# 0117401: Operating System
# 计算机原理与设计

## Chapter 3: Process

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# 温馨提示：

为了您和他人的工作学习，
请在课堂上关机或静音。

不要在课堂上接打电话。

# Overview


1. 多道程序技术和程序并发执行的条件
2. Process Concept
3. Process Scheduling
4. Operation on processes
5. Interprocess Communication (进程间通信, IPC)
6. Example of IPC Systems
7. Communication in C/S Systems
8. 小结和作业

# Outline


1. 多道程序技术和程序并发执行的条件
   - 多道程序技术的难点
   - Seriel execution of programs (程序的顺序执行)
   - Concurrent execution of programs (程序的并发执行)

## Some easily confused terms

- In our course:
  - **Program**(程序): passive entity, usually a file containing a list of instructions stored on disk (often called an **executable file**).
  - **Tasks**(任务): a general reference
  - **Jobs**(作业): in batch system, user programs (and data) waiting to be loaded and executed
  - **Processes**(进程): a program in execution
- Usually, the term **job** and **process** are used **interchangeably**.

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# Multiprogramming(多道程序) techniques

- From Simple Batch system →Multiprogramming system
  - Memory must be shared by multiple programs
  - CPU must be multiplexing(复用) by multiple programs
  - 4 basic components:
    1. Process management
    2. Memory management
    3. I/O system management
    4. file management

# Difficulties of multiprogramming techniques

- 与单道相比，在多道系统中，进程之间的运行随着调度的发生而具有无序性，那么
  - How to ensure correct concurrent?
- Related theory:
  - Conditions of the concurrent execution of program
  - Theoretical model: Precedence graph (前趋图)
    - Analysis on the serial execution of programs based on precedence graph
    - Analysis on the concurrent execution of programs based on precedence graph

# Precedence Graph（前趋图）

- Goal:
  准确的描述语句、程序段、进程之间的执行次序

**Definition**

Precedence graph（前趋图）is a Directed Acyclic Graph（有向无环图，DAG）.

- Node(结点):
  一个执行单元（如一条语句、一个程序段或进程）
- Edge(边，directed edge(有向边)):
  The precedence relation（前趋关系）“$\rightarrow$”，
  $\rightarrow = \{(P_i, P_j) \mid P_i$必须在$P_j$开始执行前执行完$\}$

# Precedence Graph（前趋图）

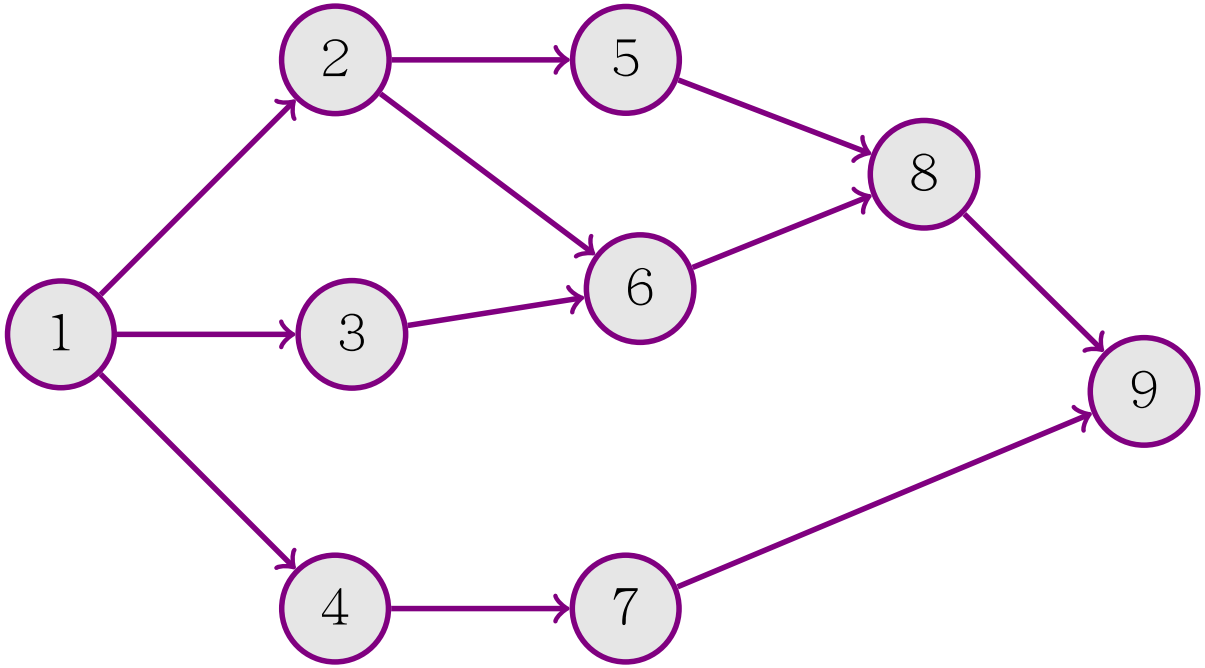
- If $(P_i, P_j) \in \rightarrow$, then $P_i \rightarrow P_j$
  Here,
  $P_i$ is called the **predecessor(前趋)** of $P_j$, and
  $P_j$ the **subsequent(后继)** of $P_i$

- 没有前趋的结点称为**初始结点**（initial node）
- 没有后继的结点称为**终止结点**（final node）

- 结点上使用一个**权值**（weight）表示
  该结点所含的程序量或结点的执行时间

# Precedence Graph（前趋图）

- Example:



# Outline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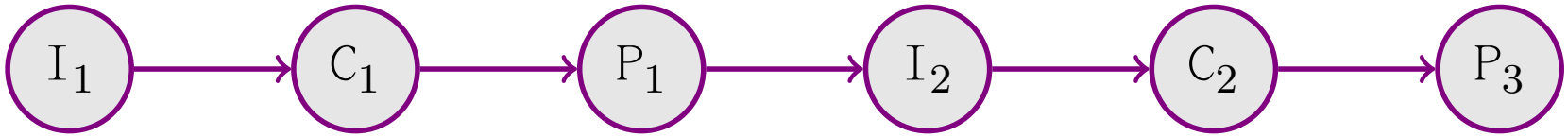
   - Concurrent execution of programs (程序的并发执行)

# Seriel execution of programs(程序的顺序执行)

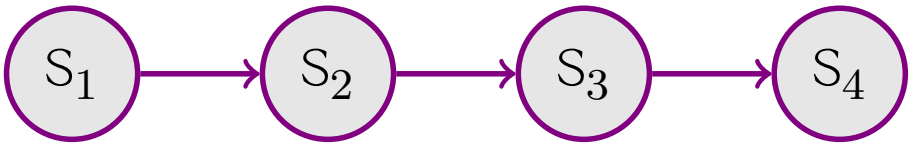
- 一个较大的程序通常包含若干个程序段。程序在执行时，必须按照某种先后顺序逐个执行，仅当前一个程序段执行完，后一个程序段才能执行。
  例如



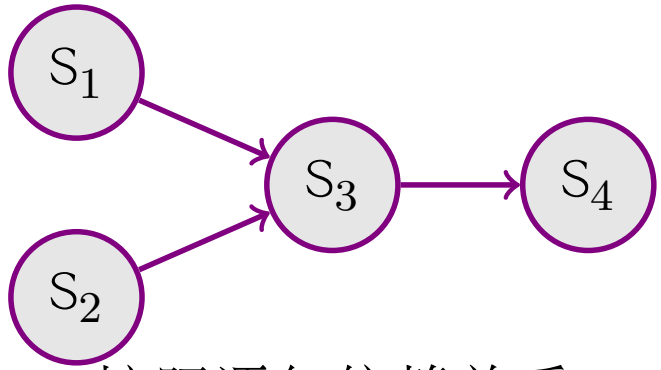

  其中
  - I代表用户程序和数据的输入;
  - C代表计算;
  - P代表输出结果

# Seriel execution of programs(程序的顺序执行)

- 在一个程序段中，多条语句也存在执行顺序的问题。
  在下面的例子中，S1和S2必须在S3执行前执行完。
  类似的，S4必须在S3执行完才能执行。
  1. S1：a＝x＋3
  2. S2：b＝y＋4
  3. S3：c＝a＋b
  4. S4：d＝a＋c




按指令地址顺序执行




按照语句依赖关系

# 程序顺序执行时的特征

## 1 顺序性

- 严格按照程序规定的顺序执行

## 2 封闭性

- 程序是在封闭的环境下运行的。独占全机资源。一旦开始运行，结果不受外界因素的影响。

## 3 可再现性

- 只要程序执行时的环境和初始条件相同，都将获得相同的结果。

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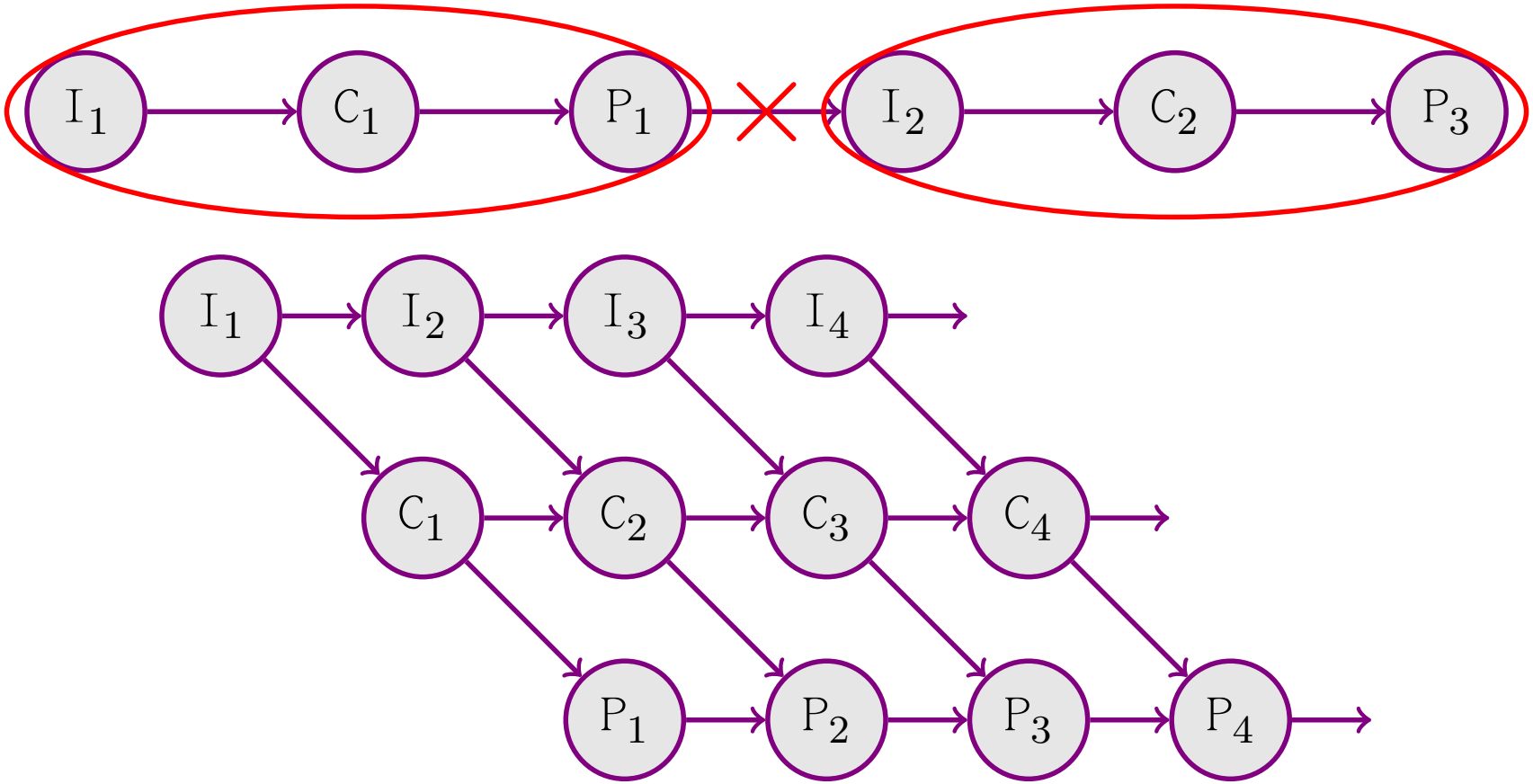
# Concurrent execution of programs（程序的并发执行）

