Fall COMP 3511 Operating Systems

Tutorial and Lab #4

Outline

- Review Questions
- Inter-Process Communication or IPC
- Thread
- Scheduling

Q. 1

- Distinguish between data and task parallelism.
  - ***Data parallelism*** involves distributing subsets of the same data across multiple computing cores and performing the same operation on each core.
  - ***Task parallelism*** involves distributing tasks across the different computing cores where each task is performing a unique operation.

Q. 2

- Distinguish between parallelism and concurrency.
  - A ***parallel*** system can perform more than one task simultaneously.
  - A ***concurrent*** system supports more than one task by allowing multiple tasks to make progress.

Q. 3

- What are the general components of a thread in Windows?

  - a unique ID
  - a register set that represents the status of the processor
  - a user stack for user mode
  - a kernel stack for kernel mode
  - a private storage area used by run-time libraries and dynamic link libraries.

Q. 4

- List the four major categories of the benefits of multithreaded programming. Briefly explain each.

  - Four categories: ***responsiveness, resource sharing, economy***, and ***utilization of multiprocessor architectures***.

  - **Responsiveness:** a multithreaded program can allow a program to run even if part of it is blocked.

  - **Resource sharing:** an application has several different threads of activity within the same address space. Threads share the resources of the process

Q. 4 (cont.)

- List the four major categories of the benefits of multithreaded programming. Briefly explain each.
  - **Economy**: it is more economical to create new threads than new processes.
  - **utilization of multiprocessor architectures:**
    - A single-threaded process can only execute on one processor regardless of the number of processors actually available.
    - Multithreaded programs can run on multiple processors, taking full utilization of the computing resources, thereby increasing efficiency.

Q. 5

- Explain the difference between response time and turnaround time. These times are both used to measure the effectiveness of scheduling schemes.

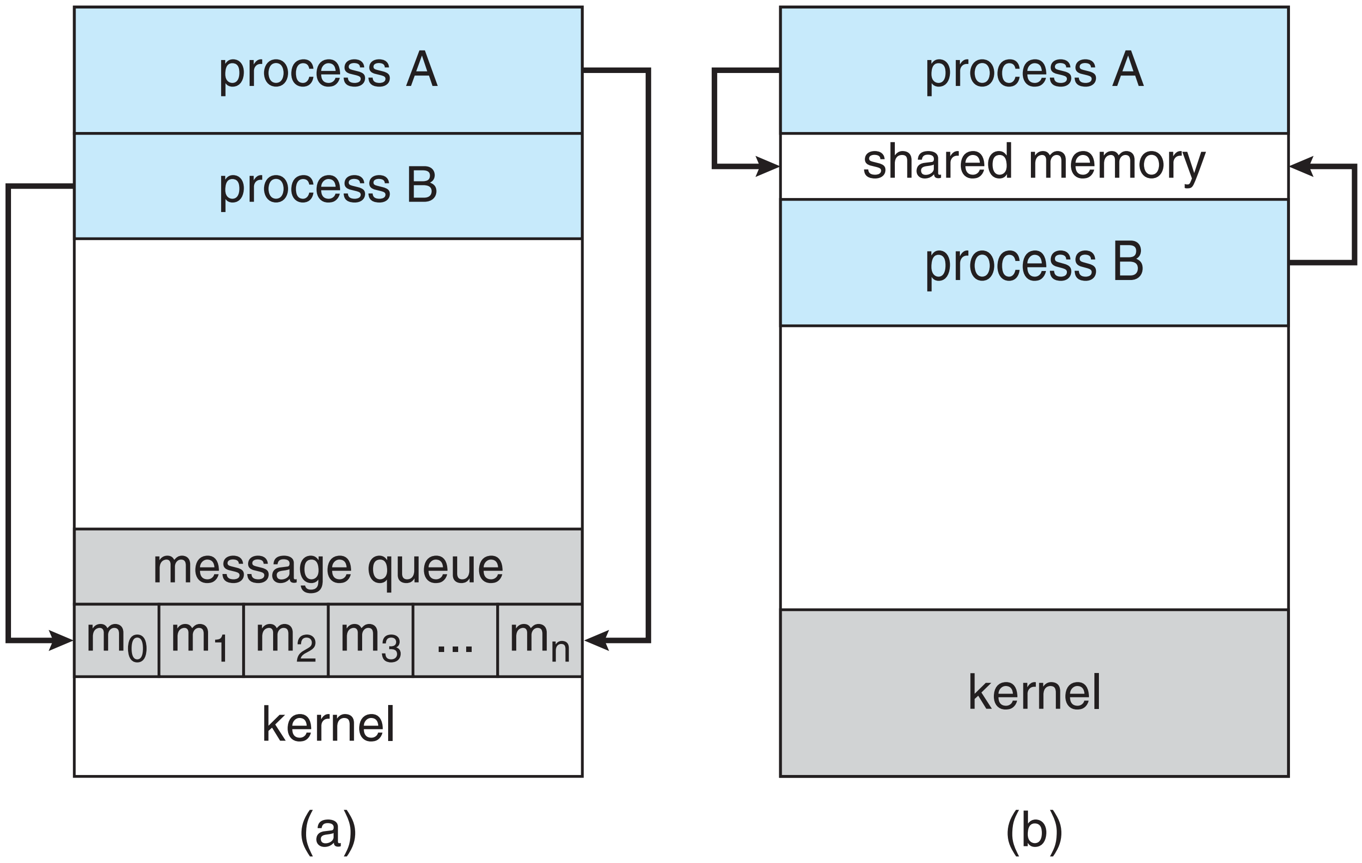
  - ***Turnaround time*** is the sum of the periods that a process is spent waiting to get into memory, waiting in the ready queue, executing on the CPU, and doing I/O. Turnaround time essentially measures the amount of time it takes to execute a process.

