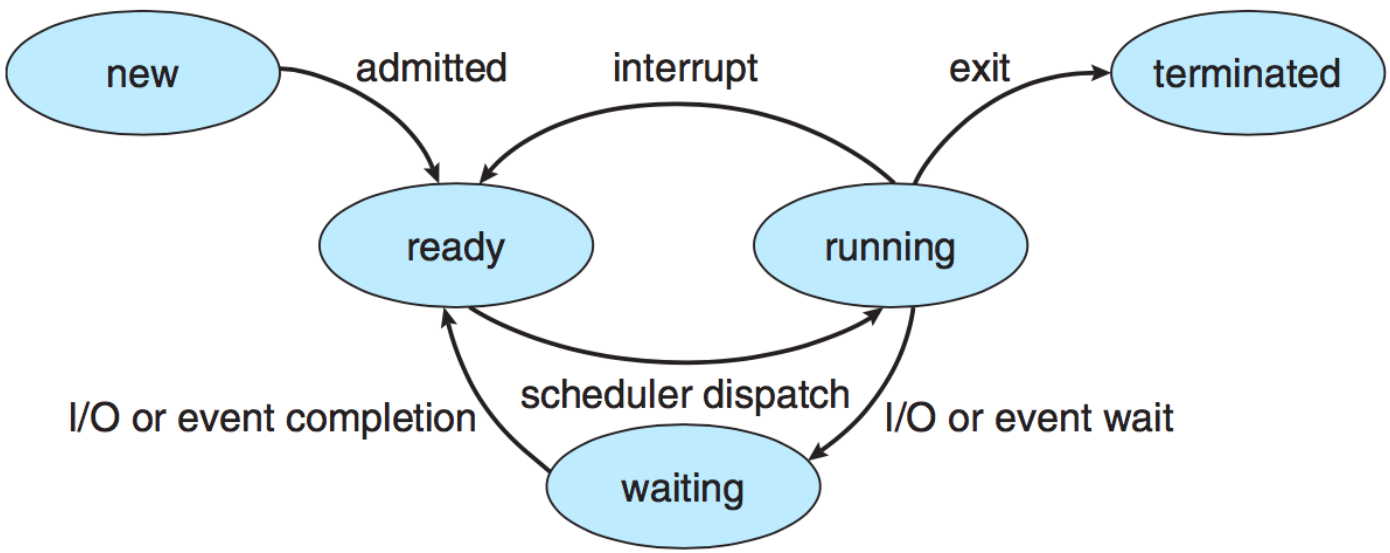
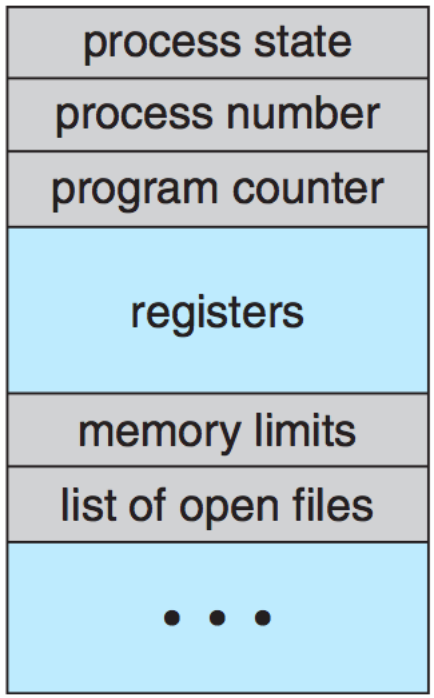


Process control block (PCB)

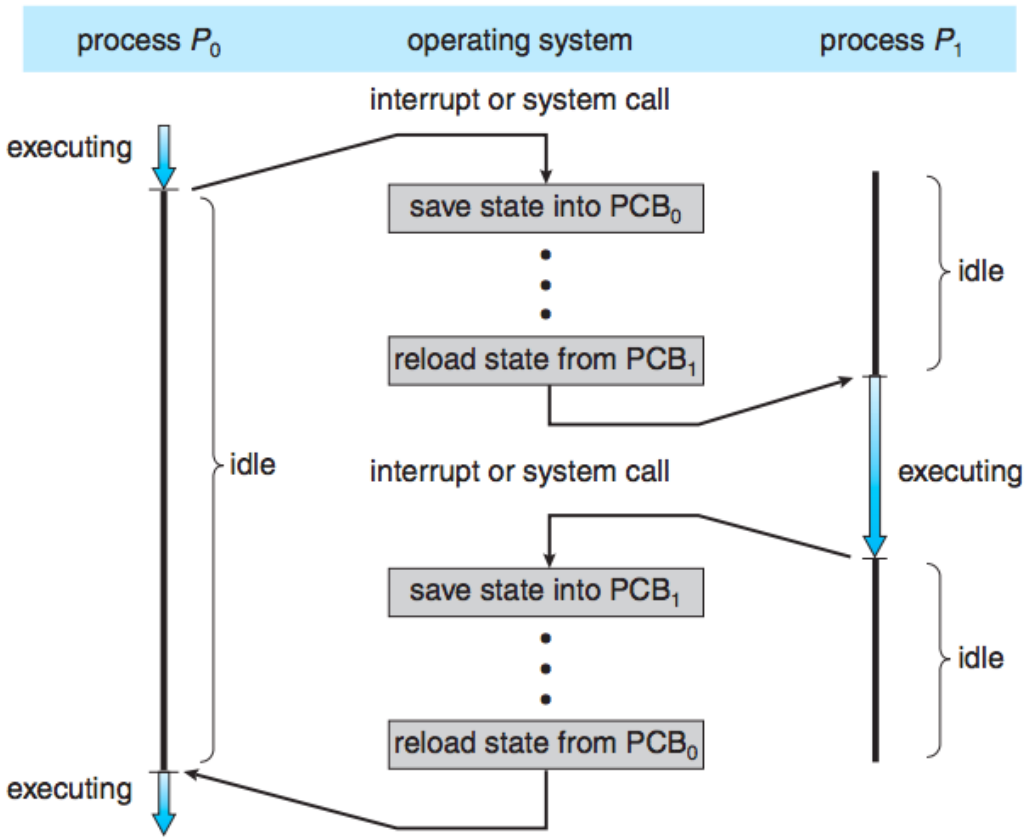
Following information is for a process in operating system, stored in process control block

- Process state
- Program counter
- CPU registers
- CPU scheduling information (e.g., process priority, pointers to scheduling queues)
- Memory management information (e.g., base/limit registers, segment tables)
- Accounting information
- I/O status information (e.g., open files)



Process switching

PCBs are used for process switching in a mutiple tasking operating system



Context switching

- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process
- Context-switch time is overhead. The system does no useful work while switching
  - Time dependent on hardware support
    Ex.: UltraSPARC uses multiple register sets

