合肥學院
HEFEI UNIVERSITY

Distributed Computing
Lesson 8: Threads and Parallelism

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Outline

website

Overview

- Servers need to deal with multiple clients at the same time.
- Dealing with clients may involve I/O to/from the disk or communication with other processes, meaning that at times, the CPU does no real work for a task (but waits for I/O completion)?
- The CPU time can be used more efficiently if "shared" between clients.
- Threads allow for having multiple, independent, (quasi-)parallel streams of execution in a program.
- Threads are resources that can be pooled and cached.

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- So what to do?

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- 3rd generation systems: virtualization: memory, processors

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     - handles not visible/useful for other processes

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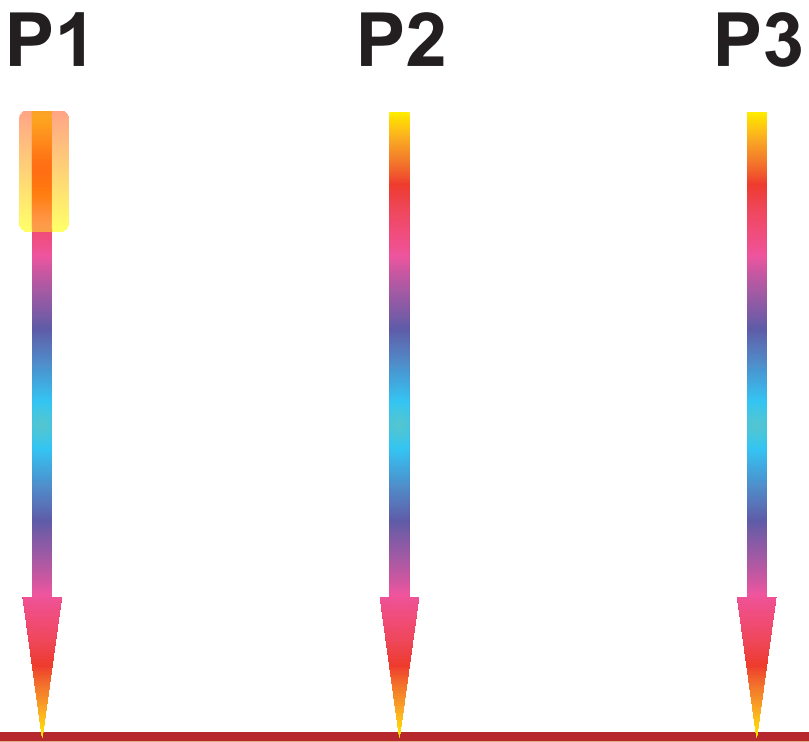

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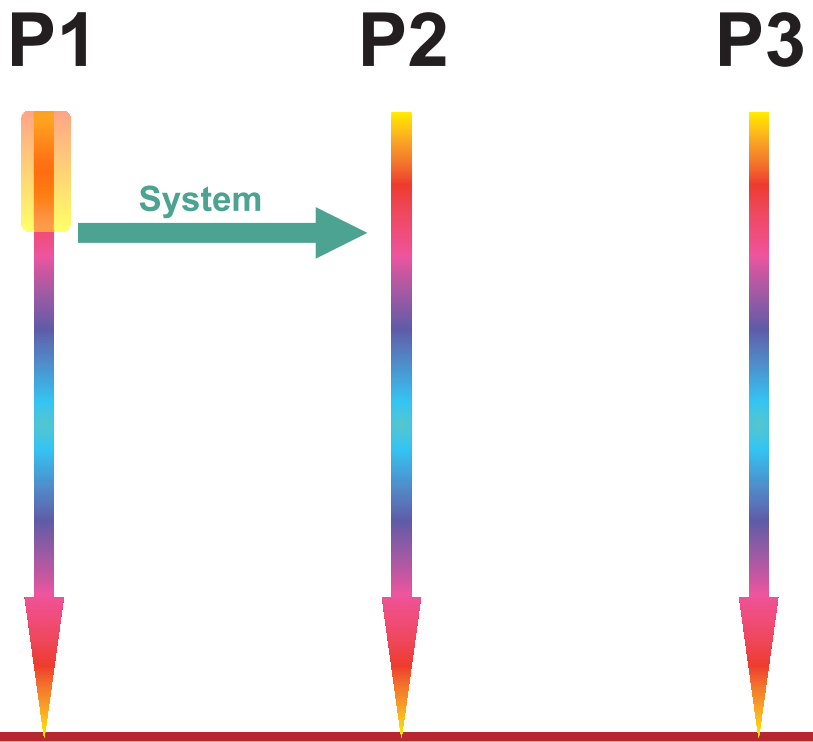