  - ***Response time***, on the other hand, is a measure of the time that elapses between a request and the first response produced.

Interprocess Communication - IPC

- 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
- Cooperating processes need **interprocess communication** (**IPC**)
- Two models of IPC
  - **Shared memory**
  - **Message passing**

Communications Models



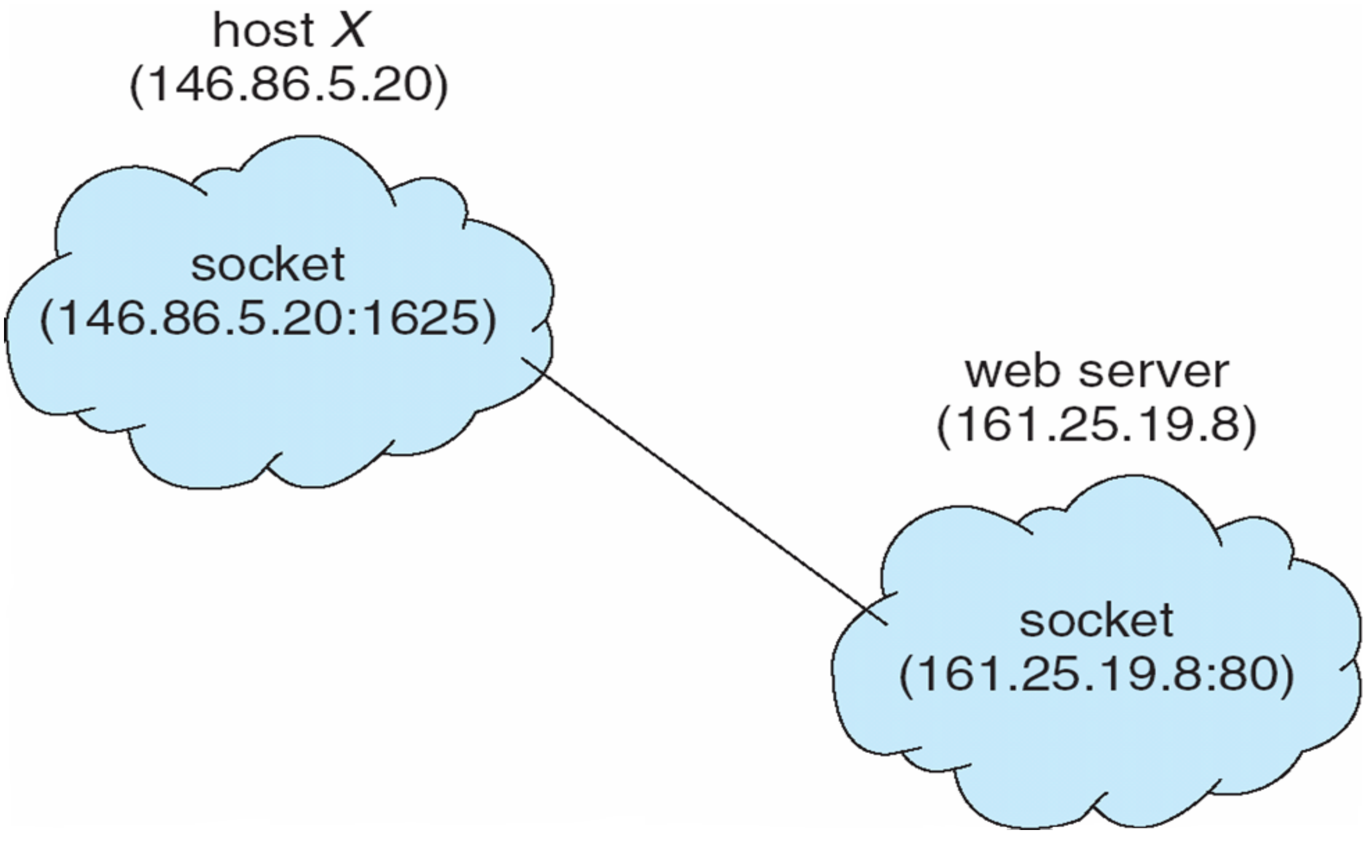
Cooperating Processes

- **Independent** process cannot affect or be affected by the execution of another process