Outline

Process scheduling queues

In 5-state process model, we need more than 1 queue to store jobs

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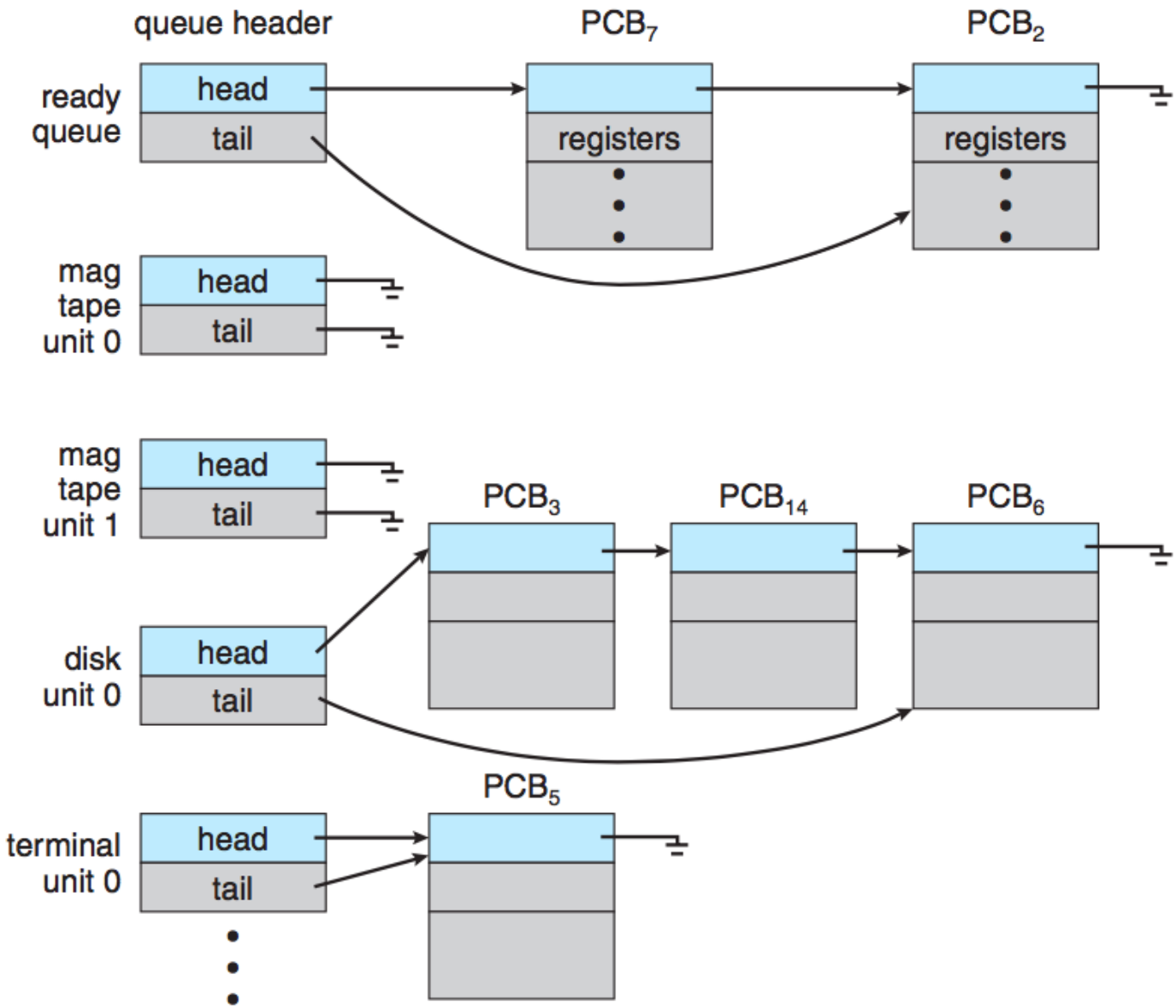
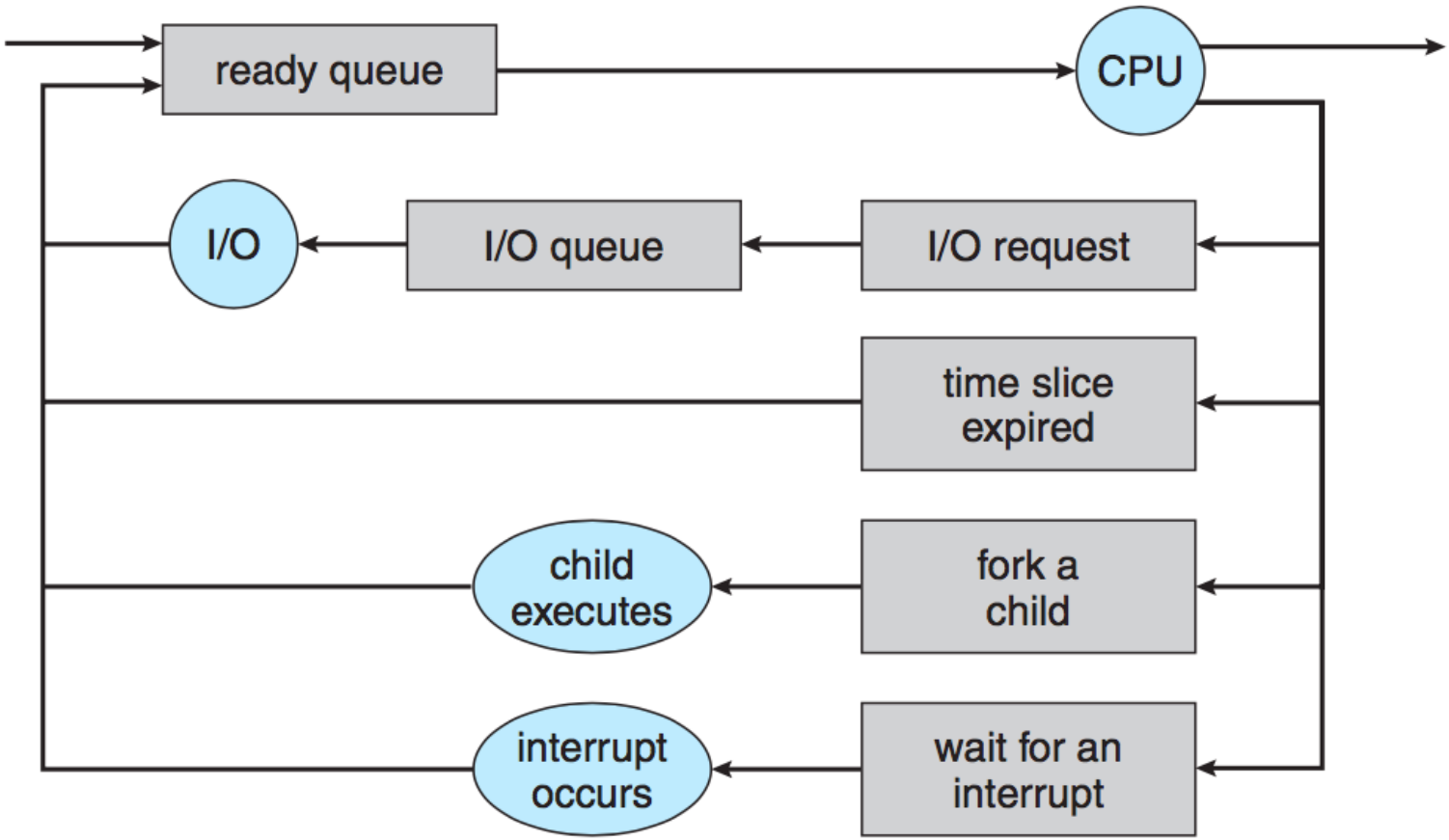
- Queue types:
  - Job queue: set of all processes in the system
  - Ready queue: set of all processes residing in main memory, ready, and waiting to execute
  - Device queues: set of processes waiting for an I/O device
- Process migration between the various queues

