

Processes

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(*partly based on slides of Le Thanh Van*)

Outline

- 1 Process concept
- 2 Process scheduling
- 3 Operations on processes
- 4 Interprocess communication
- 5 Communication in client-server model

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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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The textbook

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Oxford dictionary

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

Process vs. Program

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 - data section

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- User and OS processes
 - jobs (batch system)
 - tasks (time-shared system)
 - process (generic)

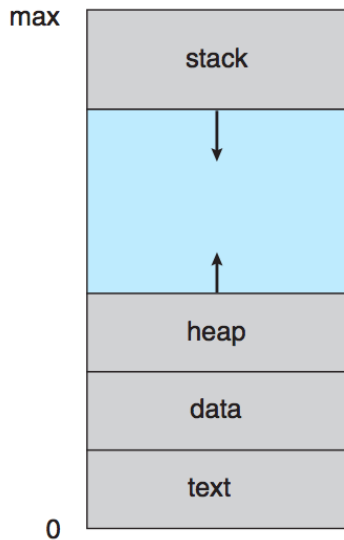
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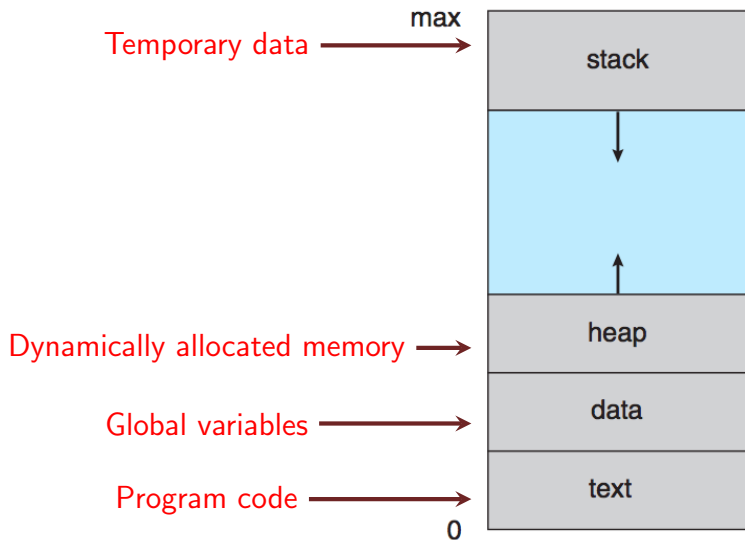
J. Brisendine (*writer*)

Life is a process, not a thing

Process in memory

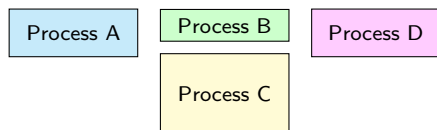


Process in memory



Process in execution

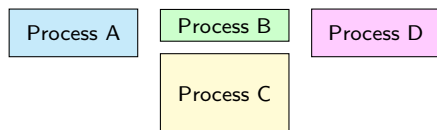
Conceptual model of
process execution



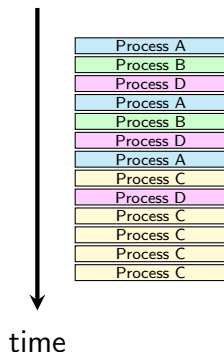
time

Process in execution

Conceptual model of
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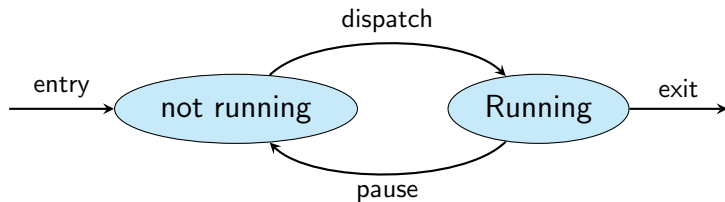
Actual interleaved ex-
ecution of the processes