- **Cooperating** process can affect or be affected by the execution of another process
- Advantages of process cooperation
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

Sockets

- 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



Sockets in Java

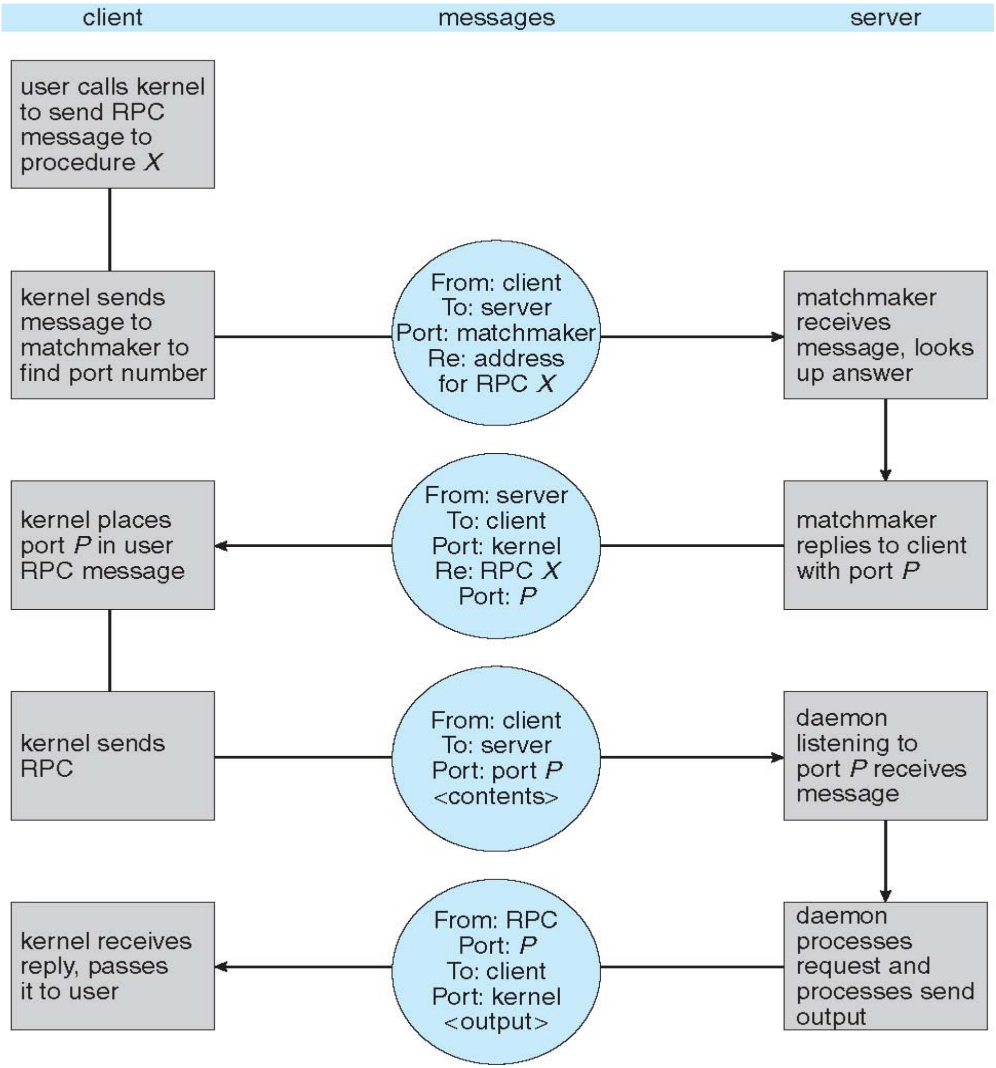
- Three types of sockets
  - **Connection-oriented** (**TCP**)
  - **Connectionless** (**UDP**)
  - **`MulticastSocket`** class– data can be sent to multiple recipients
- Consider this "Date" server:

```
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);
    }
  }
}
```