Process queues as linked lists



Queueing diagram



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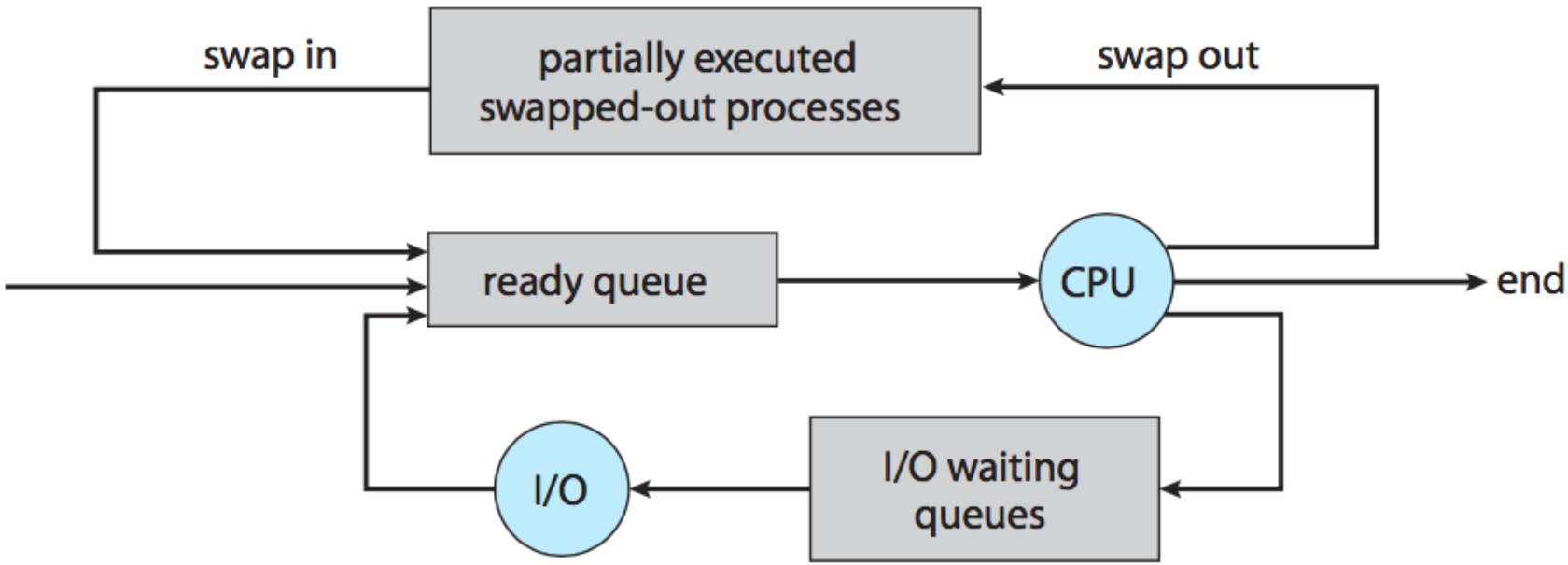
- Job scheduler is for batch systems
- CPU scheduler is for time-sharing systems

Medium-term scheduler

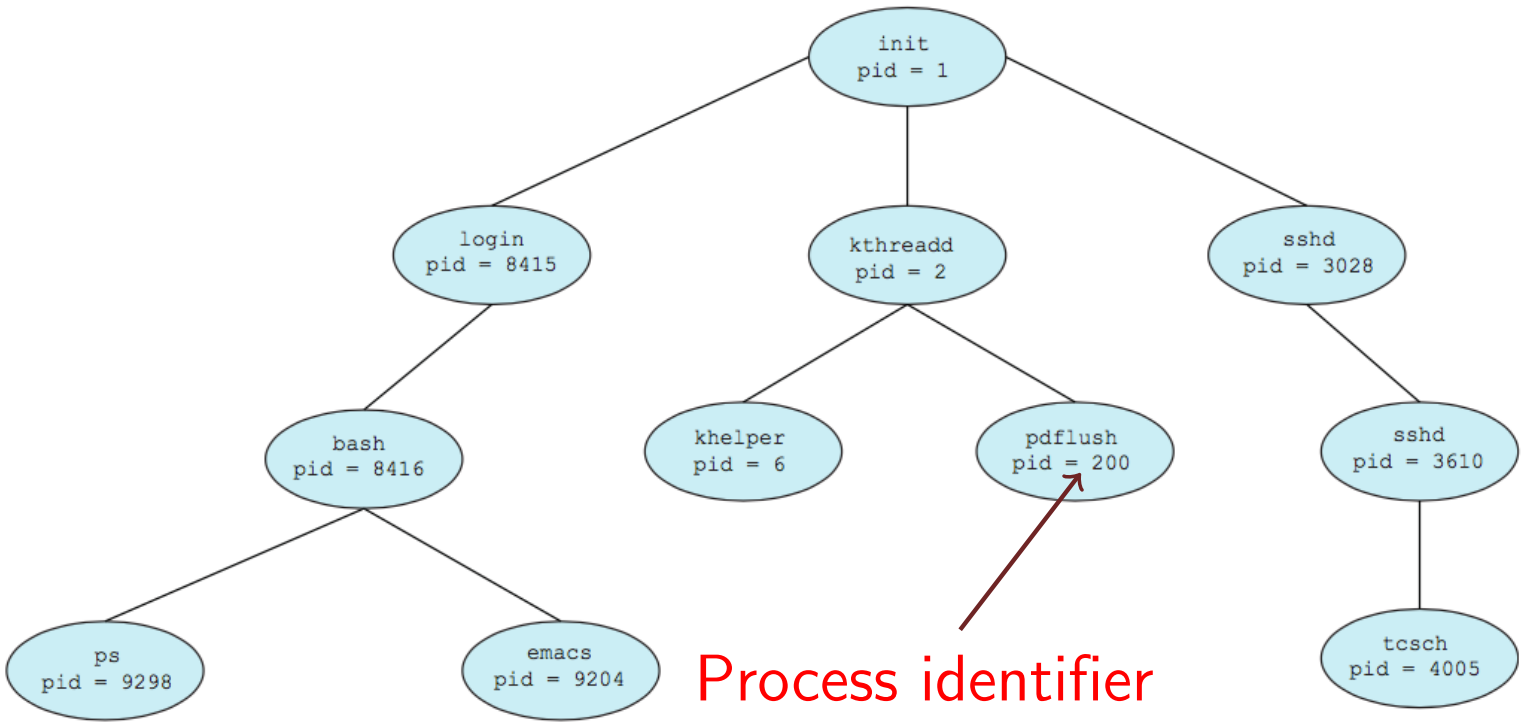


- Swaping is useful to release some resources (for other ready processes)
  - Mobile OSs utilize swaping to save memory and power

Outline

Process tree

Processes are organized in a form of tree



Process creation

- Parent creates children processes

Process creation

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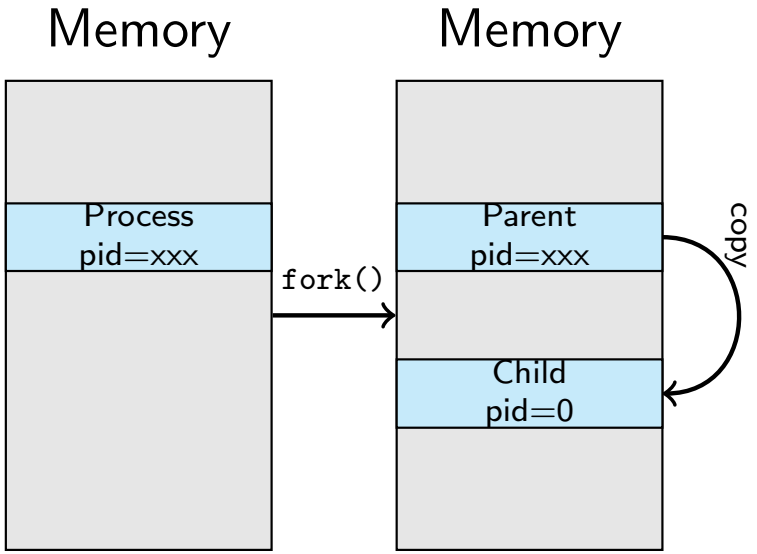
- Resource sharing: 3 possibilities
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and children share no resources
- Execution: 2 possibilities
  - Parent and children execute concurrently
  - Parent waits until children terminate
- Address-space: 2 possibilities
  - Children duplicate of the parent (program & data)
  - Children load new program