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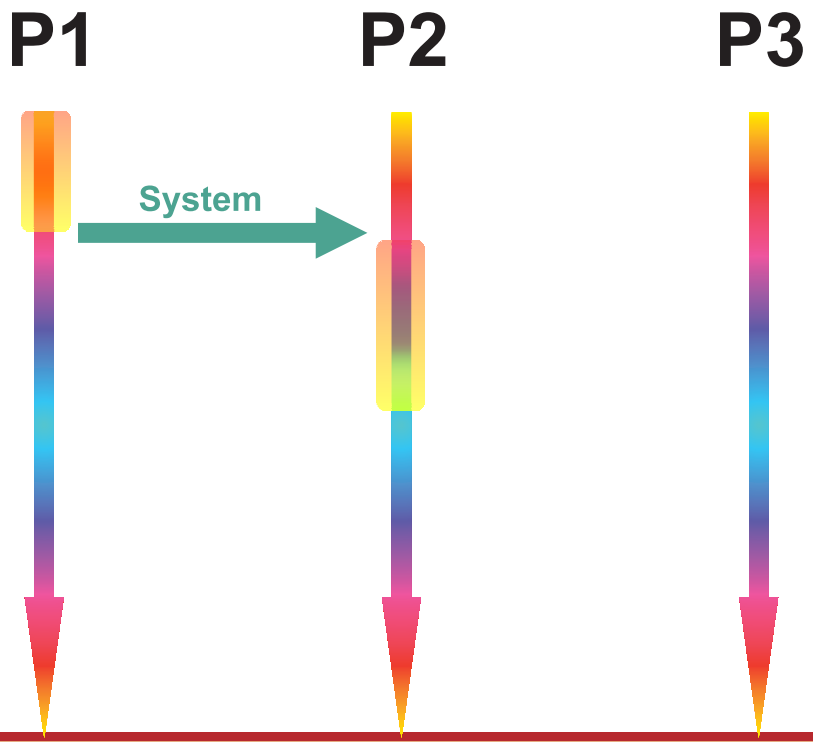

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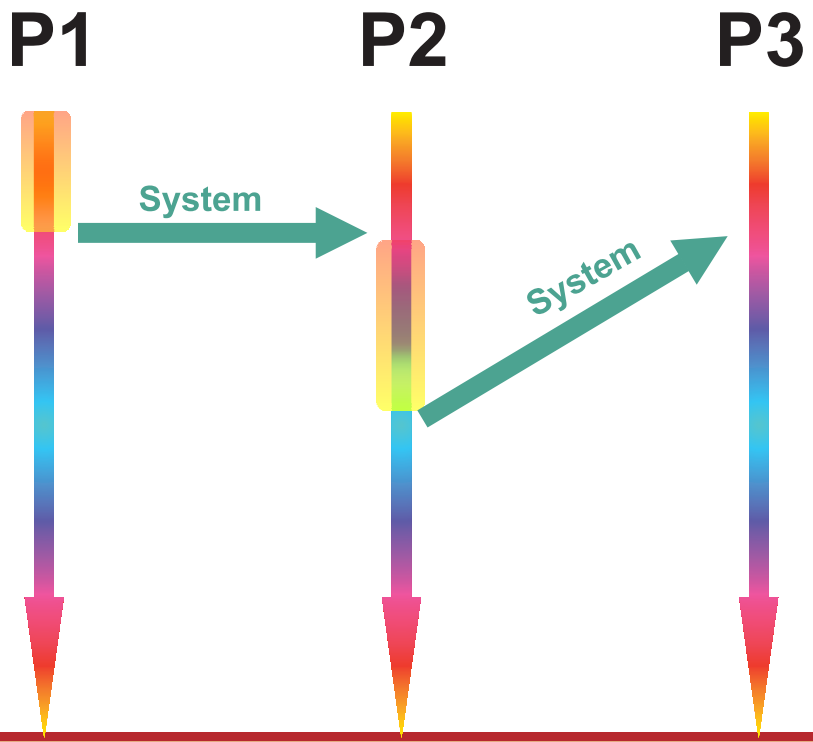

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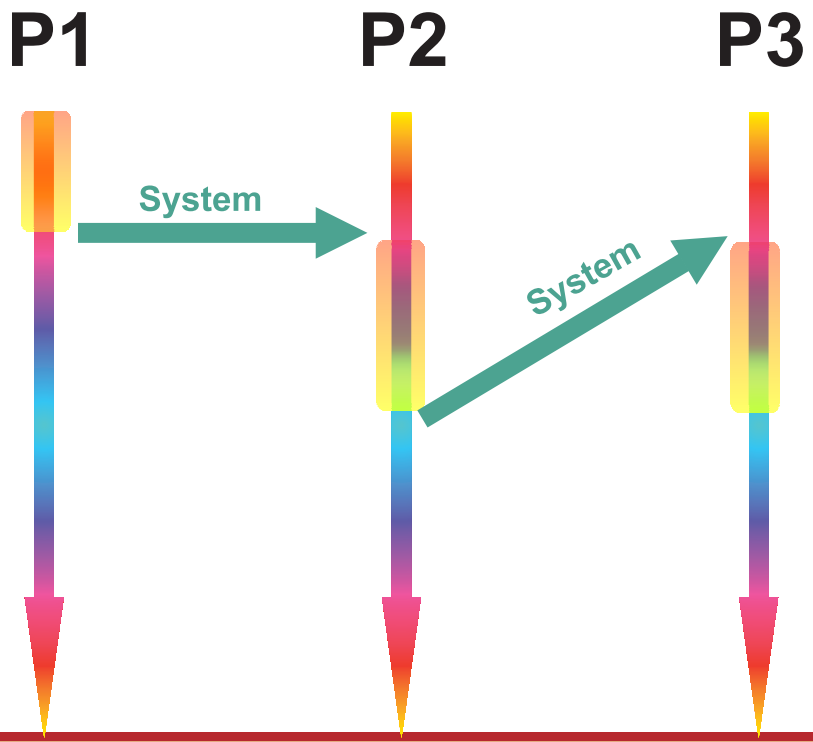