Remote Procedure Calls

- Remote procedure call (RPC) abstracts procedure calls between processes on networked systems
  - Again uses ports for service differentiation
- **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 performs the procedure on the server
- On Windows, stub code compile from specification written in **Microsoft Interface Definition Language** (**MIDL**)
- Data representation handled via **External Data Representation** (**XDL**) format to account for different architectures
  - **Big-endian** and **little-endian**
- Remote communication has more failure scenarios than local
  - Messages can be delivered ***exactly once*** rather than ***at most once***
- OS typically provides a rendezvous (or **matchmaker**) service to connect client and server

Execution of RPC



Thread Libraries

- **Thread library** provides programmer with API for creating and managing threads

- Two primary ways of implementing
  - Library entirely in user space
  - Kernel-level library supported by the OS

Pthreads

- May be provided either as user-level or kernel-level
- A POSIX standard (IEEE 1003.1c) API for thread creation and synchronization
- **Specification**, not **implementation**
- API specifies behavior of the thread library, implementation is up to development of the library
- Common in UNIX operating systems (Solaris, Linux, Mac OS X)

Pthreads Example

```
#include <pthread.h>
#include <stdio.h>

int sum; /* this data is shared by the thread(s) */
void *runner(void *param); /* threads call this function */

int main(int argc, char *argv[])
{
   pthread_t tid; /* the thread identifier */
   pthread_attr_t attr; /* set of thread attributes */

   if (argc != 2) {
      fprintf(stderr,"usage: a.out <integer value>\n");
      return -1;
   }
   if (atoi(argv[1]) < 0) {
      fprintf(stderr,"%d must be >= 0\n",atoi(argv[1]));
      return -1;
   }
```

Pthreads Example (Cont.)

```
   /* get the default attributes */
   pthread_attr_init(&attr);
   /* create the thread */
   pthread_create(&tid,&attr,runner,argv[1]);
   /* wait for the thread to exit */
   pthread_join(tid,NULL);

   printf("sum = %d\n",sum);
}

/* The thread will begin control in this function */
void *runner(void *param)
{
   int i, upper = atoi(param);
   sum = 0;

   for (i = 1; i <= upper; i++)
      sum += i;

   pthread_exit(0);
}
```

Figure 4.9 Multithreaded C program using the Pthreads API.

Pthreads Code for Joining 10 Threads

```
#define NUM_THREADS 10

/* an array of threads to be joined upon */
pthread_t workers[NUM_THREADS];

for (int i = 0; i < NUM_THREADS; i++)
   pthread_join(workers[i], NULL);
```

Figure 4.10 Pthread code for joining ten threads.