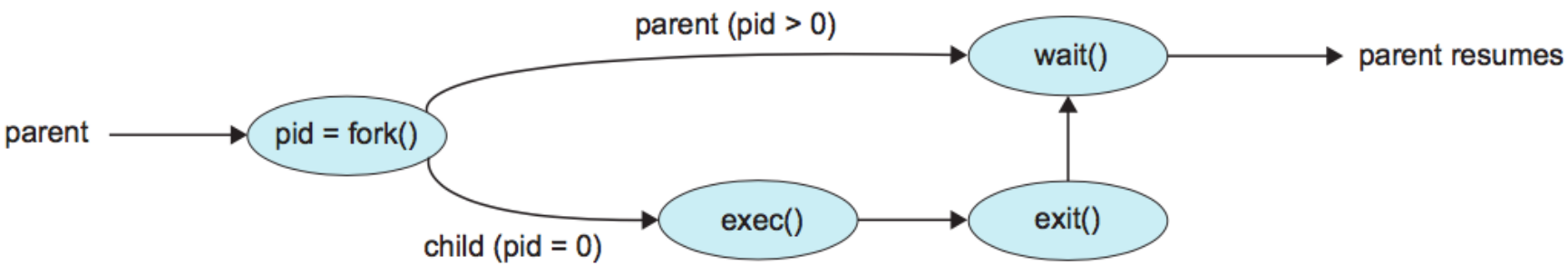
fork() system call

```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>

int main()
{
  pid_t pid;

  /* fork a child */
  pid = fork();
  if ( pid < 0 ){          /* error occurs */
    fprintf( stderr, "Fork failed\n" );
    return 1;
  } else if ( pid == 0 ){ /* child process  */
    execlp( "/bin/ls", "ls", NULL );
  } else {                 /* parent process */
    wait(NULL);
    printf( "Child complete!\n" );
  }
  return 0;
}
```





Process termination

- Process executes the last statement and asks OS to decide it (`exit()`)
  - Output data from child to parent (via `wait()`)
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  - Process's resources are deallocated by OS
- Parent may terminate execution of children processes (`abort()`)
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - Parent is exiting
    - OS does not allow child to continue if its parent terminates $\Rightarrow$ Cascading termination
    - Parent did not invoke `wait()` and instead terminated, thereby leaving its child processes as orphans

Outline

Process relationship

- Independent process: cannot affect or be affected by others
  - Independent process does not share data
- Cooperating process: can affect or be affected by others
  - Cooperating process does share data

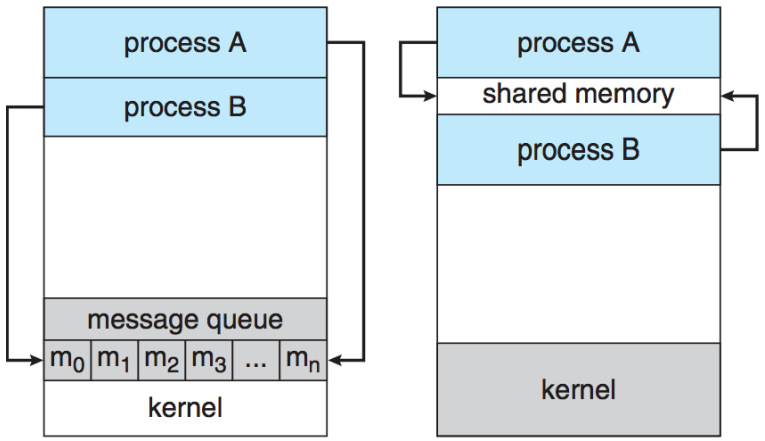
Reasons for process cooperation

- Information sharing
- Computation speedup
- Modularity
- Convenience

Interprocess communication (IPC)

IPC

- IPC is used to exchange data and information
- 2 IPC models: shared-memory and message-passing



- Shared-memory: fast
- Message-passing: no conflict ; suitable for distributed system; better performance on multiple core architecture

Shared-memory

- All things for IPC are decided by processes in communication themselves, not under OS's control

Producer

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

Consumer

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

- At most `BUFFER_SIZE-1` items in the buffer at the same time

Message-passing

- IPC facility provides at least 2 operations
  - `send(message)`
  - `receive(message)`
- If P and Q wish to communicate, they need to
  - establish a *communication link* between them
  - exchange a message via `send()/receive()`
- Methods to implement communication link
  - physical link: shared memory, hardware bus, network, ...
  - logical link: by following methods
    - Direct or indirect communication
    - Synchronous or asynchronous communication
    - Automatic or explicit buffering

- How are links establised ?
- 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 ?

Explicit name of sender and receiver must be given

- `send(P,message)`
- `receive(Q,message)`

- Links are established automatically
- A link is associated with exactly one pair of communicating processes
- The link may be unidirectional, but is usually bi-directional

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Disadvantage

Direct communication has poor modularity

Messages are sent to or received from a mailbox or port

- `send(A,message)`
- `receive(A,message)`

`A` is a mailbox with unique identification

- A link between 2 processes is established only if both have a shared mailbox
- A link may be associated with more than 2 processes
- Between each pair, several different links may exist

- P_1, P_2 and P_3 share a mailbox.
  - P_1 sends a message
  - P_2 and P_3 receive
  - Who gets the message ?

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- A mailbox may be owned by a process or OS. If it owned by OS, system calls must be provided to
  1. Create a new mailbox
  2. Send and receive messages through the mailbox
  3. Delete a mailbox

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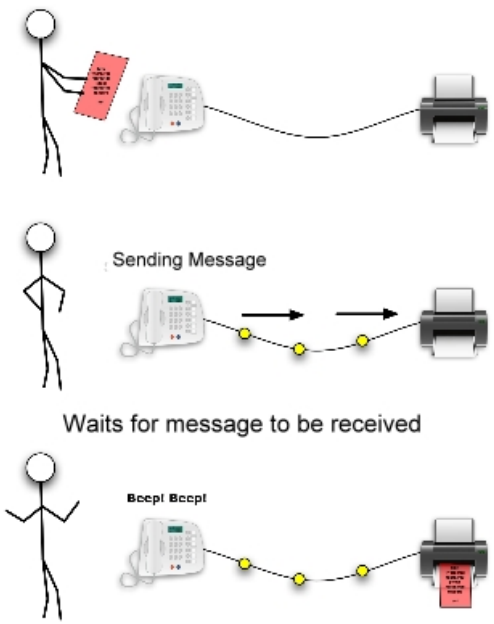

(source: cfd-online.com)

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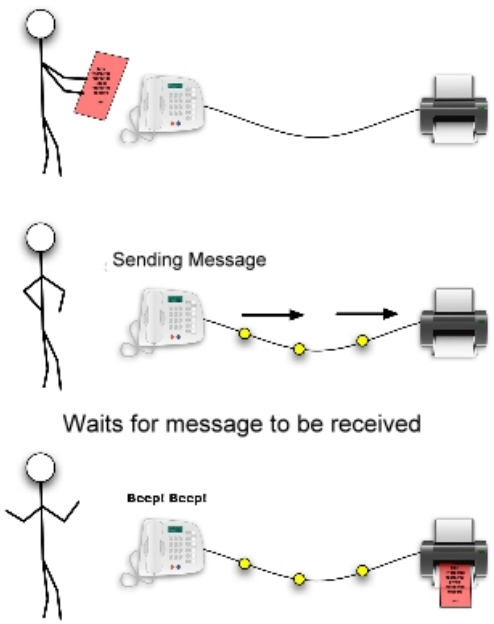

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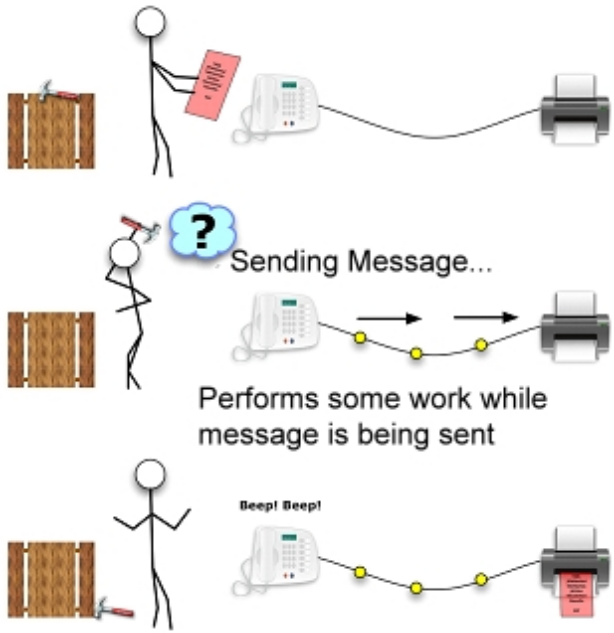