- $P_i$与$I_{i+1}$之间不存在内在的前趋关系




程序并发执行时的前趋图

# 程序并发执行时的特征

## 1 间断性

- 并发程序“执行——暂停执行——执行”

## 2 失去封闭性

- 由于资源共享，程序之间可能出现相互影响的现象

## 3 不可再现性

- 原因同上。
- 举例：变量N的共享，设某时刻N＝n，则若执行顺序为：

```
1. N:＝N＋1; print(N); N:=0; N的值依次为n＋1; n＋1; 0
2. print(N); N:=0; N:＝N＋1;  N的值依次为n; 0; 1
3. print(N); N:＝N＋1; N:=0; N的值依次为n; n＋1; 0
```

# 程序并发执行的条件(Bernstein's conditions)

- 在上述3个特性中，必须防止“不可再现性”。
- 为使并发程序的执行保持“可再现性”，引入并发执行的条件。
  - **思路**：分析程序或语句的输入信息和输出信息，考察它们的相关性
  - Definitions, notation and terminology:
    - **读集**$R(p_i)$，表示程序$p_i$在执行时需要参考的所有变量的集合
    - **写集**$W(p_i)$，表示程序$p_i$在执行期间要改变的所有变量的集合
  - 1966, Bernstein: if programs $p_1$ and $p_2$ meet the following conditions, they can be executed **concurrently**, and have **reproducibility (可再现性)**
    1. If process $p_i$ writes to a memory cell $M_i$, then no process $p_j$ can read the cell $M_i$.
    2. If process $p_i$ read from a memory cell $M_i$, then no process $p_j$ can write to the cell $M_i$.
    3. If process $p_i$ writes to a memory cell $M_i$, then no process $p_j$ can write to the cell $M_i$.

$$R(p_1) \bigcap W(p_2) \bigcup R(p_2) \bigcap W(p_1) \bigcup W(p_1) \bigcap W(p_2) = \varnothing$$

# Outline


2 Process Concept
- the Processes
- Process State
- Process Control Block (PCB)

# Outline


2 Process Concept
- the Processes
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- Process Control Block (PCB)

- 进程需要使用某种方法加以描述，原因
  1. 进程运行的间断性，要求在进程暂停运行时记录该程序的现场，以便下次能正确的继续运行
  2. 资源的共享，要求能够记录进程对资源的共享情况
  3. 为保证程序“正确”的并发执行，必须将进程看成某种对象，对其进行描述并加以控制

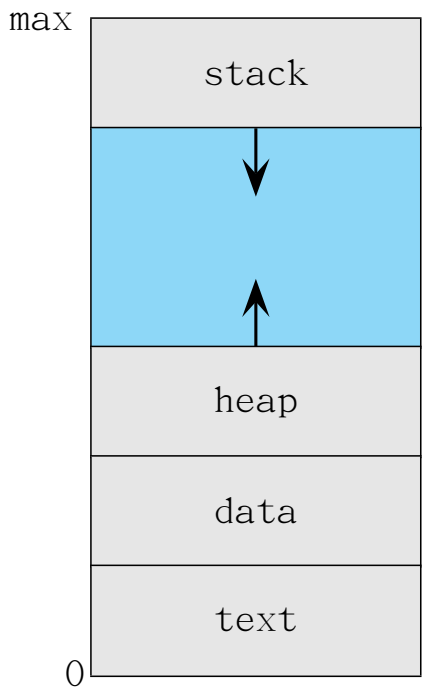
# Process Concept I

- An OS executes a variety of programs:
  - Batch system - jobs
  - Time-shared systems - user programs or tasks
  - PC - several programs: a word processor, a web browser, etc.
- we call all of them process
  - a program in execution;
  - process execution must progress in sequential fashion

# Process Concept II

## A process includes:

- text section⇐program code
- program counter + other registers⇐current activity
- stack⇐temporary data
- data section⇐global variables
- heap




## COMPARE: Program vs. Process?

- Program: a passive entity (静态的)
- Process: a active entity (活动的)

# 进程的五大特征

1. 动态性：最基本的特性
2. 并发性
3. 独立性
4. 异步性
5. 结构特征

# 进程的五大特征

1. **动态性：最基本的特性**

   “它由创建而产生，由调度而执行，因得不到资源而暂停执行，以及由撤销而消亡”

   - 具有生命期
2. **并发性**
3. **独立性**
4. **异步性**
5. **结构特征**

# 进程的五大特征

1. 动态性：最基本的特性
2. 并发性
   - 多道
   - 既是进程也是OS的重要特征
3. 独立性
4. 异步性
5. 结构特征

# 进程的五大特征

1. **动态性：最基本的特性**
2. **并发性**
3. **独立性**
   - 进程是一个能独立运行的基本单位，也是系统中独立获得资源和独立调度的基本单位。
4. **异步性**
5. **结构特征**

# 进程的五大特征

1. **动态性：最基本的特性**
2. **并发性**
3. **独立性**
4. **异步性**
   - 进程按各自独立的、不可预知的速度向前推进。
   - 导致“不可再现性”
   - OS必须采取某种措施来保证各程序之间能协调运行。
5. **结构特征**

# 进程的五大特征

1. 动态性：最基本的特性
2. 并发性
3. 独立性
4. 异步性
5. 结构特征
   - 从结构上看，进程实体是由程序段、数据段及进程控制块三部分组成

$$\text{进程映像} = \text{程序段} + \text{数据段} + \text{进程控制块}$$

# Outline


2 Process Concept
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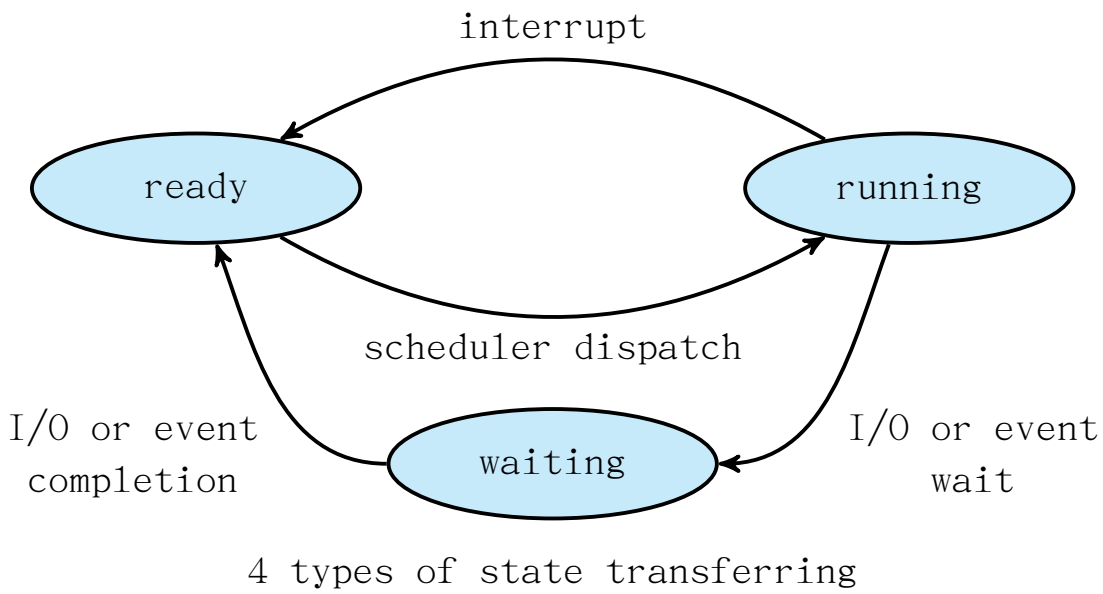
# Process State

- As a process executes, it changes its state.

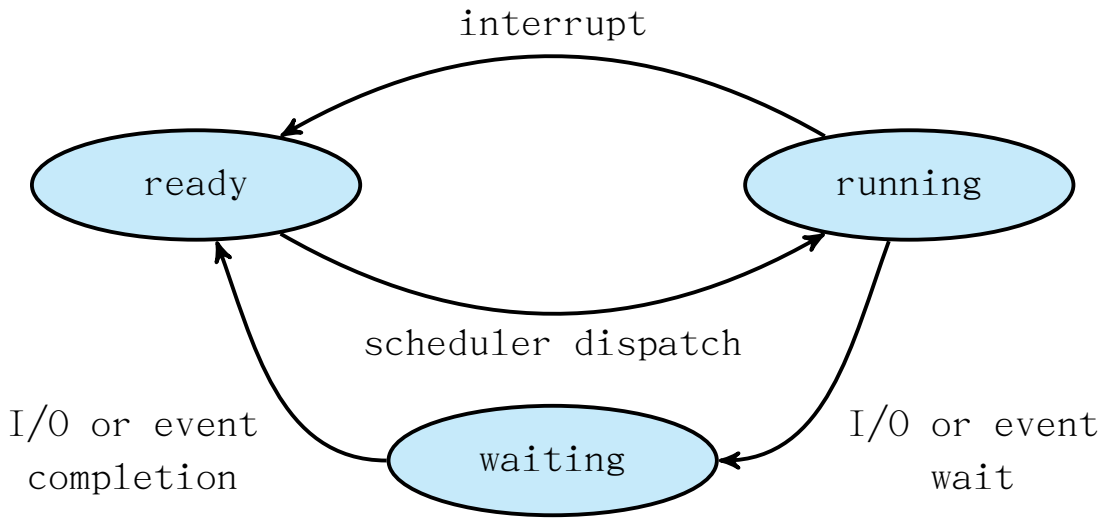
## State Models（状态模型）

1. 最基本的“三状态”模型
2. 引入“新”和“终止”态的“五状态”模型
3. 引入“挂起”状态的“七状态”模型

- 三种最基本的状态
  1. ready（就绪）：“万事具备，只欠CPU”
  2. running（执行）
  3. waiting（等待，also blocked(阻塞)，sleeping(睡眠)）

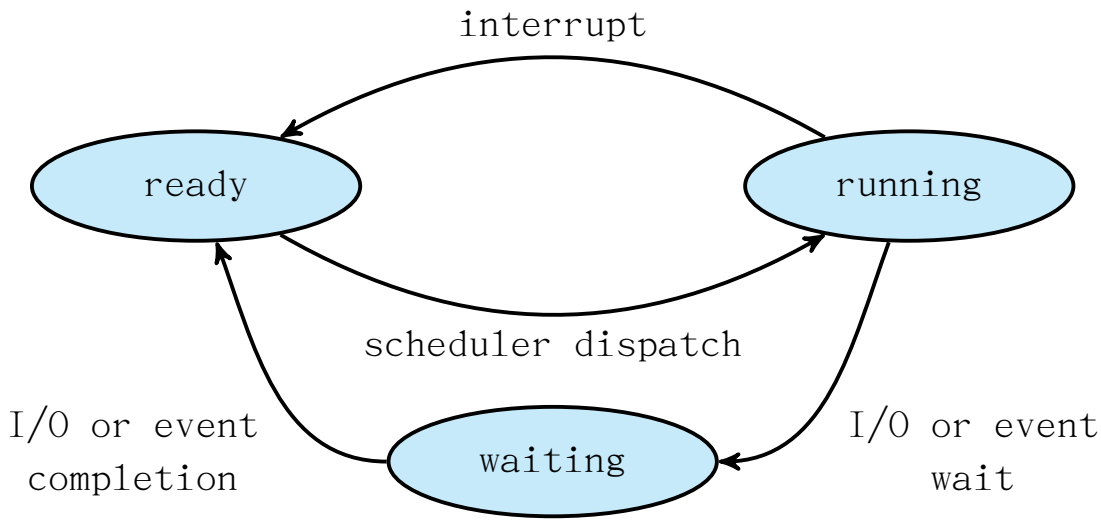


- 三种最基本的状态
  1. ready (就绪): “万事具备，只欠CPU”
     - DataStructure: ready queue
  2. running (执行)
  3. waiting (等待, also blocked(阻塞), sleeping(睡眠))