Win32 API Multithreaded C Program

```
#include <windows.h>
#include <stdio.h>
DWORD Sum; /* data is shared by the thread(s) */

/* the thread runs in this separate function */
DWORD WINAPI Summation(LPVOID Param)
{
   DWORD Upper = *(DWORD*)Param;
   for (DWORD i = 0; i <= Upper; i++)
      Sum += i;
   return 0;
}

int main(int argc, char *argv[])
{
   DWORD ThreadId;
   HANDLE ThreadHandle;
   int Param;

   if (argc != 2) {
      fprintf(stderr,"An integer parameter is required\n");
      return -1;
   }
   Param = atoi(argv[1]);
   if (Param < 0) {
      fprintf(stderr,"An integer >= 0 is required\n");
      return -1;
   }
```

Win32 API Multithreaded C Program (Cont.)

```
    /* create the thread */
    ThreadHandle = CreateThread(
      NULL, /* default security attributes */
      0, /* default stack size */
      Summation, /* thread function */
      &Param, /* parameter to thread function */
      0, /* default creation flags */
      &ThreadId); /* returns the thread identifier */

    if (ThreadHandle != NULL) {
       /* now wait for the thread to finish */
      WaitForSingleObject(ThreadHandle,INFINITE);

      /* close the thread handle */
      CloseHandle(ThreadHandle);

      printf("sum = %d\n",Sum);
    }
}
```

Java Threads

- Java threads are managed by the JVM
- Typically implemented using the threads model provided by underlying OS
- Java threads may be created by:
  - Extending Thread class
  - Implementing the Runnable interface

```
public interface Runnable
{
    public abstract void run();
}
```

Java Multithreaded Program

```
class Sum
{
  private int sum;

  public int getSum() {
   return sum;
  }

  public void setSum(int sum) {
   this.sum = sum;
  }
}

class Summation implements Runnable
{
  private int upper;
  private Sum sumValue;

  public Summation(int upper, Sum sumValue) {
   this.upper = upper;
   this.sumValue = sumValue;
  }

  public void run() {
   int sum = 0;
   for (int i = 0; i <= upper; i++)
      sum += i;
   sumValue.setSum(sum);
  }
}
```

Java Multithreaded Program (Cont.)

```
public class Driver
{
   public static void main(String[] args) {
     if (args.length > 0) {
      if (Integer.parseInt(args[0]) < 0)
       System.err.println(args[0] + " must be >= 0.");
      else {
       Sum sumObject = new Sum();
       int upper = Integer.parseInt(args[0]);
       Thread thrd = new Thread(new Summation(upper, sumObject));
       thrd.start();
       try {
          thrd.join();
          System.out.println
                  ("The sum of "+upper+" is "+sumObject.getSum());
      } catch (InterruptedException ie) { }
      }
     }
     else
      System.err.println("Usage: Summation <integer value>"); }
}
```

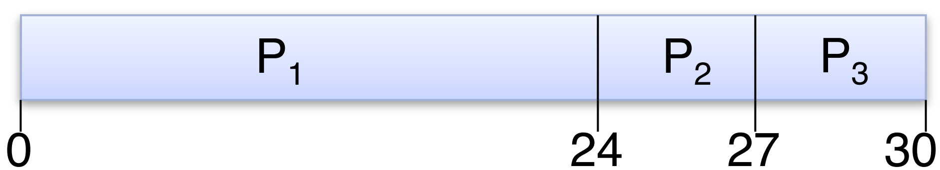
Scheduling Criteria

- To Maximize:
  - **CPU utilization** – keep the CPU as busy as possible
  - **Throughput** – # of processes that complete their execution per time unit (favour short jobs)
- To Minimize:
  - **Turnaround time** – amount of time to execute a particular process
  - **Waiting time** – the total amount of time a process has been waiting in the ready queue
  - **Response time** – amount of time it takes from when a request was submitted until the first response is produced, not output (for time-sharing environment)

First-Come, First-Served (FCFS) Scheduling

- First-Come-First-Serve (FCFS)
- Pro: easy to implement
- Con: potentially bad for short jobs
-