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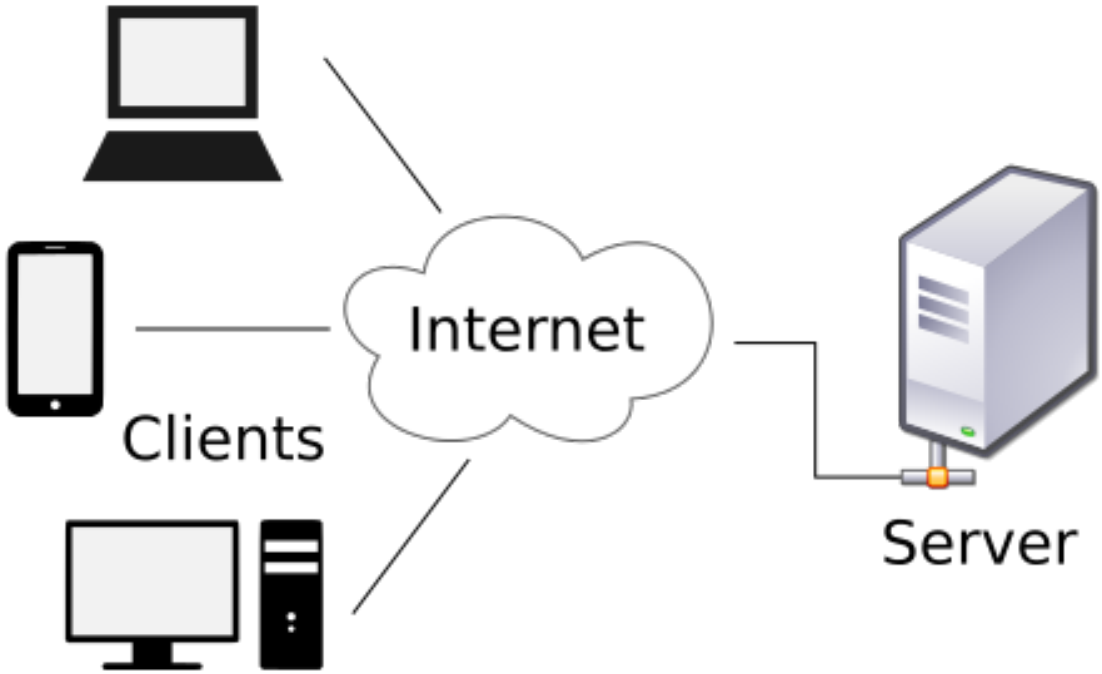
- Message queues attached to the link; implemented in one of 3 ways
  - Zero capacity: 0 message; sender must wait for receiver
  - Bounded capacity: finite length of n; sender must wait if link is full
  - Unbounded capacity: infinite length; sender never waits

Outline

Client-server communication



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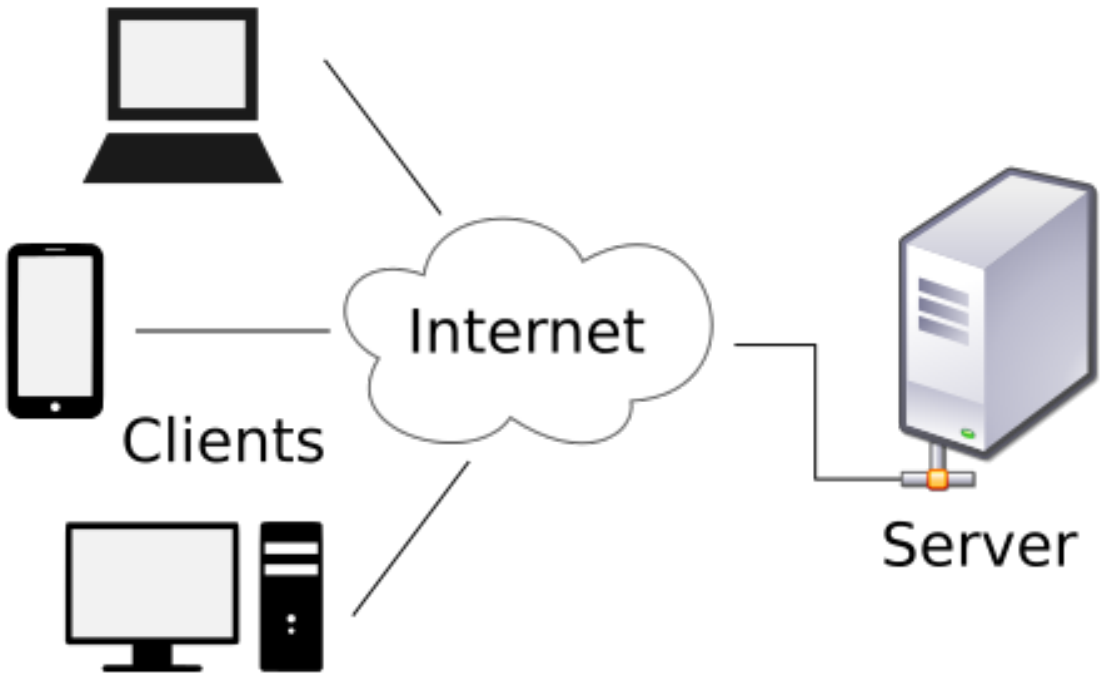

(source: wikipedia)