4 types of state transferring

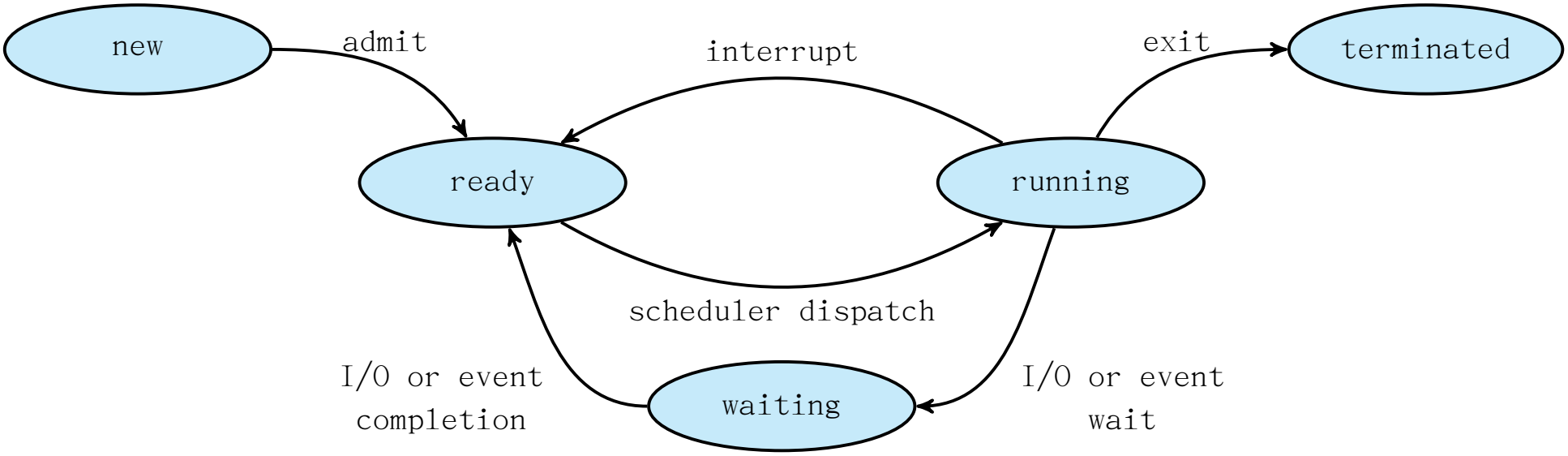
- 三种最基本的状态
  1. ready (就绪): “万事具备，只欠CPU”
  2. running (执行)
  3. waiting (等待, also blocked(阻塞), sleeping(睡眠))
     The process is waiting for some event to occur:
     - I/O completion, reception of a signal, resource allocation, etc.
     - DataStructure: waiting queue




4 types of state transferring

# 2 “五状态”模型

- Two more states is added to the “three state” model.
  1. **new** (新状态): The process is beig created
     - initialization, resource preallocation, etc.
  2. **terminated** (终止状态): The process has finished execution, normally or abnormally.
     - removed from ready queue, but still not destroyed.
     - other process may gather some information from the terminated processes




6 types of state transferring

- 进程因自身内部的一些原因，无法继续运行时，暂时进入“等待”状态，当等待的原因消除后，就可以返回就绪状态；
  但有时会因进程外部的一些原因，使得进程暂时不能继续运行。
  外部原因主要有
  1. 终端用户的需要
  2. 父进程的需求
  3. 操作系统的需要
  4. 对换(swapping)的需要
  5. 负载(work load)调节的需要

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**引入“挂起”状态**

- 进程因自身内部的一些原因，无法继续运行时，暂时进入“等待”状态，当等待的原因消除后，就可以返回就绪状态；
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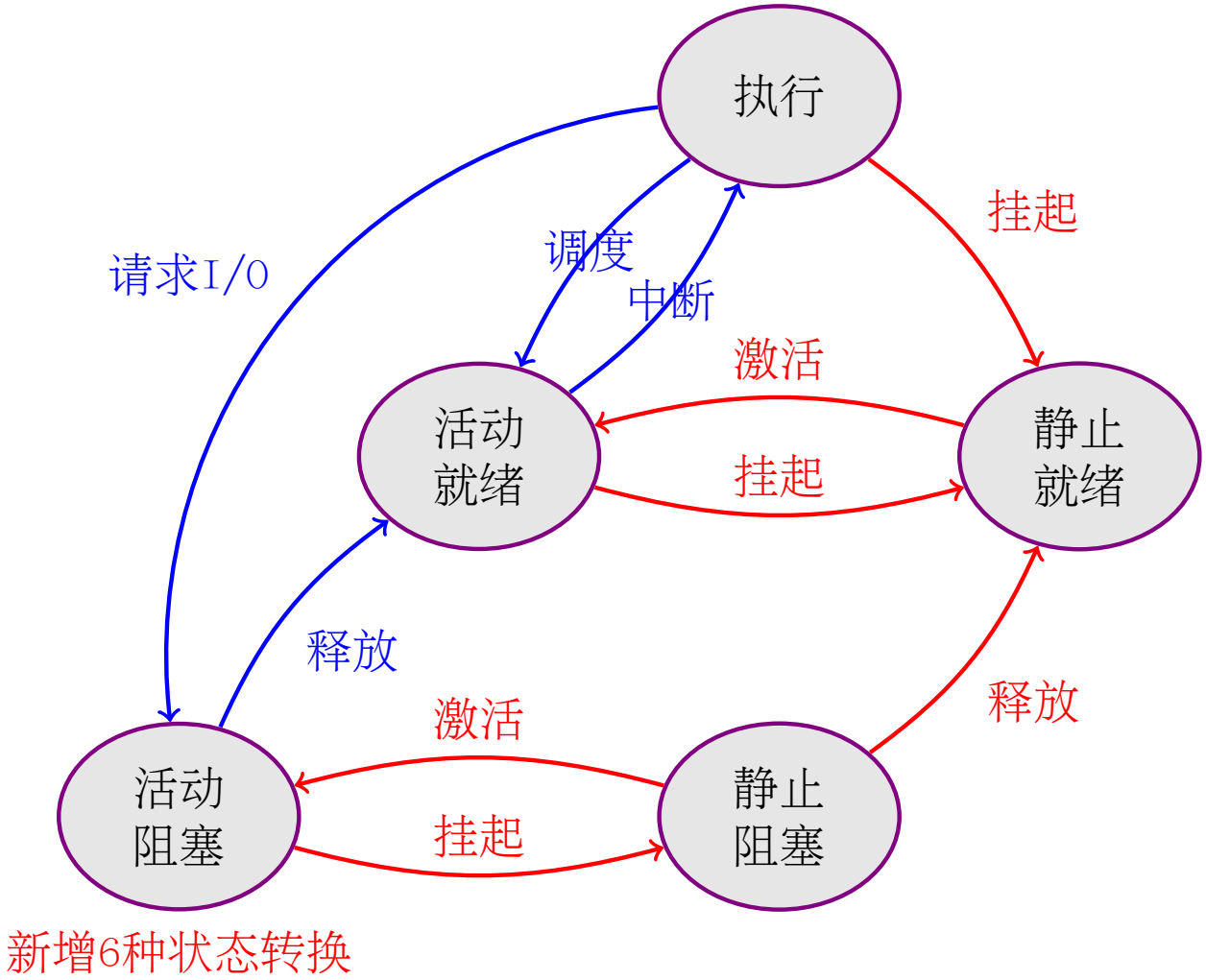
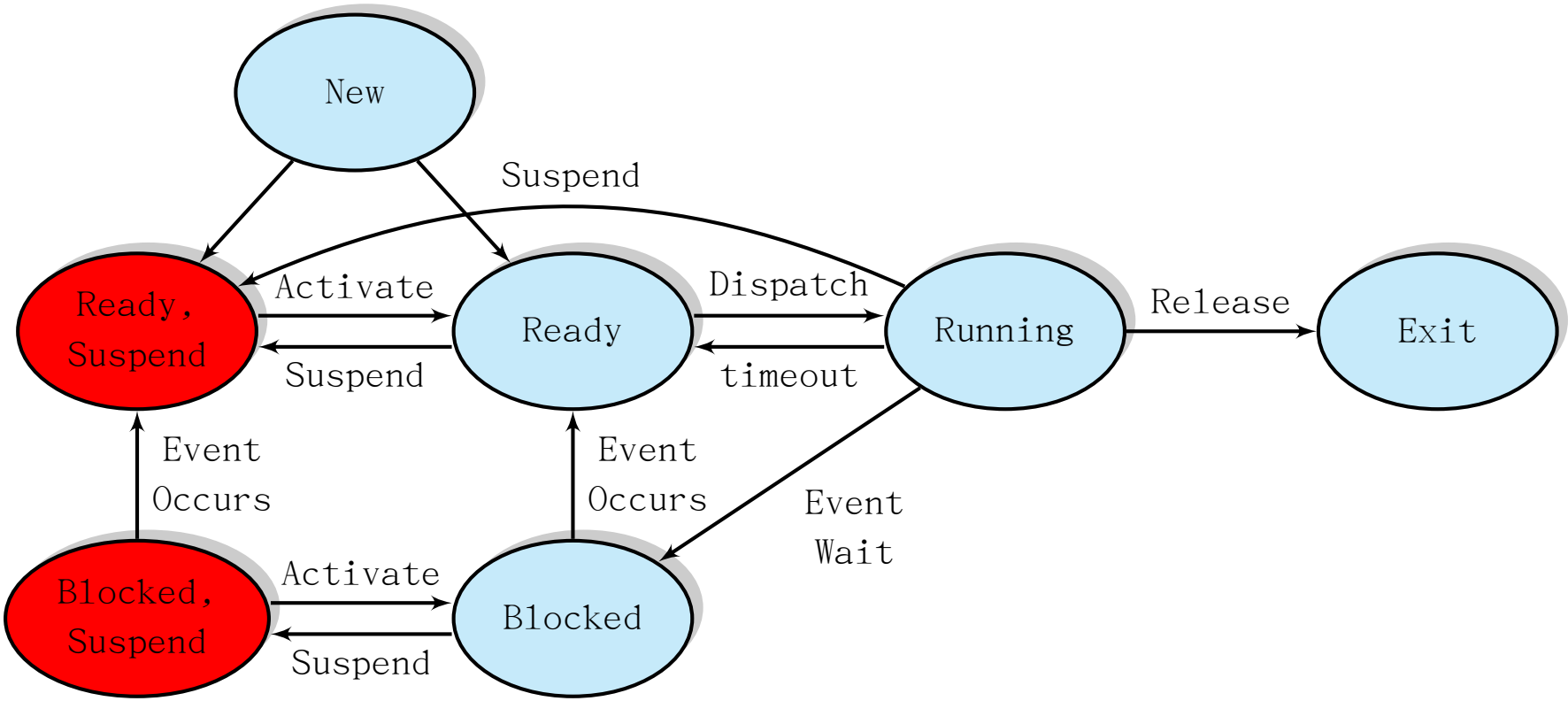
## 引入“挂起”状态