Process state

2 state process model

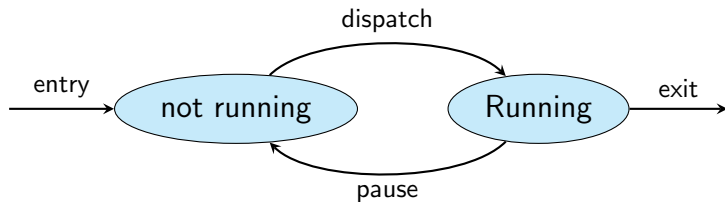
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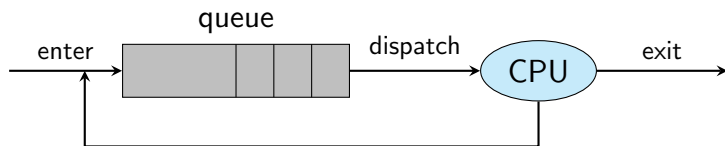
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- A process is either “**running**” or “**not running**”



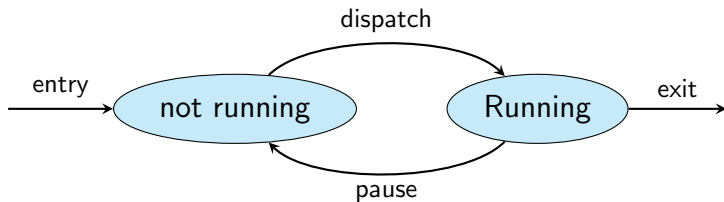
- Queueing diagram



Process state

2 state process model

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- Queueing diagram

queue

Weakness

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

Process state

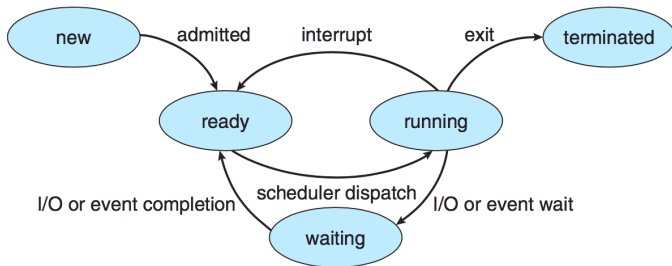
As a process executes, it changes **state**

- **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

Process state

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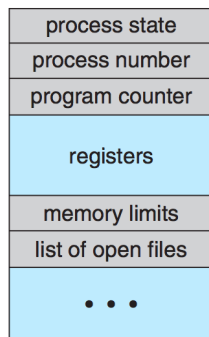
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Process control block (PCB)

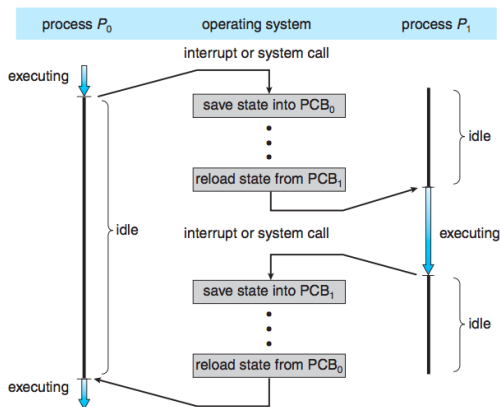
Following information is for a process in operating system, stored in **process control block**

- 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 multiple 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
 - UltraSPARC uses multiple register sets