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

Socket

Socket is an endpoint, consisting of

- IP address
- port

- Socket
  161.25.19.8:1625
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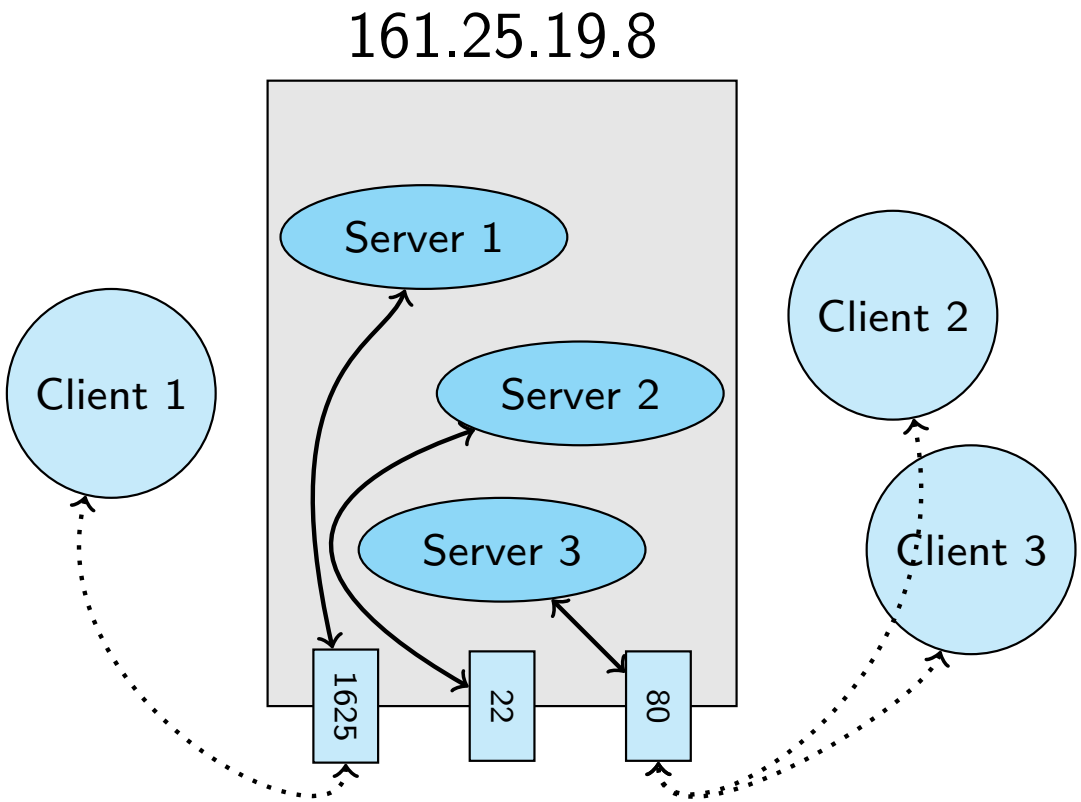
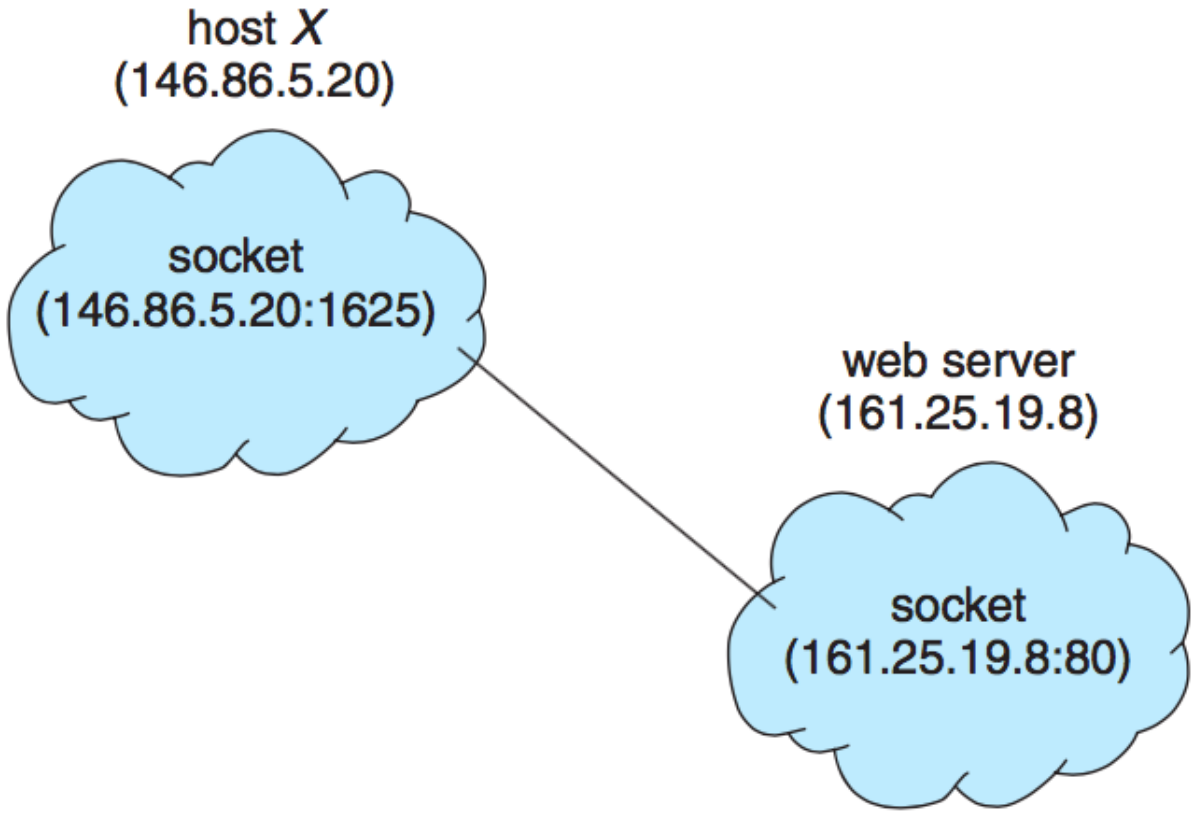


Socket communication



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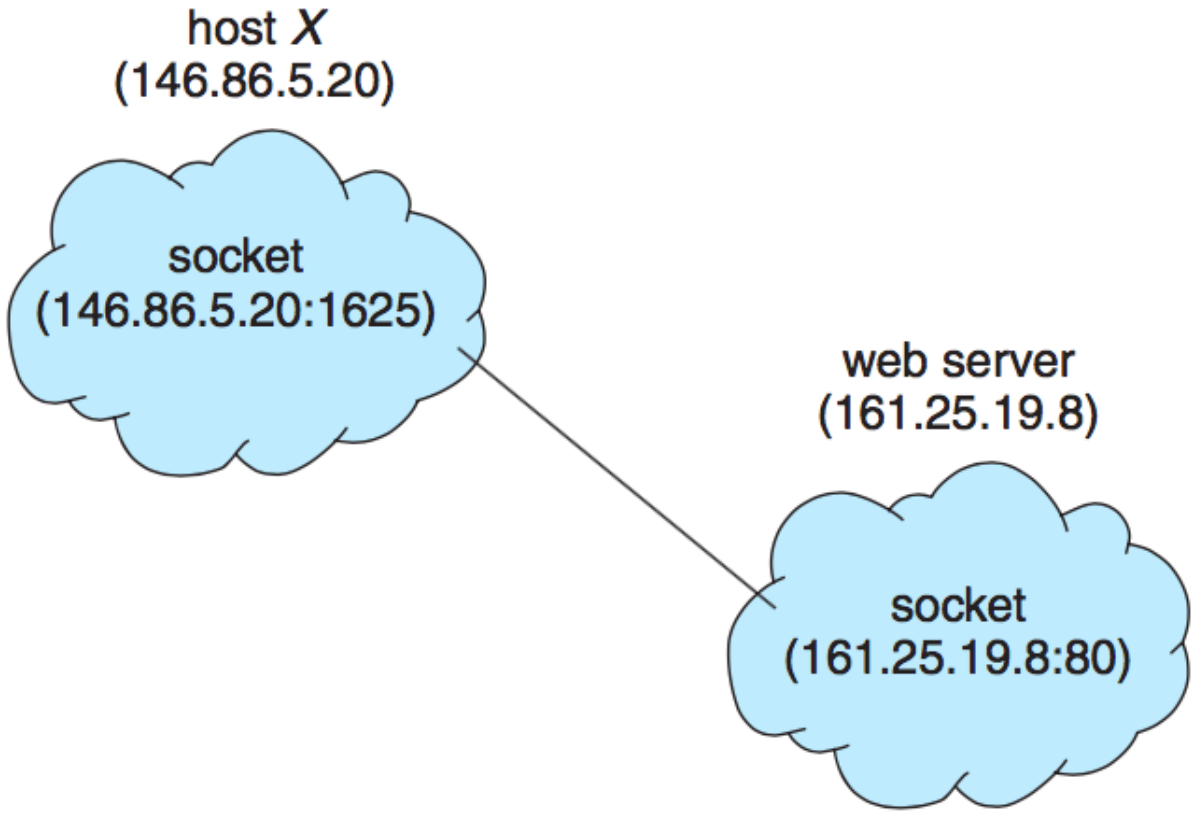