- “挂起”状态不是一种状态，而是**一类状态**
  - 挂起后处于静止状态：**静止就绪**，**静止阻塞**
  - 非挂起的活动状态：**活动就绪**，**活动阻塞**，还包括**执行态**

- 在状态转换中，增加了活动状态与静止状态之间、静止状态内部之间的状态转换



- 包含“挂起”状态的“7状态”模型



# Outline


2 Process Concept
- the Processes
- Process State
- Process Control Block (PCB)

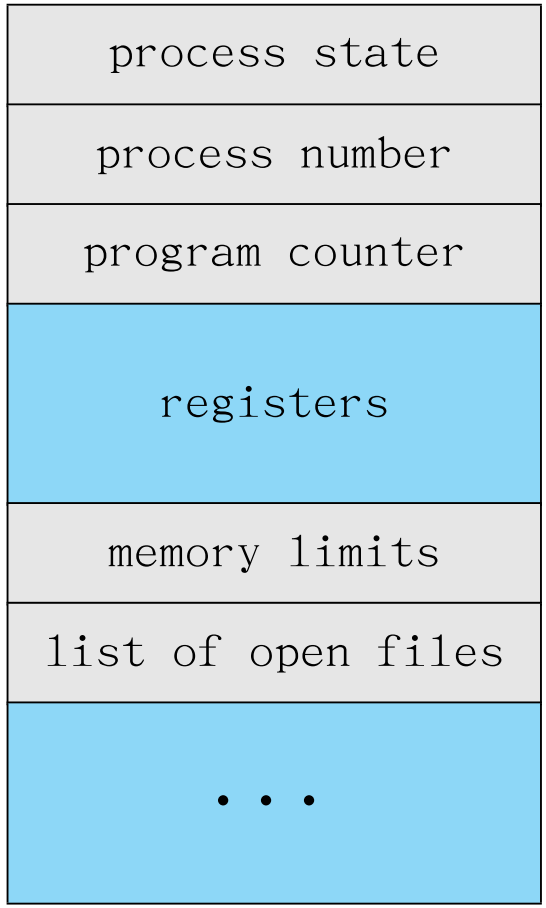
# Process Control Block（进程控制块，PCB）

- Each process is represented in the OS by a PCB, also called Task Control Block, TCB
  是操作系统中的一种关键数据结构
  - 由操作系统进程管理模块维护
  - 常驻内存
- 操作系统根据PCB来控制和管理并发执行的进程

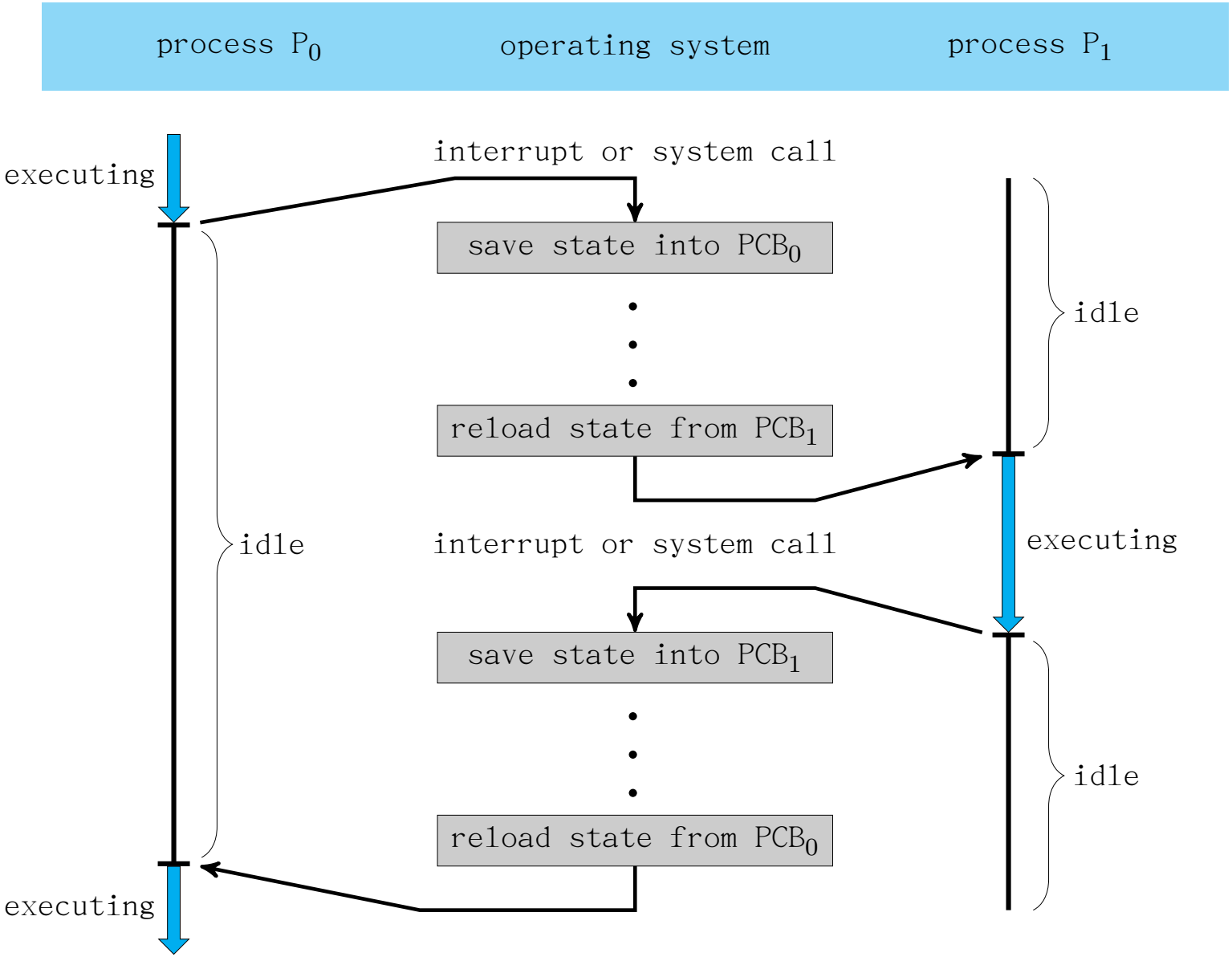
**PCB是进程存在的唯一标志**

# Process Control Block（进程控制块，PCB）

- Information associated with each process
  - Process state (...)
  - Program counter
  - CPU registers
  - CPU-scheduling information
  - Memory-management information
  - Accounting information: time used, time limit, ...
  - I/O status information



# CPU Switch From Process to Process



# Examples I

- 观察：数据结构和状态
  - struct task_struct in Linux0.11 & Linux 2.6.26
  - struct OS_TCB in $\mu$C/OS-II

```
typedef struct os_tcb {
    OS_STK *OSTCBStkPtr; /* Pointer to current top of stack */
#if OS_TASK_CREATE_EXT_EN > 0
    void *OSTCBExtPtr; /* Pointer to user definable data for TCB extension */
    OS_STK *OSTCBStkBottom; /* Pointer to bottom of stack */
    INT32U OSTCBStkSize; /* Size of task stack (in number of stack elements) */
    INT16U OSTCBOpt; /* Task options as passed by OSTaskCreateExt() */
    INT16U OSTCBId; /* Task ID (0..65535) */
#endif
    struct os_tcb *OSTCBNext; /* Pointer to next TCB in the TCB list */
    struct os_tcb *OSTCBPrev; /* Pointer to previous TCB in the TCB list */
#if ((OS_Q_EN > 0) && (OS_MAX_QS > 0)) || (OS_MBOX_EN > 0) || (OS_SEM_EN > 0) ||
(OS_MUTEX_EN > 0)
    OS_EVENT *OSTCBEventPtr; /* Pointer to event control block */
#endif
#if ((OS_Q_EN > 0) && (OS_MAX_QS > 0)) || (OS_MBOX_EN > 0)
```

# Examples II

```
    void *OSTCBMsg; /* Message received from OSMboxPost() or OSQPost() */
#endif
#if (OS_VERSION >= 251) && (OS_FLAG_EN > 0) && (OS_MAX_FLAGS > 0)
#if OS_TASK_DEL_EN > 0
    OS_FLAG_NODE *OSTCBFlagNode; /* Pointer to event flag node */
#endif
    OS_FLAGS OSTCBFlagsRdy; /* Event flags that made task ready to run */
#endif
    INT16U OSTCBDly; /* Nbr ticks to delay task or, timeout waiting for event */
    INT8U OSTCBStat; /* Task status */
    INT8U OSTCBPrio; /* Task priority (0 == highest, 63 == lowest) */
    INT8U OSTCBX; /* Bit position in group corresponding to task priority (0..7) */
    INT8U OSTCBY; /* Index into ready table corresponding to task priority */
    INT8U OSTCBBitX; /* Bit mask to access bit position in ready table */
    INT8U OSTCBBitY; /* Bit mask to access bit position in ready group */
#if OS_TASK_DEL_EN > 0
    BOOLEAN OSTCBDelReq; /* Indicates whether a task needs to delete itself */
#endif
} OS_TCB;
```

# Outline


3 Process Scheduling
- Process Scheduling Queues
- Schedulers
- Context Switch(上下文切换)

# Process Scheduling

**The objective of multiprogramming**

to have some process running at all times, to maximize CPU utilization.

**The objective of time sharing**

to switch the CPU among processes so frequently that users can interact with each program whilt it is running.

**What the system need?**

the process scheduler selects an available process to execute on the CPU.