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Process scheduling queues

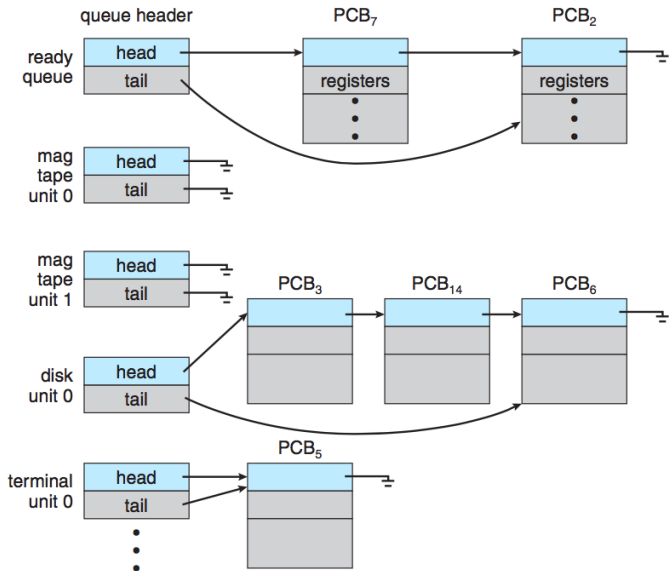
In 5-state process model, we need more than 1 queue to store jobs

Process scheduling queues

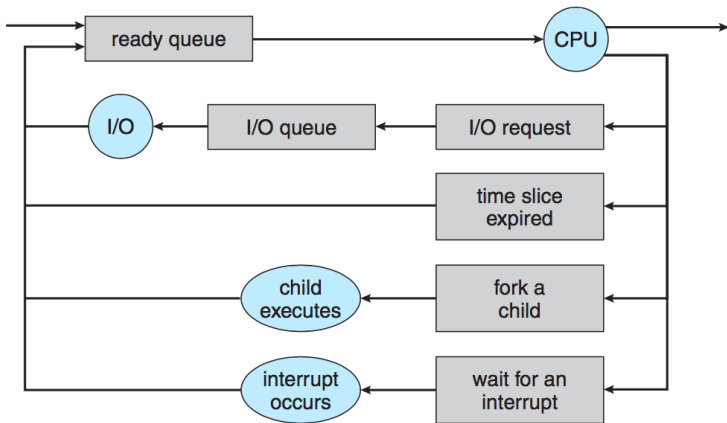
In 5-state process model, we need more than 1 queue to store jobs

- 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



Schedulers

Processes are selected from the queues for migration, under some **selection strategies** managed by **schedulers**.

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- **Long-term scheduler** (or **job scheduler**): selects which processes should be **brought into the ready queue**
 - Frequency: only necessary **when a process leaves**
 - Efficiency depends strongly on I/O bound or CPU bound

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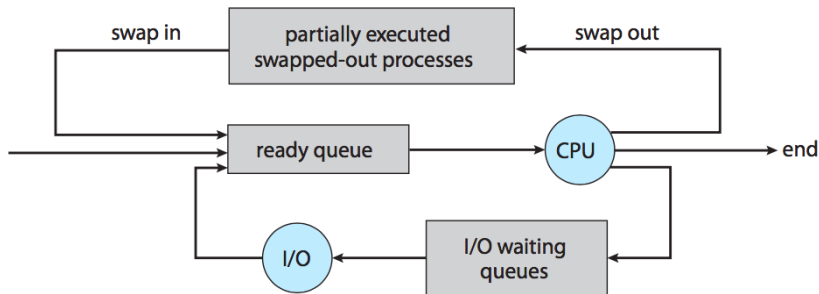
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-
- Job scheduler is for batch systems
 - CPU scheduler is for time-sharing systems

Medium-term scheduler



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

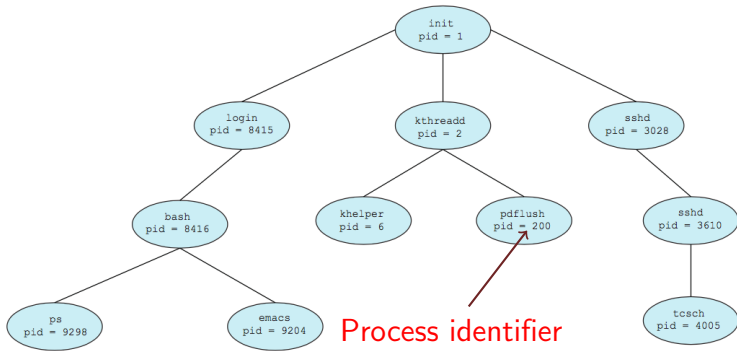
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Process tree