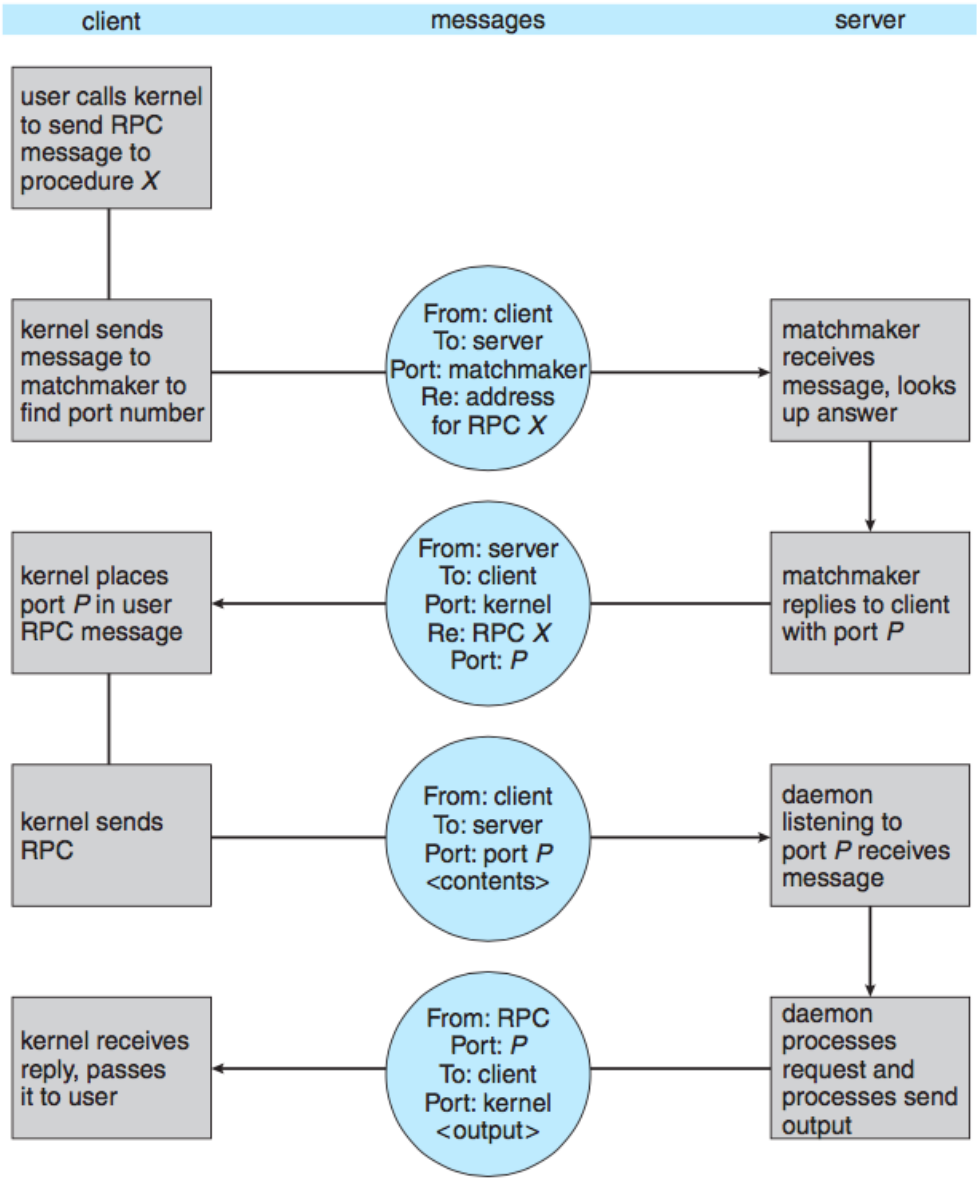
Socket is low-level form of communication in which data is transferred in unstructured stream.

Remote procedure call (RPC)

Remote procedure call (RPC) abstracts procedure calls between processes on networked systems

- Messages exchanged in RPC are well-structured (function name, parameters)
- Stubs: client-side proxy for the actual procedure on the server
  - separate stub for each separate remote procedure
  - stub locates port on server and marshalls parameters into a package (by a mechanism of External Data Representation (XDR))
- The server-side stub receives this message, unpacks the marshalled parameters, and peforms the procedure on the server

Execution of RPC



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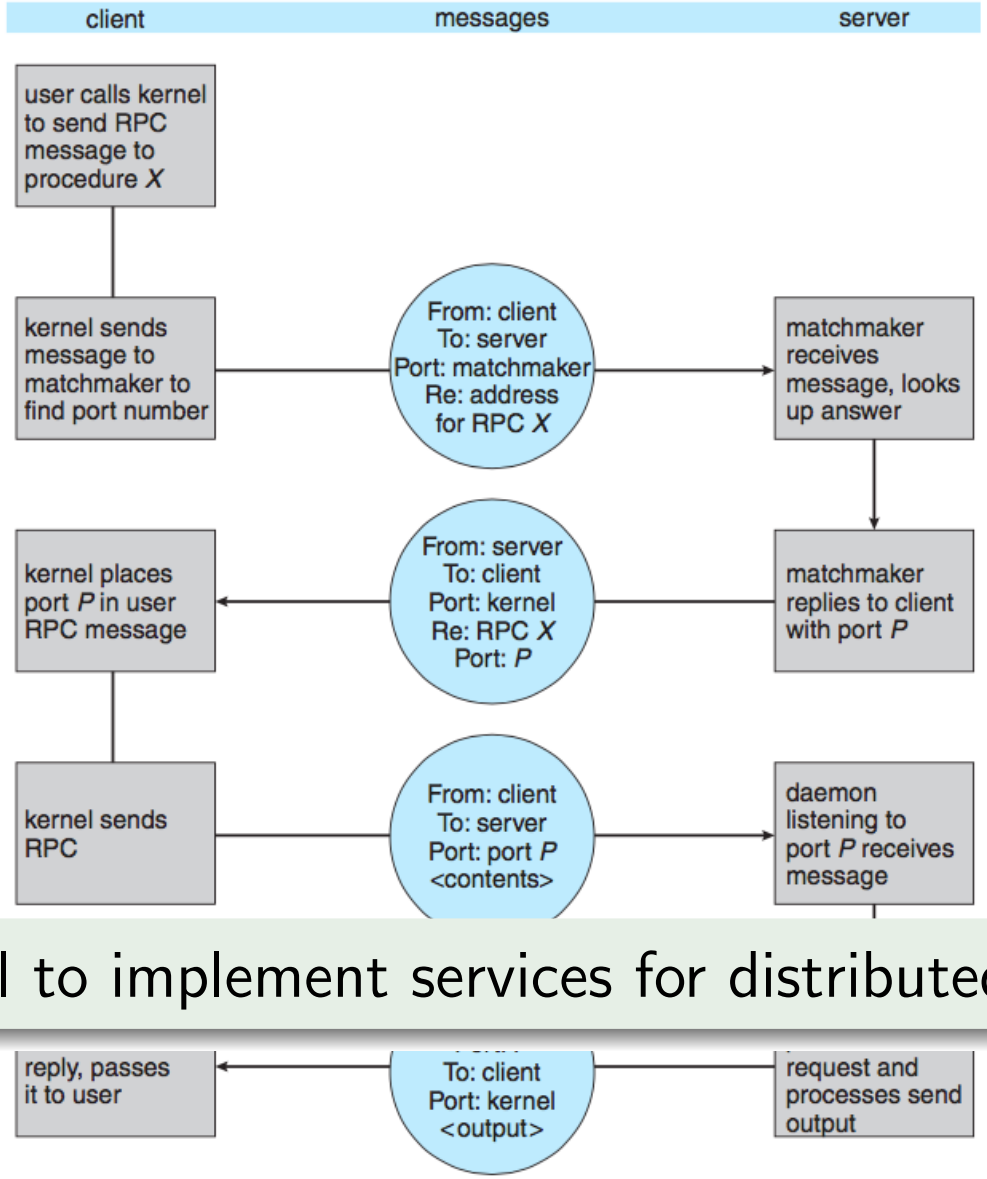
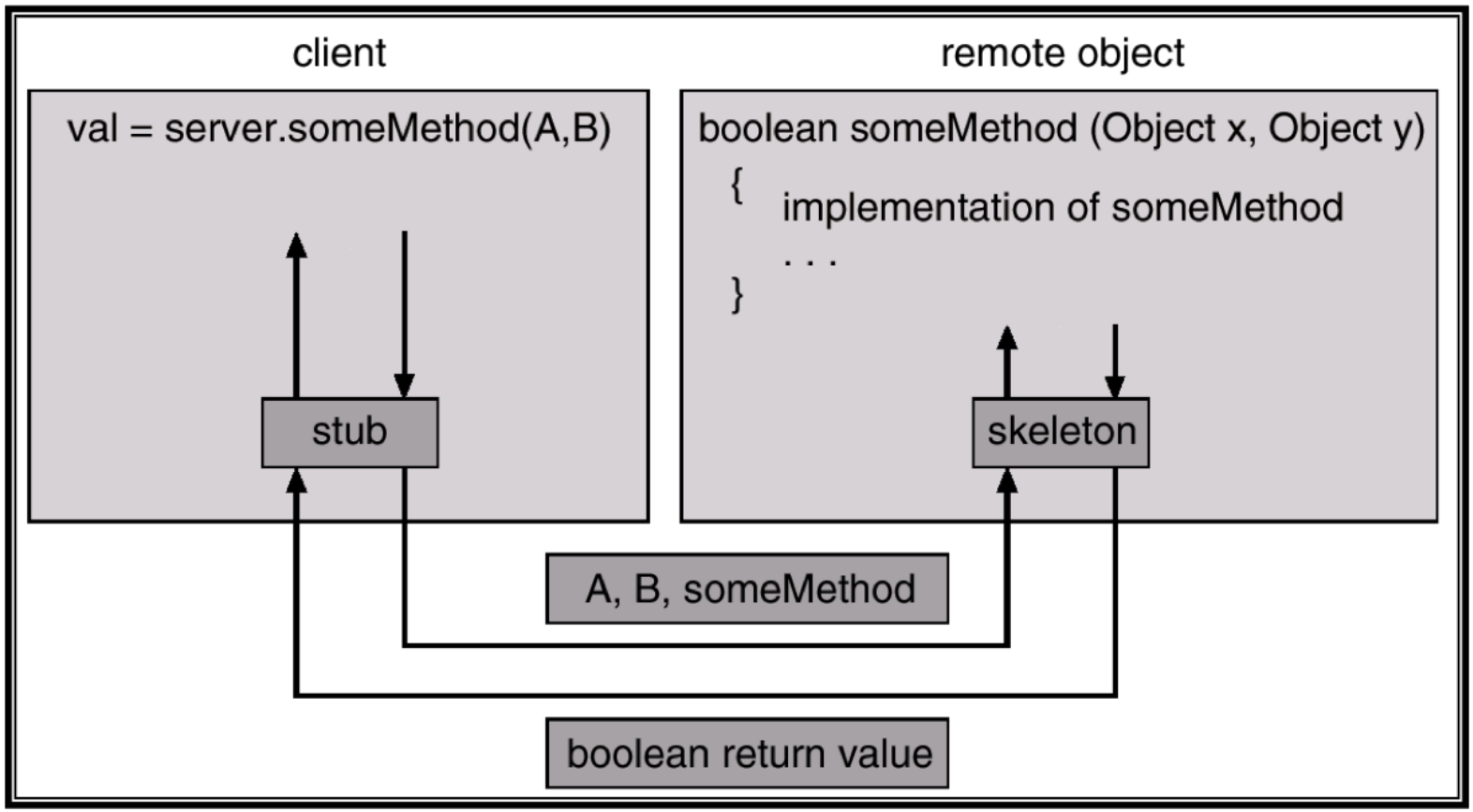