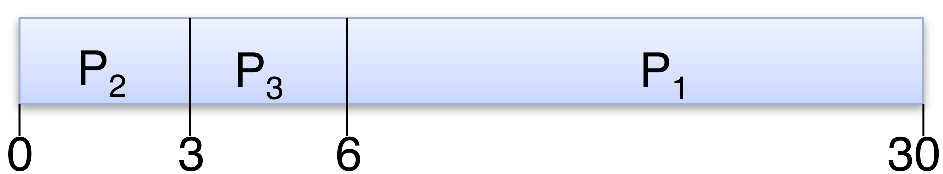
Process	Burst Time
P_1	24
P_2	3
P_3	3



Average waiting time:
(0 + 24 + 27)/3 = 17

Average Turnaround time:
(24+27+30)/3 = 27

- If arrive in the order P_2 , P_3 , P_1

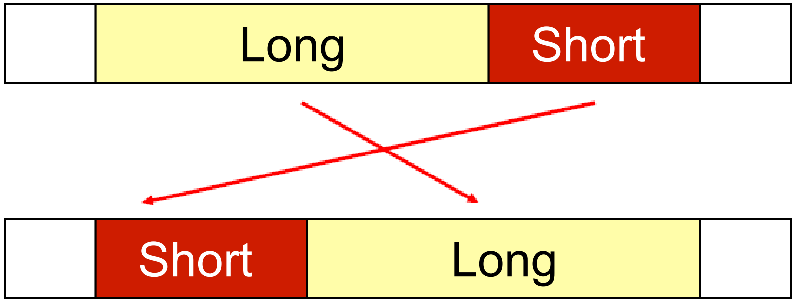


Average waiting time:
(6 + 0 + 3)/3 = 3

Average Turnaround time:
(30+3+6)/3 = 13

Shortest-Job-First (SJF) Scheduling

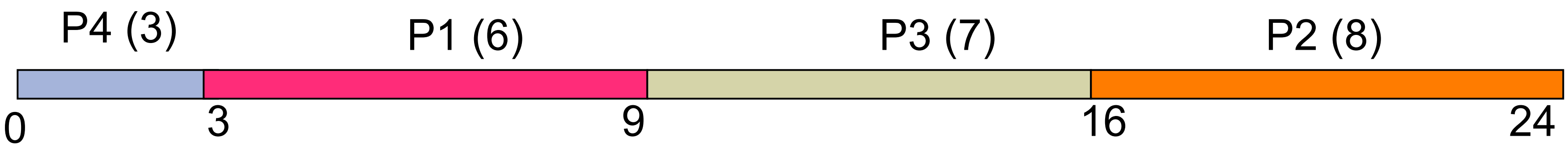
- Associate with each process the length of its next CPU burst. Use these lengths to schedule the process with the shortest time
- Two schemes:
  - **Non-preemptive** – once CPU given to the process it cannot be preempted until completes its current CPU burst
  - **Preemptive** – if a new process arrives with CPU burst length less than remaining time of current executing process, preempt. This scheme is know as the **Shortest-Remaining-Time-First (SRTF)**



SJF is optimal gives minimum average waiting time for a given set of processes

Non-preemptive SJF: Example

Process	Burst Time	Arrival Time
P1	6	0
P2	8	0
P3	7	0
P4	3	0

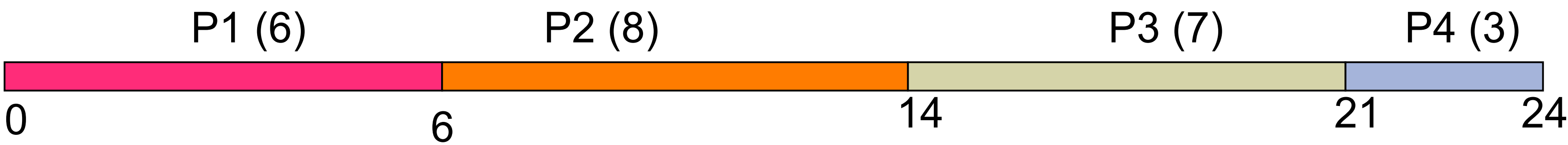


P4 waiting time: 0
P1 waiting time: 3
P3 waiting time: 9
P2 waiting time: 16

The average waiting time
(0+3+9+16)/4 = 7

Comparing to FCFS

Process	Burst Time	Arrival Time
P1	6	0
P2	8	0
P3	7	0
P4	3	0



P1 waiting time: 0
P2 waiting time: 6
P3 waiting time: 14
P4 waiting time: 21

Assume execution order is
P1, P2, P3, P4

The average waiting time
(0+6+14+21)/4 = 10.25 > 7