Process tree

Processes are organized in a form of **tree**



Process creation

- Parent creates children processes

Process creation

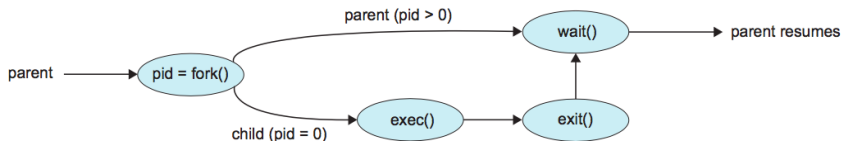
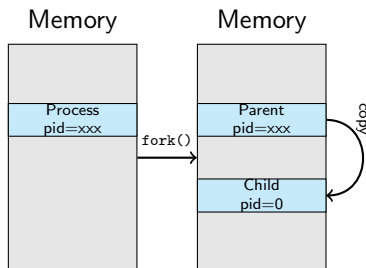
- Parent creates children processes
- Resource sharing: 3 possibilities
 - Parent and children share all resources
 - Children share subset of parent's resources
 - Parent and children share no resources
- Execution: 2 possibilities
 - Parent and children execute concurrently
 - Parent waits until children 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()`)
 - Process's resources are deallocated by OS

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 - Output data from child to parent (via `wait()`)
 - 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 ⇒ **Cascading termination**
 - Parent did not invoke `wait()` and instead terminated, thereby leaving its child processes as **orphans**

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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**

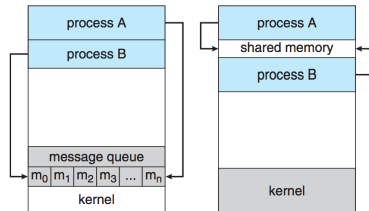
Reasons for process cooperation

- 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

- 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 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

Direct communication

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
- Between each pair there exists **exactly one link**
- The link may be unidirectional, but is **usually bi-directional**

Message-passing

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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

Message-passing

Indirect communication (1)

- 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 link associated with 2 processes at most
 - Allowing one process to perform `receive()` at a time
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 - Allowing one process to perform `receive()` at a time
 - An algorithm to choose which process to perform `receive()` (e.g., round-robin)
- 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

Message-passing

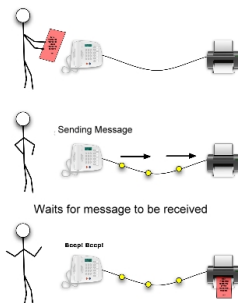
Synchronization

`send()` and `receive()` can be **blocking** (**synchronous**) or **non-blocking** (**asynchronous**)

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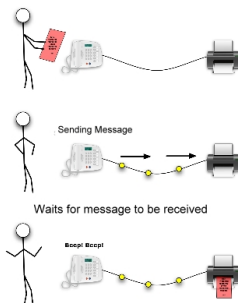


(source: cfd-online.com)