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# Outline

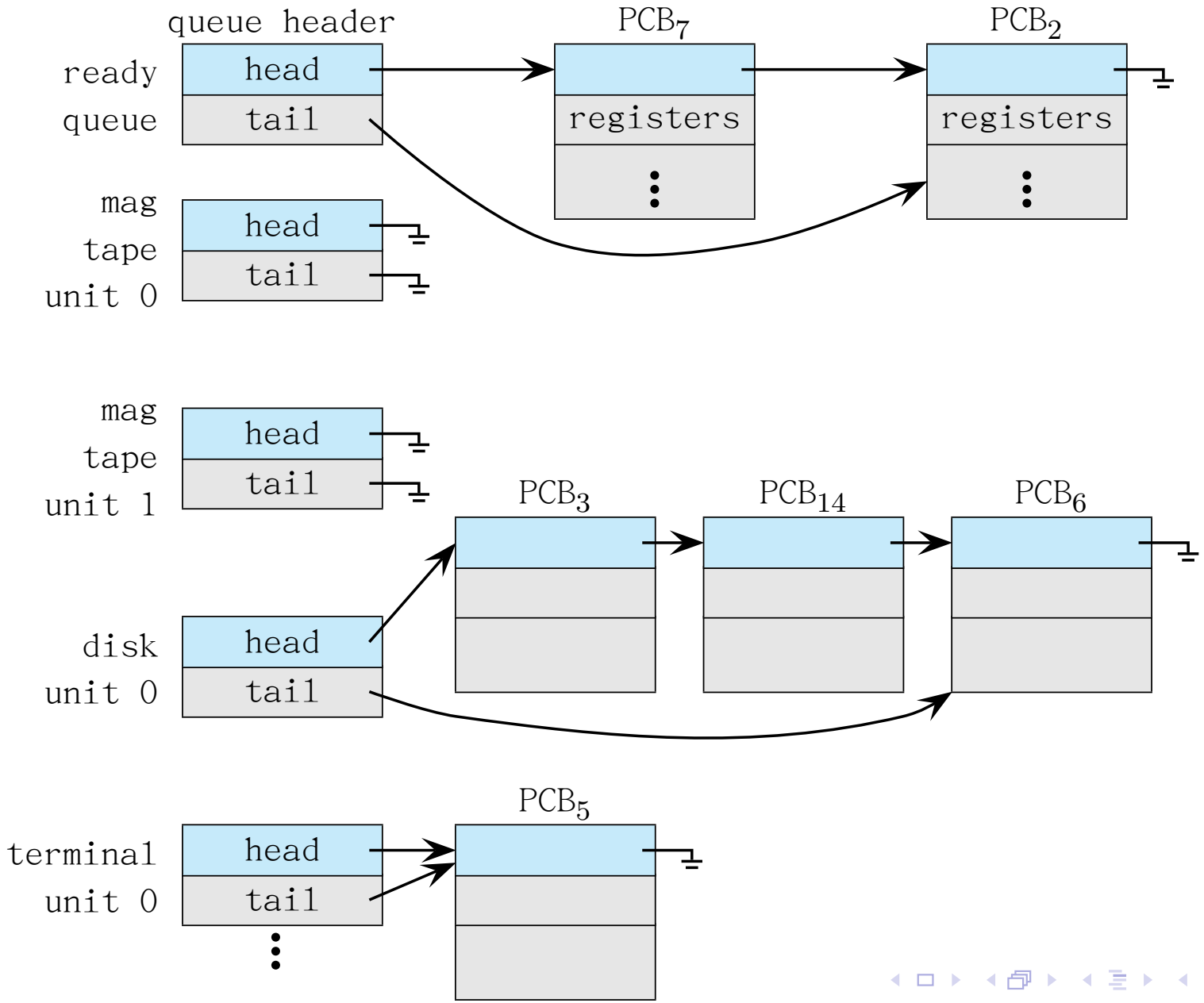

3 Process Scheduling
- Process Scheduling Queues
- Schedulers
- Context Switch(上下文切换)

# Process Scheduling Queues

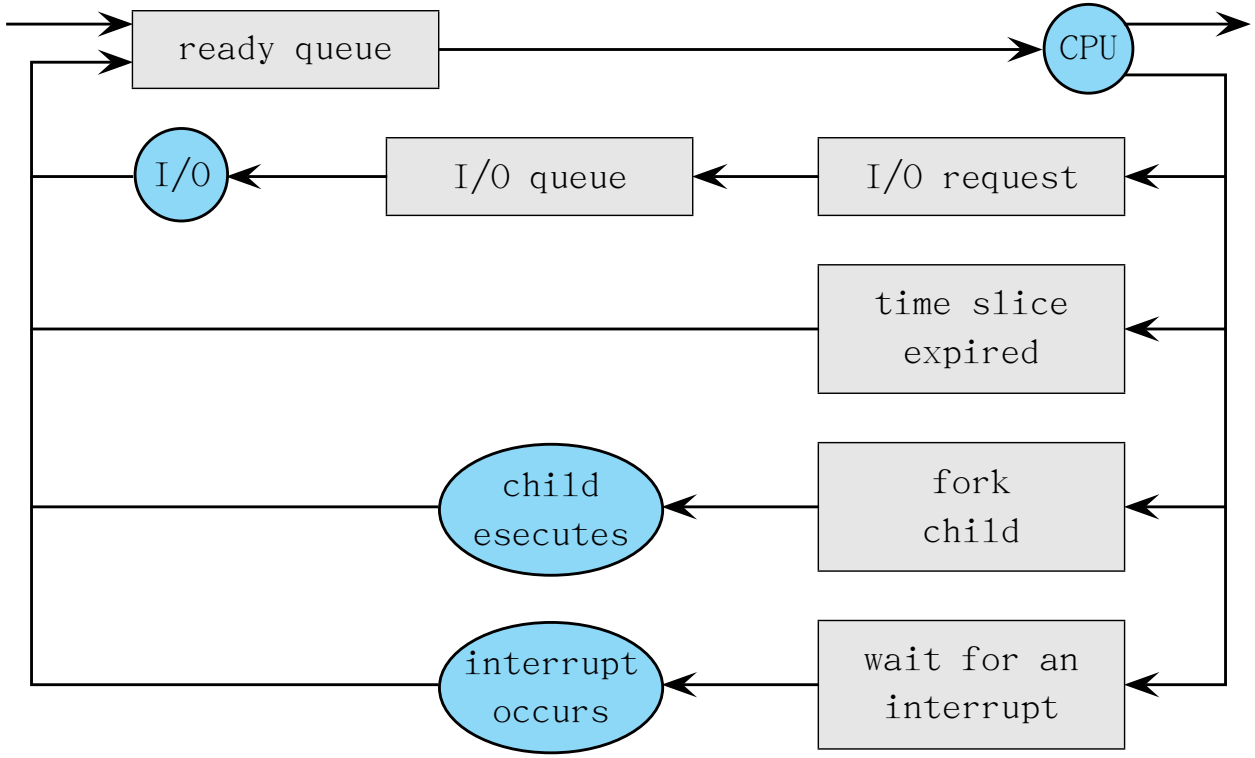
## Processes migrate among the various queues

- **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

# Ready Queue And Various I/O Device Queues



# Representation of Process Scheduling




Queueing-diagram representation of process scheduling

# Outline


3 Process Scheduling
- Process Scheduling Queues
- Schedulers
- Context Switch(上下文切换)

# Schedulers I

## Long-term (长期) scheduler (or job scheduler)

- selects which processes should be brought into the ready queue

## Short-term (短期) scheduler (or CPU scheduler)

- selects which process should be executed next and allocates CPU

# The primary distinction between long-term & short-term schedulers I

- The prilmary distinction between long-term & short-term schedulers lies in frequency of execution
  - Short-term scheduler is invoked very frequently (UNIT: ms) $\Rightarrow$ must be fast
  - Long-term scheduler is invoked very infrequently (UNIT: seconds, minutes) $\Rightarrow$ may be slow
  - WHY?
- The long-term scheduler controls the degree of multiprogramming (多道程序度)
  - the number of processes in memory.
  - stable?

# The primary distinction between long-term & short-term schedulers II

- Processes can be described as either:

**I/O-bound (I/O密集型) process**

- spends more time doing I/O than computations, many short CPU bursts

**CPU-bound (CPU密集型) process**

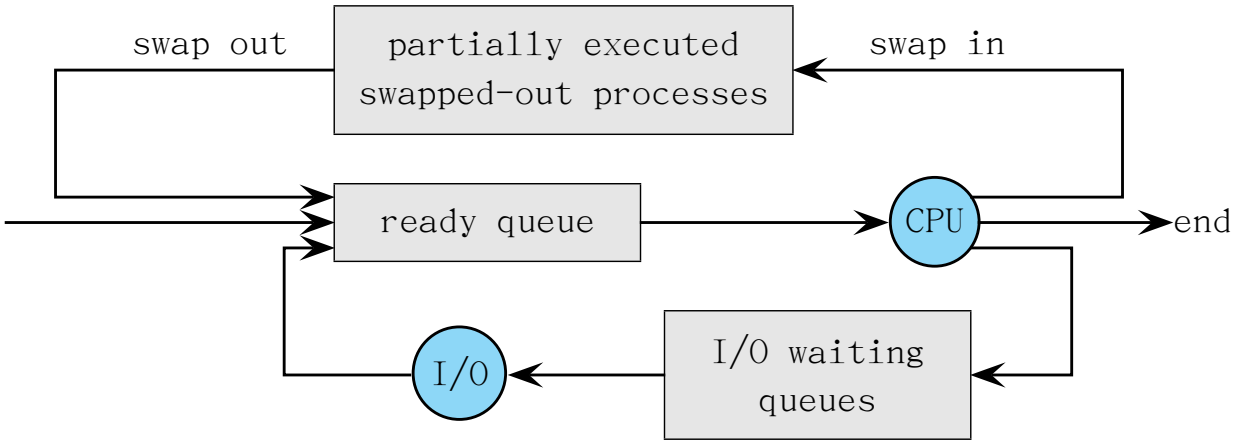
- spends more time doing computations; few very long CPU bursts

- IMPORTANT for long-term scheduler:
  - A good process mix of I/O-bound and CPU-bound processes.

- The long-term scheduler may be absent or minimal
  - UNIX, MS Windows, ...
  - The stability depends on
    - physical limitation
    - self-adjusting nature of human users

# Addition of Medium Term (中期) Scheduling

- **Medium-Term (中期) Scheduler**
  - can **reduce** the degree of multiprogramming
  - the scheme is called **swapping (交换)**: swap in VS. swap out




Addition of medium-term scheduling to the queueing diagram

# Outline


3 Process Scheduling
- Process Scheduling Queues
- Schedulers
- Context Switch(上下文切换)

# Context Switch（上下文切换）

- CONTEXT（上下文）
  - when an interrupt occurs; When scheduling occurs

**the context is represented in the PCB of the process**

- CPU registers
- process state
- memory-management info
- ...

  - operation: state save VS. state restore

# Context Switch（上下文切换）

- Context switch
  - 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 (typical: n $\mu$s)
    - CPU & memory speed
    - N of registers
    - the existence special instructions

# Code reading

- 观察
  - 队列的组织
  - 上下文的内容和组织
  - 上下文切换
- linux-0.11
- linux-2.6.26
- uC/OS-II

# Outline


4 Operation on processes
- Process Creation
- Process Termination

# Operation on processes

- The processes in most systems can execute concurrently, and they may be created and deleted dynamically.
- The OS must provide a mechanism for
  - process creation
  - process termination

# Outline


4 Operation on processes
- Process Creation
- Process Termination

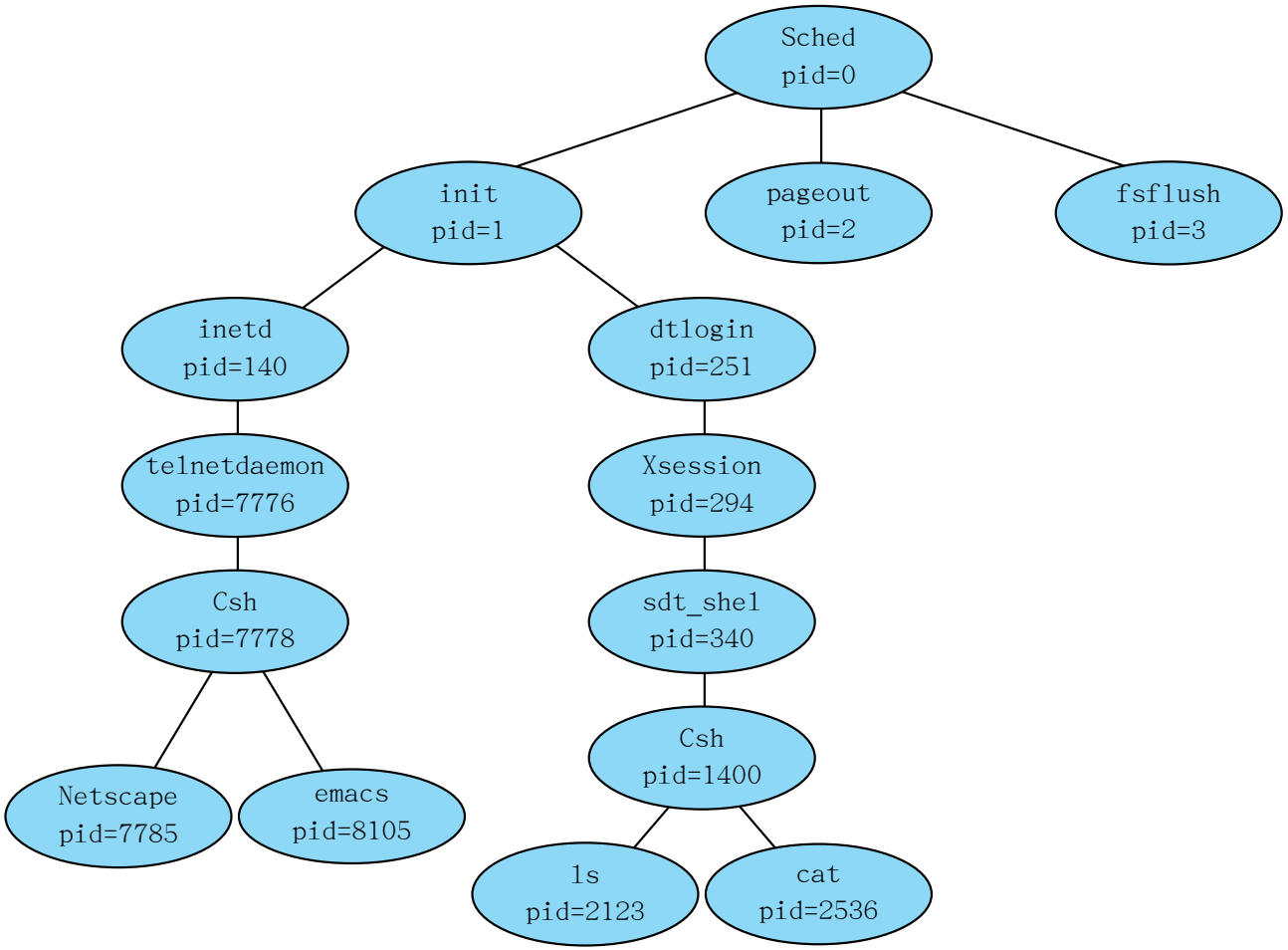
# Process Creation I

- Parent process (父进程) create children processes (子进程), which, in turn create other processes, forming a tree of processes
- Most OSes identify processes according to a unique process identifier (pid).
  - typically an integer number
- UNIX & Linux