RPC is useful to implement services for distributed systems

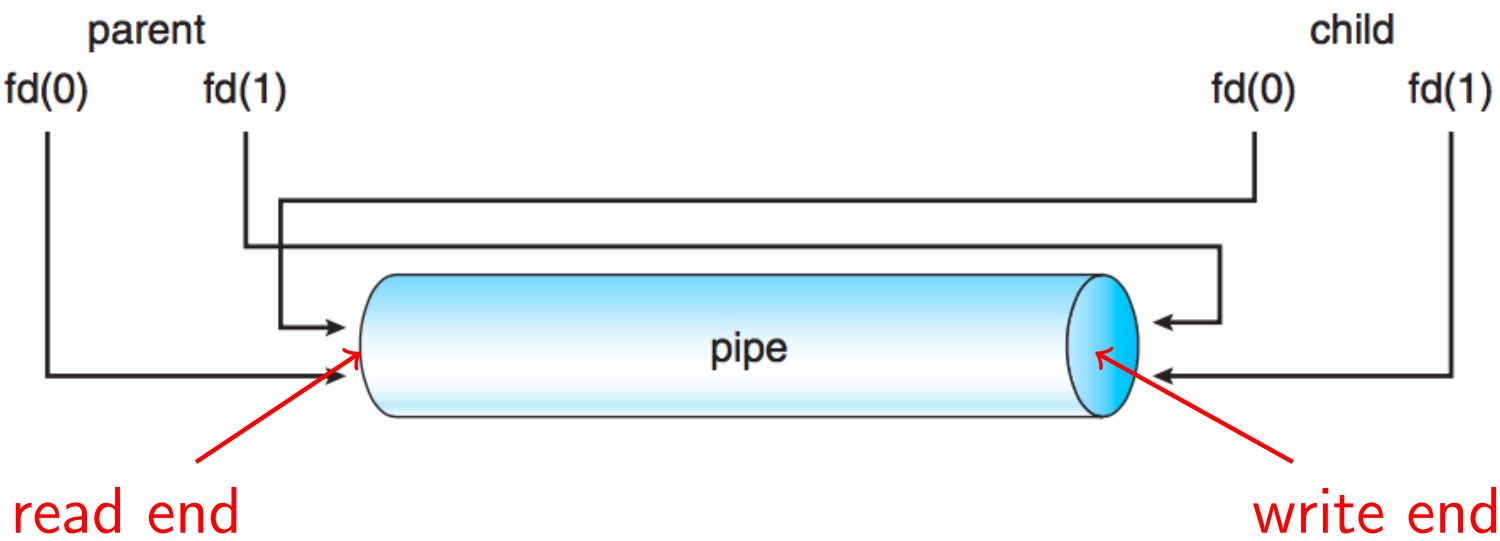
Remote method invocation

- A Java mechanism and quite similar to RPC
- RMI allows a Java program on one machine to invoke a method on a remote object



Pipe

- Pipe is one of very first IPC mechanisms in early UNIX
- Ordinary pipe is unidirectional
- Pipes can be treated as a special type of file



Anonymous pipe

```
#include <sys/types.h>
#include <stdio.h>
#include <string.h>
#include <unistd.h>

#define BUFFER_SIZE 25
#define READ_END     0
#define WRITE_END    1

int main(void)
{
  char write_msg[BUFFER_SIZE] = "Greetings";
  char read_msg[BUFFER_SIZE];
  int fd[2];
  pid_t pid;

  /* create  the pipe */
  if ( pipe( fd ) == 1 ){
    fprintf( stderr, "Pipe failed!\n" );
    return 1;
  }

  /* fork a child process */
  pid = fork();
  if ( pid < 0 ){
    fprintf( stderr, "Fork failed!\n" );
    return 1;
  }
  if ( pid > 0 ){
    /* close unused end of pipe */
    close( fd[READ_END] );

    /* write to the pipe */
    write( fd[WRITE_END], write_msg,
             strlen(write_msg) + 1 );

    /* close the write end */
    close( fd[WRITE_END] );
  }
  else {
    /* close unused end of pipe */
    close( fd[WRITE_END] );

    /* write to the pipe */
    read( fd[READ_END], read_msg, BUFFER_SIZE );

    /* close the read end */
    close( fd[READ_END] );
  }

  return 0;
}
```

Homeworks

1. Read materials on Thread: textbook, slides (Le Thanh Van)
2. There is quiz in April 1, 2021) on Process & Thread

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2. There is quiz in April 1, 2021) on Process & Thread
3. Quiz grade (of students in 2017)