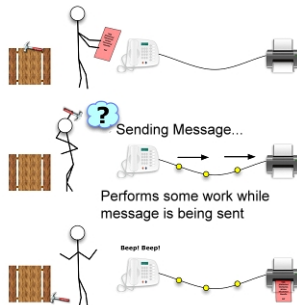
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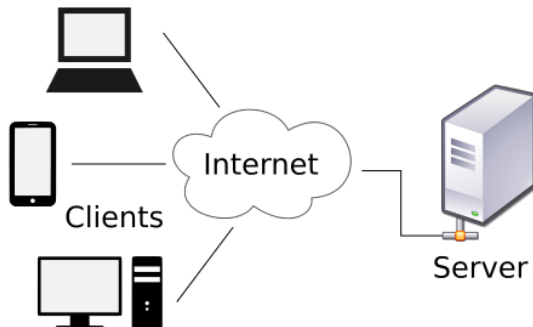
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- Message queues attached to the link; implemented in one of 3 ways
 - **Zero capacity**: 0 message; sender must wait for receiver
 - **Bounded capacity**: finite length of n ; sender must wait if link is full
 - **Unbounded capacity**: infinite length;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

Outline

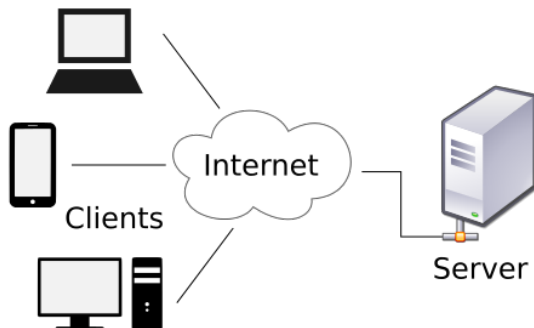
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Client-server communication



(source: wikipedia)

Client-server communication



(source: wikipedia)

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

Socket is an endpoint, consisting of

- IP address
- port

- Socket

161.25.19.8:1625

refers to port 1625

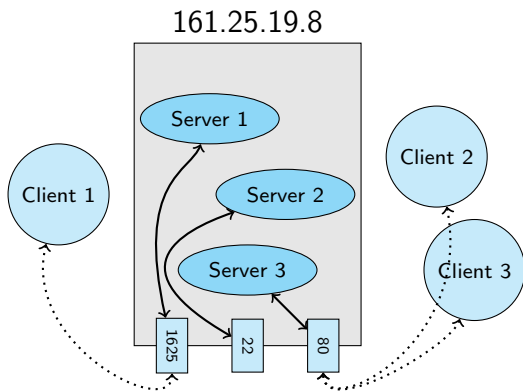
on host 161.25.19.8

Socket

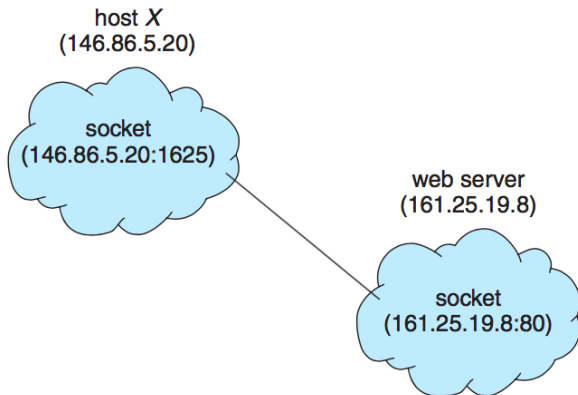
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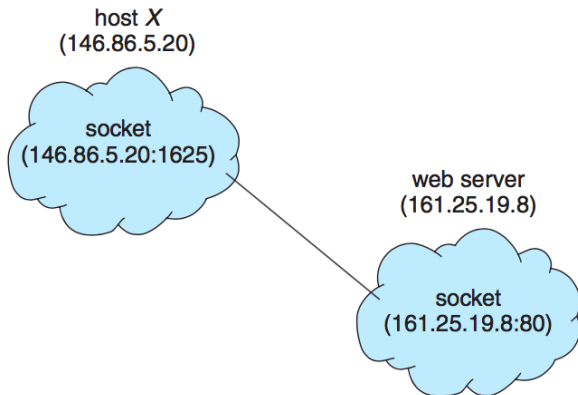
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Socket communication