**Command:**

```
ps -el
```

# Process Creation II



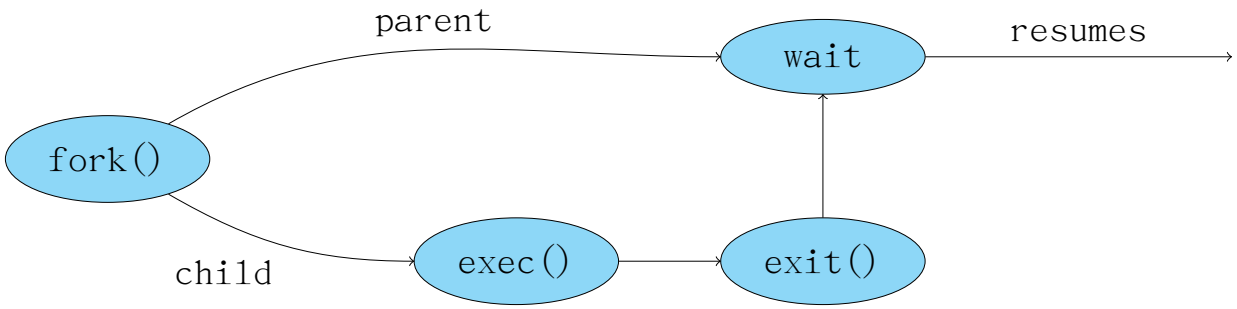

A tree of processes on a typical Solaris

# Parent and children

- **Resource sharing**
  - In general, a process will need certain resources (CPU time, memory, files, I/O devices) to accomplish its task.
  - When a process creates a subprocesses
    - Parent and children may **share all** resources, or
    - Children may **share subset** of parent's resources, or
    - Parent and child may **share no** resources
- **Execution**
  - Parent and children execute concurrently
  - Parent **waits** until children terminate
- **Address space**
  - Child duplicate of parent
  - Child has a program loaded into it

# UNIX examples: fork + exec

- fork system call creates new process
- exec system call used after a fork to replace the process' memory space with a new program




```
#include <unistd.h>
pid_t fork(void);
```

```
#include <unistd.h>
extern char **environ;
int execl(const char *path, const char *arg, ...);
int execlp(const char *file, const char *arg, ...);
int execle(const char *path, const char *arg, ..., char * const envp[]);
int execv(const char *path, char *const argv[]);
int execvp(const char *file, char *const argv[]);
```

# C Program Forking Separate Process

```
int main(void) {
    pid_t pid;
    /* fork another process */
    pid = fork();
    if (pid < 0) {      /* error occurred */
        fprintf(stderr, "Fork Failed");
        exit(-1);
    } else if (pid == 0) {      /* child process */
        execlp("/bin/ls", "ls", NULL);
    } else {      /* parent process */
        /* parent will wait for the child to complete */
        wait (NULL);
        printf ("Child Complete");
        exit(0);
    }
}
```

# Outline


4 Operation on processes
- Process Creation
- Process Termination

# Process Termination

1. [Self]Process executes last statement and asks the OS to delete it by using the **exit()** system call.
   - Output data (**a status value**, typically an integer) **from child to parent** (via **wait()**)
   - Process' **resources** are **deallocated** by the OS
2. [Other]Termination can be caused by another process
   - Example: TerminateProcess() in Win32
3. [User]Users could **kill** some jobs.

# Process Termination

4. [Parent]Parent may terminate execution of children processes (abort)
   - Child has exceeded allocated resources
   - Task assigned to child is no longer required
   - If parent is exiting

**Some operating system do not allow child to continue if its parent terminates**

- All children terminated - cascading termination

# Process Termination

- UNIX Example:
  - If the parent terminates, all its children have assigned as their new parent the init process.

```
#include <stdlib.h>
void exit(int status);
```

```
#include <sys/types.h>
#include <sys/wait.h>
pid_t wait(int *status);
```

# Example: echo.

```
#include <stdio.h>
int main(void){
    char string[80];
    int i;
    printf("HELLO! NICE TO MEET YOU!\n");
    for (i=0;i<10;i++){
        printf("Input %d: ",i);
        scanf("%s",string);
        printf("You say: %s\n",string);
    }
    printf("GOODBYE!\n");
}
```

**Describe the whole life of a process executing echo.**

# Outline

5 Interprocess Communication (进程间通信, IPC)
- Shared-Memory systems
- Message-Passing Systems

# Interprocess Communication（进程间通信，IPC）

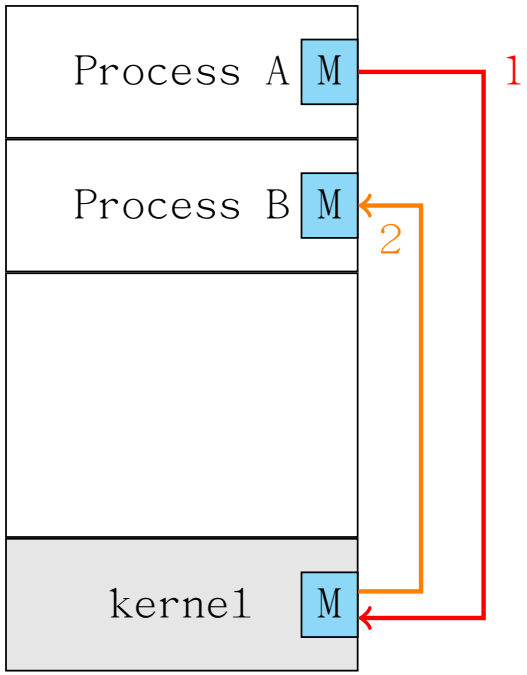
- Processes executing concurrently in the OS may be either **independent processes** or **cooperating processes**
  - **Independent process cannot** affect or be affected by the execution of other processes
  - **Cooperating process can** affect or be affected by the execution of other processes
- **Advantages** of allowing process cooperation
  - **Information sharing**: a shared file VS. several users
  - **Computation speed-up**: 1 task VS. several subtasks in parallel with multiple processing elements (such as CPUs or I/O channels)
  - **Modularity**
  - **Convenience**: 1 user VS. several tasks
- Cooperating processes require an **IPC mechanism** that will allow them **to exchange data and information**.

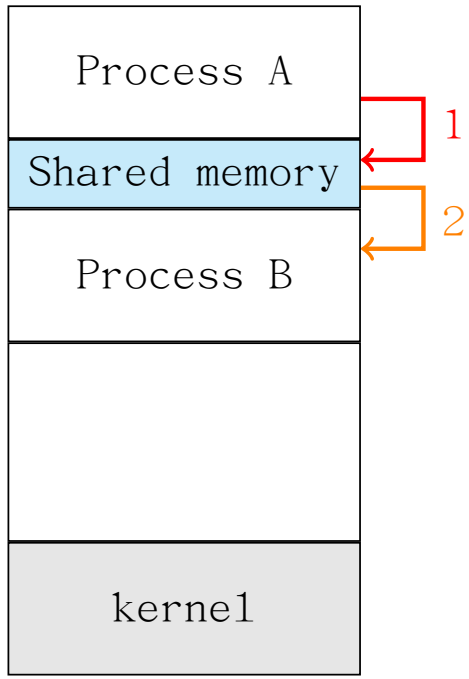
## Two fundamental models of IPC:

1. Message-passing（消息传递）model
   - useful for exchange **smaller amount of data**, because no conflicts need be avoided.
   - **easier to implement**
   - **exchange information via system calls** such as send(), receive()
2. Shared-memory（共享内存）model

## Two fundamental models of IPC:

1. Message-passing（消息传递）model
2. Shared-memory（共享内存）model
   - **faster** at memory speed via memory accesses.
   - system calls only used to establish shared memory regions



# Outline


5 Interprocess Communication (进程间通信, IPC)
- Shared-Memory systems
- Message-Passing Systems

# Shared-Memory systems

- Normally, the OS tries to prevent one process from accessing another process's memory.
- Shared memory requires that two or more processes agree to remove this restriction.
  - exchange information by R/W data in the shared areas.
  - The form of data and the location are determined by these processes and not under the OS's control.
  - The processes are responsible for ensuring that they are not writing to the same location simultaneously.

# Example: Producer-Consumer Problem (生产者-消费者问题)

- Producer-Consumer Problem (生产者-消费者问题, PC问题): Paradigm for cooperating processes
  - producer (生产者) process produces information that is consumed by a consumer (消费者) process.
- Shared-Memory solution
  - a buffer of items shared by producer and consumer
- Two types of buffers:
  1. unbounded-buffer places no practical limit on the size of the buffer
  2. bounded-buffer assumes that there is a fixed buffer size

# Example: Producer-Consumer Problem (生产者-消费者问题)

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  - **producer (生产者)** process produces information that is consumed by a **consumer (消费者)** process. Example:

$$\text{complier} \xrightarrow{\text{assembly code}} \text{assembler} \xrightarrow{\text{object models}} \text{loader}$$

- **Shared-Memory solution**
  - a buffer of items shared by producer and consumer
- **Two types of buffers:**
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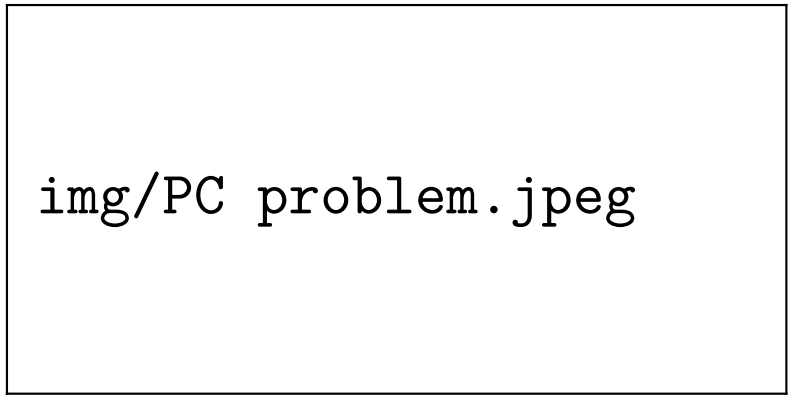


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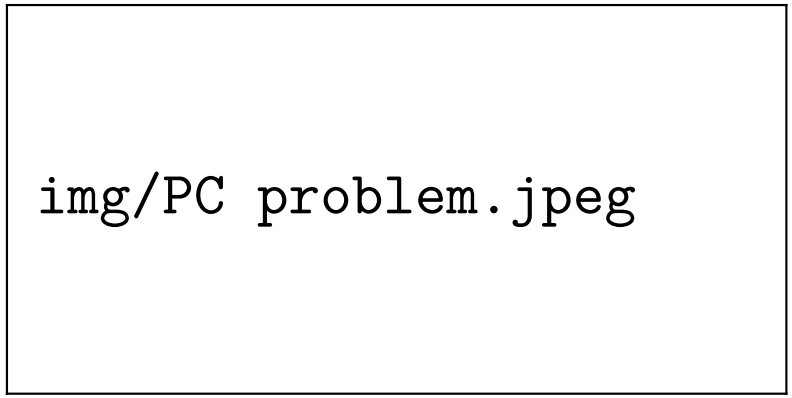


- Two types of buffers:
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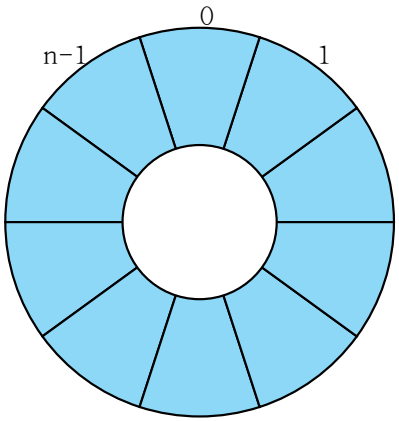
# Bounded-Buffer — Shared-Memory Solution




## Insert() Method

```
while (true) {
      /* Produce an item */
      while (((in + 1) % BUFFER_SIZE) == out)
            ; /* do nothing — no free buffers */
      buffer[in] = item;
      in = (in + 1) % BUFFER SIZE;
}
```

## Shared variables reside in a shared region

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

item buffer[BUFFER_SIZE];
int in = 0; // index of the next empty buffer
int out = 0; // index of the next full buffer
```

## Remove() Method

```
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;
}
```

- all empty? all full? ⇒Solution is "correct", but can only use BUFFER_SIZE-1 elements

# Outline


5 Interprocess Communication (进程间通信, IPC)
- Shared-Memory systems
- Message-Passing Systems

# Message-Passing Systems

- Message passing (消息传递)
  - provides a mechanism for processes to communicate and to synchronize their actions without sharing the same address space.
  - processes communicate with each other without resorting to shared variables
  - particularly useful in a distributed environmet.
- IPC facility provides at least two operations:
  1. send(message) — message size fixed or variable
  2. receive(message)
- If process P and Q wish to communicate, they need to:
  1. establish a communication link between them
  2. exchange messages via send/receive
- Implementation of communication link
  1. physical (e.g., shared memory, hardware bus)
  2. logical (e.g., logical properties)

# Implementation Questions

- 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?

# 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 communication link in this scheme
  - 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
- Symmetry VS asymmetry
  - send(P, message)
  - receive(id, message) - receive a message from any process

# Indirect Communication

- Messages are directed and received from mailboxes (also referred to as ports)
  - Each mailbox has a unique id (such as POSIX message queues)
  - Processes can communicate only if they share a mailbox
  - Primitives are defined as:
    - send(A, message) — send a message to mailbox A
    - receive(A, message) — receive a message from mailbox A
- Properties of communication link in this scheme
  - 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

- **Mailbox sharing problem**
  - P1, P2, and P3 share mailbox A
  - P1, sends; P2 and P3 receive
  - Who gets the message?
- **Solutions to choose**
  - 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.

# Indirect Communication

- Who is the **owner** of a mailbox?
  - **a process**
    - **only owner can receive** messages through its mailbox, others can only send messages to the mailbox.
    - when the process terminates, its mailbox disappears.
  - **the OS**
    - the mailbox is independent and is not attached to any particular process.
- **Operations**
  1. **create** a new mailbox
  2. **send/receive** messages through mailbox
  3. **destroy** a mailbox

# 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
- Difference combinations are possible.
  - If both are blocking ≡**rendezvous(集合点)**
- **The solution to PC problem** via message passing is trivial when we use blocking send()/receive().

# Buffering

- Queue of messages attached to the link; **implemented in one of three ways**
  1. **Zero capacity** — 0 messages
     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

# Outline


6 Example of IPC Systems
- POSIX Shared Memory
- Mach (by yourself)
- Windows XP

# Outline


6 Example of IPC Systems
- POSIX Shared Memory
- Mach (by yourself)
- Windows XP

## POSIX API for shared memory

```
#include<sys/ipc.h>
#include<sys/shm.h>
int shmget(key_t key, size_t size, int shmflg);
int shmctl(int shmid, int cmd, struct shmid_ds *buf);

#include<sys/types.h>
#include<sys/shm.h>
void* shmat(int shmid, const void* shmaddr, int shmflg);
int shmdt(const void* shmaddr);
```

## C program illustrating POSIX shared-memory API

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

int main(){
    int segment_id;
    char* shared_memory;
    const int size = 4096;

    segment_id = shmget(IPC_PRIVATE, size, S_IRUSR|S_IWUSR);
    shared_memory = (char*) shmat(segment_id, NULL, 0);

    sprintf(shared_memory, " Hi there!" );
    printf(" %s\n" ,shared_memory);

    shmdt(shared_memory);
    shmctl(segment_id, IPC_RMID, NULL);
    return 0;
}
```

## Two program using POSIX shared-memory: program1

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

int main(void) {
    key_t key;
    int shm_id;
    char * shm_addr;

    key=ftok(" ." ,' m' );
    shm_id=shmget(key,4096,IPC_CREAT|IPC_EXCL|S_IRUSR|
S_IWUSR);

    shm_addr=(char*)shmat(shm_id,0,0);

    sprintf(shm_addr," hello, this is llllllll\n" );
    printf(" llllll: %s" ,shm_addr);
    sleep(10);
    printf(" llllll: %s" ,shm_addr);
    shmdt(shm_addr);
    shmctl(shm_id,IPC_RMID,0);
    return 0;
}
```

## Two program using POSIX shared-memory: program2

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

int main(void) {
    key_t key;
    int shm_id;
    char * shm_addr;

    key=ftok(" ." ,' m' );
    shm_id=shmget(key,4096,S_IRUSR|S_IWUSR);

    shm_addr=(char*)shmat(shm_id,0,0);

    printf(" 22222222:" ,shm_addr);
    sprintf(shm_addr," this is 22222222\n" );
    shmdt(shm_addr);
    return 0;
}
```

# Outline


6 Example of IPC Systems
- POSIX Shared Memory
- Mach (by yourself)
- Windows XP

# Outline


6 Example of IPC Systems
- POSIX Shared Memory
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# LPC in Windows XP

- Subsystems
  - application programs can be considered clients of the Windows XP subsystems server.
  - application programs communicate via a message-passing mechanism: local procedure-call (LPC) facility.
- Port object: two types
  - connection ports: named objects, to set up communication channels
  - communication ports
    - for small message, use the port's message queue
    - for a larger message, use a section object, which sets up a region of shared memory.
      this can avoids data copying

# LPC in Windows XP

- Local procedure calls in Windows XP.

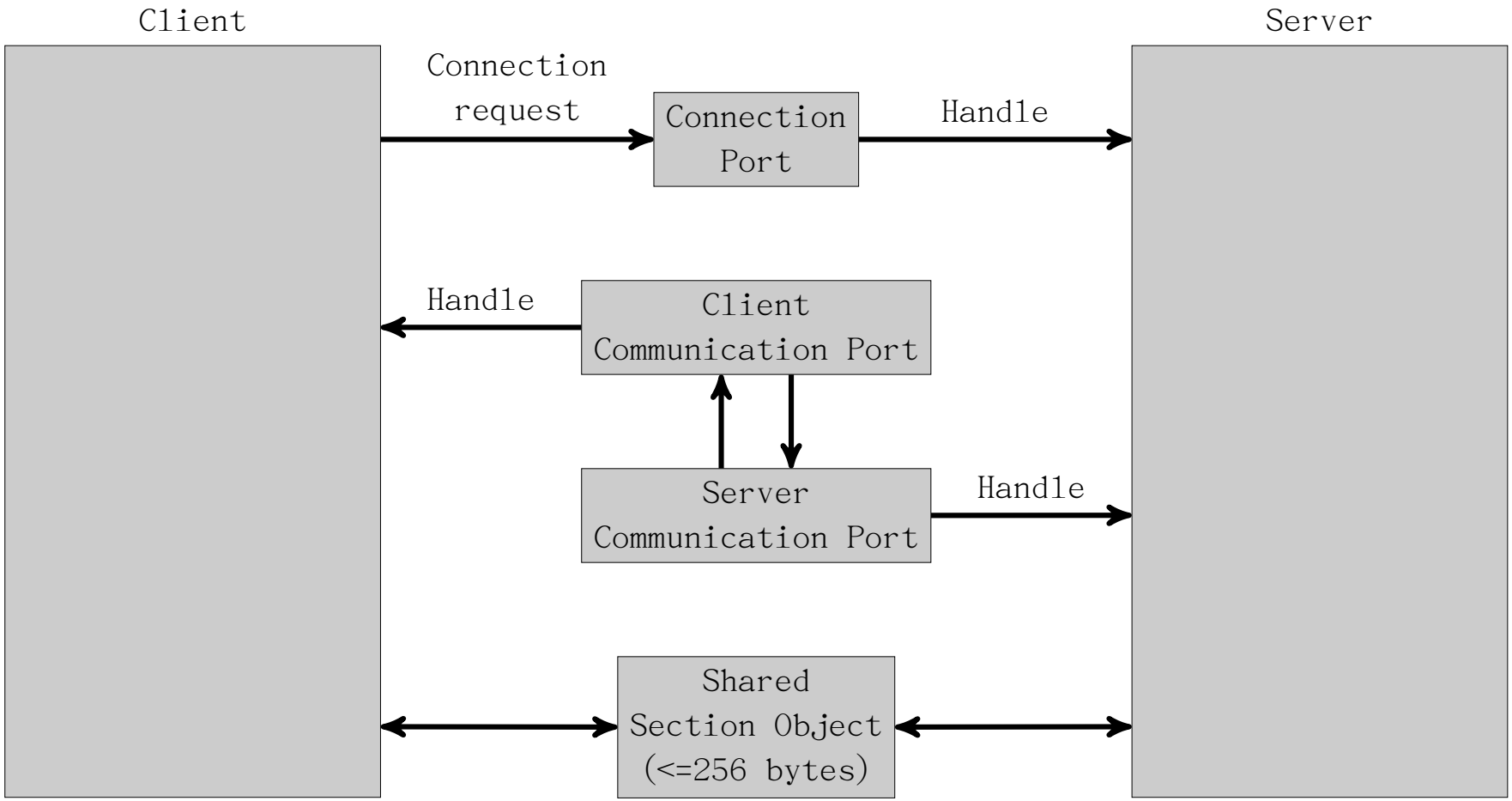



Figure 3.17 Local procedure calls in Windows XP.