Socket communication



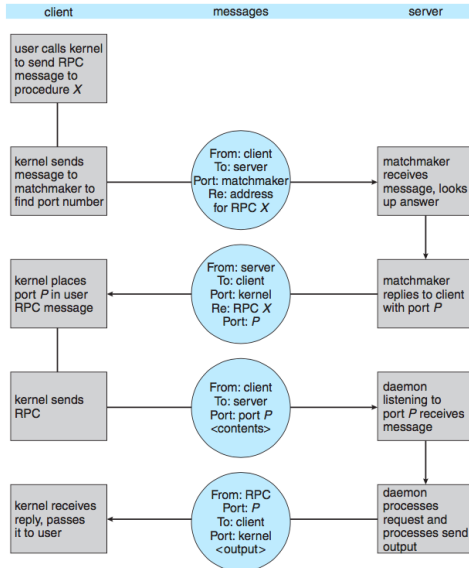
Socket is **low-level** form of communication in which data is transferred in **unstructured** stream.

Remote procedure call (RPC)

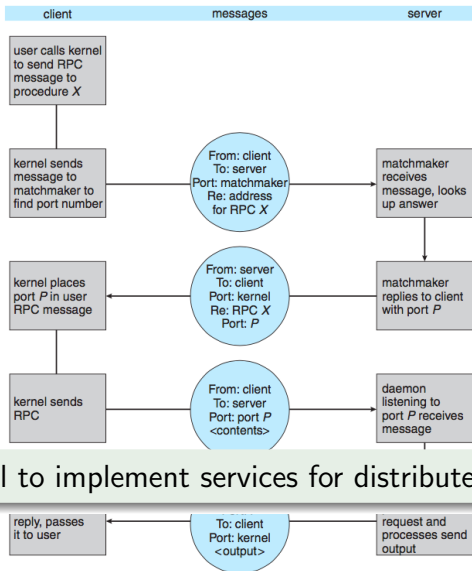
Remote procedure call (RPC) abstracts **procedure calls** between processes on networked systems

- 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 performs the procedure on the server

Execution of RPC



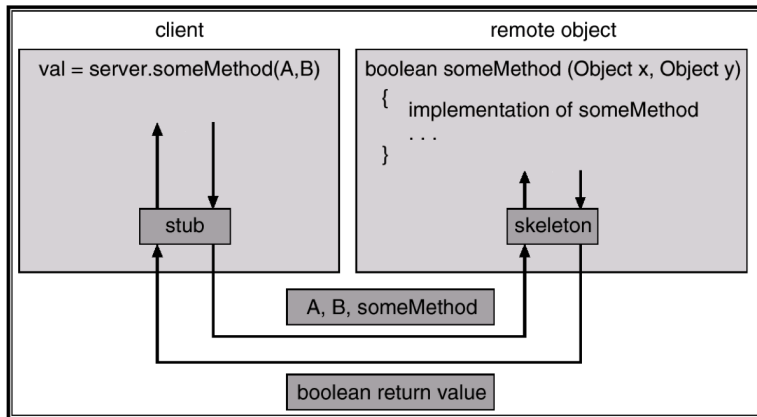
Execution of RPC



RPC is useful to implement services for distributed systems

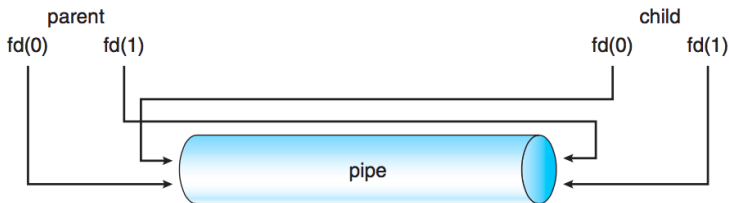
Remote method invocation

- 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 (Nguyen Thanh Son)
- 2 There is quiz-2 next week (March 3, 2017) on [Process & Thread](#)

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- 3 Quiz-1 grade

Histogram of grade\$X7