# Outline

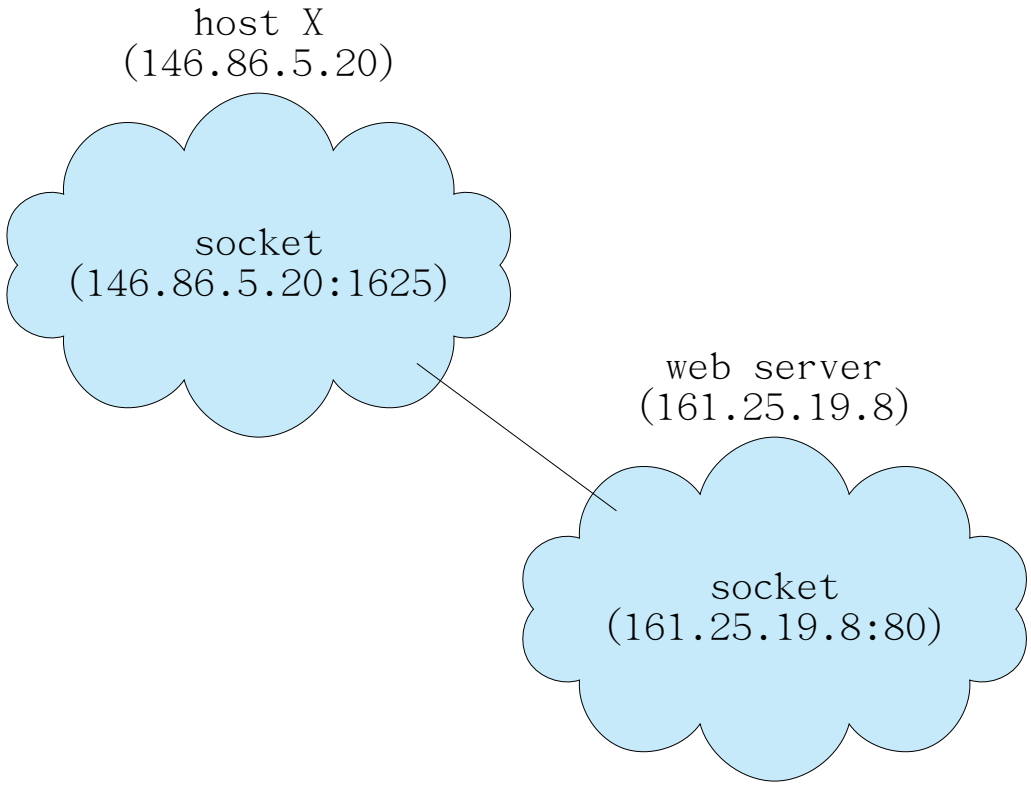
7 Communication in C/S Systems

# Client-Server Communication

- Sockets（套接字）
- Remote Procedure Calls（远程过程调用，RPC）
- Remote Method Invocation（远程方法调用，RMI）（Java）

# Sockets（套接字）

- A socket is defined as an endpoint for communication
  - Concatenation of IP address and port
  - The socket 161.25.19.8:1625 refers to port 1625 on host 161.25.19.8
- Communication consists between a pair of sockets

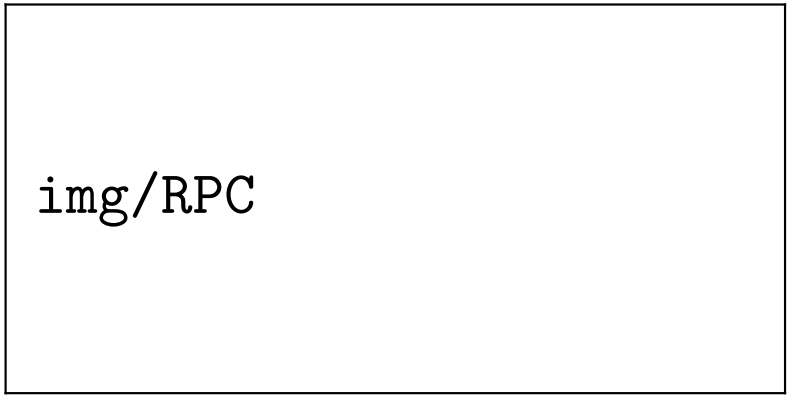


# Remote Procedure Calls(远程过程调用，RPC)

- Remote procedure call (RPC) abstracts procedure calls between processes on networked systems.
- Stubs – client-side proxy for the actual procedure on the server.
- The client-side stub locates the server and marshalls the parameters.
- The server-side stub receives this message, unpacks the marshalled parameters, and peforms the procedure on the server.

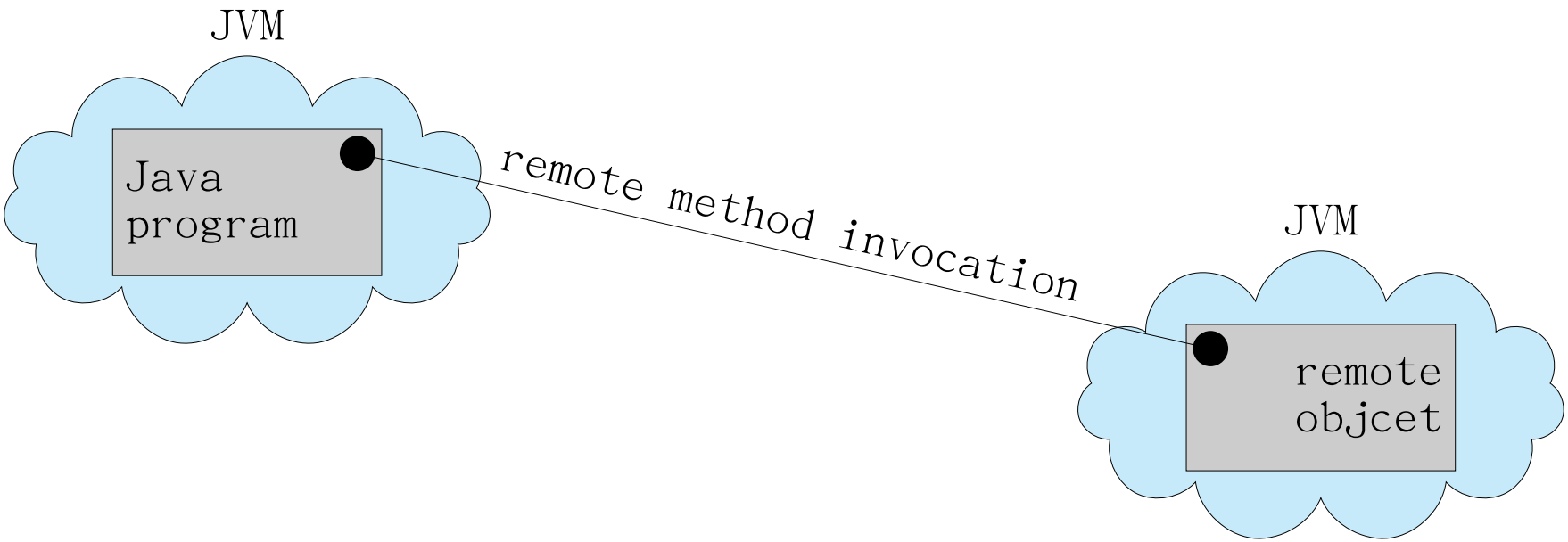
# Remote Procedure Calls(远程过程调用，RPC)

- Execution of a remote precedure call (RPC)



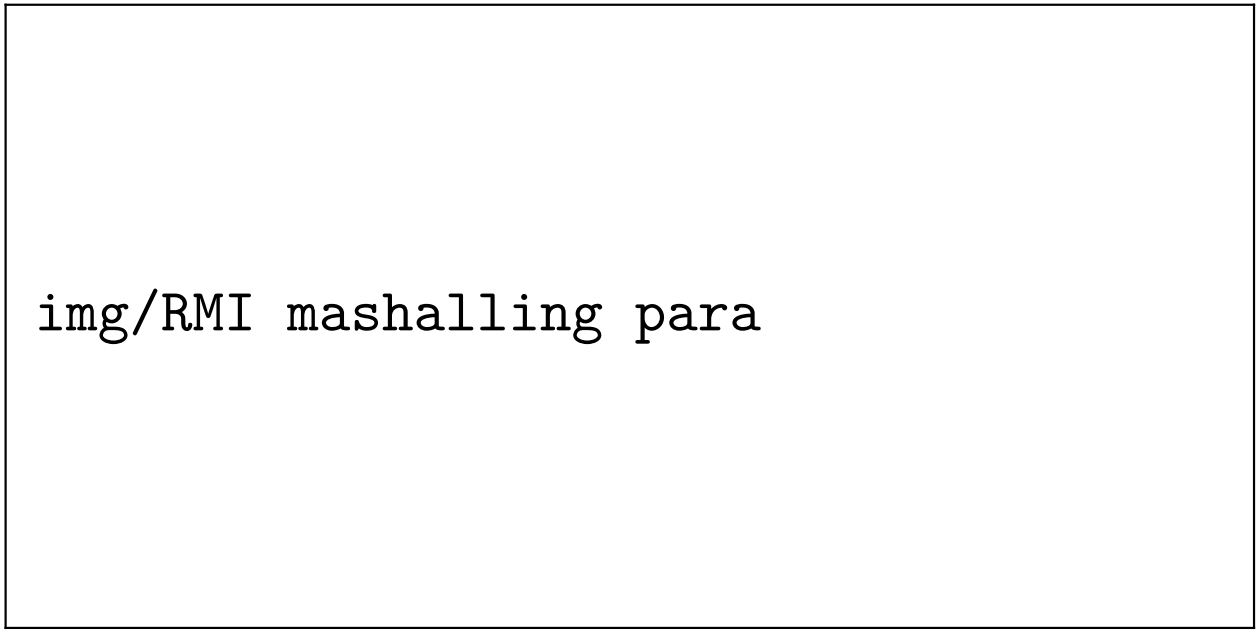
# Remote Method Invocation(远程方法调用，RMI)

- Remote Method Invocation (RMI) is a Java mechanism similar to RPCs.
- RMI allows a Java program on one machine to invoke a method on a remote object.



# Remote Method Invocation(远程方法调用，RMI)

- Marshalling Parameters



# Outline

8 小结和作业

# 小结

1. 多道程序技术和程序并发执行的条件
   - 多道程序技术的难点
   - Seriel execution of programs (程序的顺序执行)
   - Concurrent execution of programs (程序的并发执行)
2. Process Concept
   - the Processes
   - Process State
   - Process Control Block (PCB)
3. Process Scheduling
   - Process Scheduling Queues
   - Schedulers
   - Context Switch(上下文切换)
4. Operation on processes
   - Process Creation
   - Process Termination
5. Interprocess Communication (进程间通信, IPC)
   - Shared-Memory systems
   - Message-Passing Systems
6. Example of IPC Systems
   - POSIX Shared Memory
   - Mach (by yourself)
   - Windows XP
7. Communication in C/S Systems
8. 小结和作业

# 阅读

- Read related code in Linux or uC/OS-II
- Subsubsection ”An Example: Mach” of subsection ”Examples of IPC Systems”
- Subsubsection ”An Example: Windows XP” of subsection ”Examples of IPC Systems”
- Subsection ”Communication in Client-Server Systems”

# 视频作业【可选】

1. 找到某一款操作系统中的进程控制块数据结构（描述一个进程或者一个线程或者一个任务等），并对该数据结构中的主要数据项进行说明。
2. 找到某一款操作系统中的进程队列（就绪队列/等待队列/所有进程队列），说明它采用什么结构。
   - 说明在这个队列上插入一个进程和取下一个进程的流程。

- 要求:
  1. 能看清代码
  2. 能听清内容

# 作业 I

- 程序的顺序执行和并发执行有什么异同之处?
- 什么是Bernstein条件?
- 对于下面的语句:

  $S_1$: $a = 5 - x;$

  $S_2$: $b = a \cdot x;$

  $S_3$: $c = 4 \cdot x;$

  $S_4$: $d = b + c;$

  $S_5$: $e = d + 3$

  1. 画出前趋图
  2. 证明$S_2$和$S_3$是可以并发执行的，而$S_3$和$S_4$是不能并发执行的。

- 阅读至少2本操作系统相关书籍，给出这些书中关于进程的定义，要列出出处。
- 阅读linux-0.11的内核代码，找到其进程数据结构加以分析。说明linux-0.11中进程的状态及其转换关系。

# 作业 II

- 名词解释:
  - 长／中／短期调度
  - 多道程序度
  - IO密集型／CPU密集型
  - 进程上下文

谢谢！