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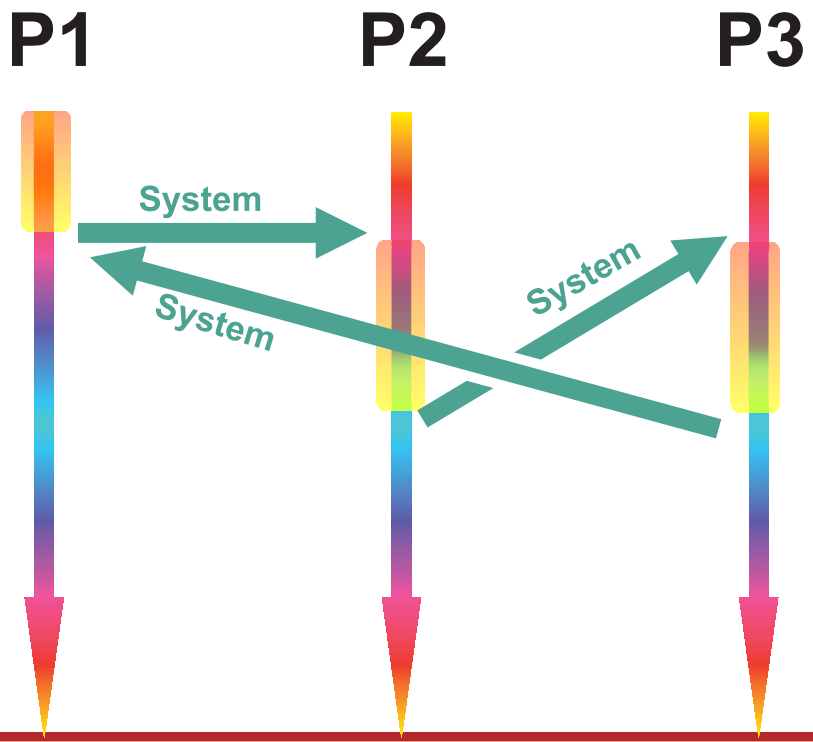

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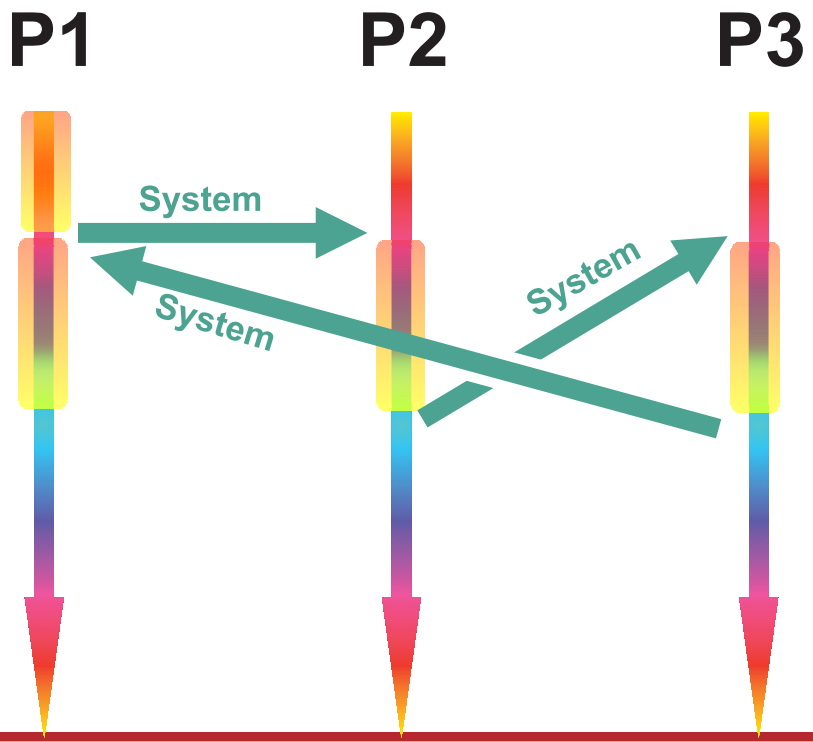

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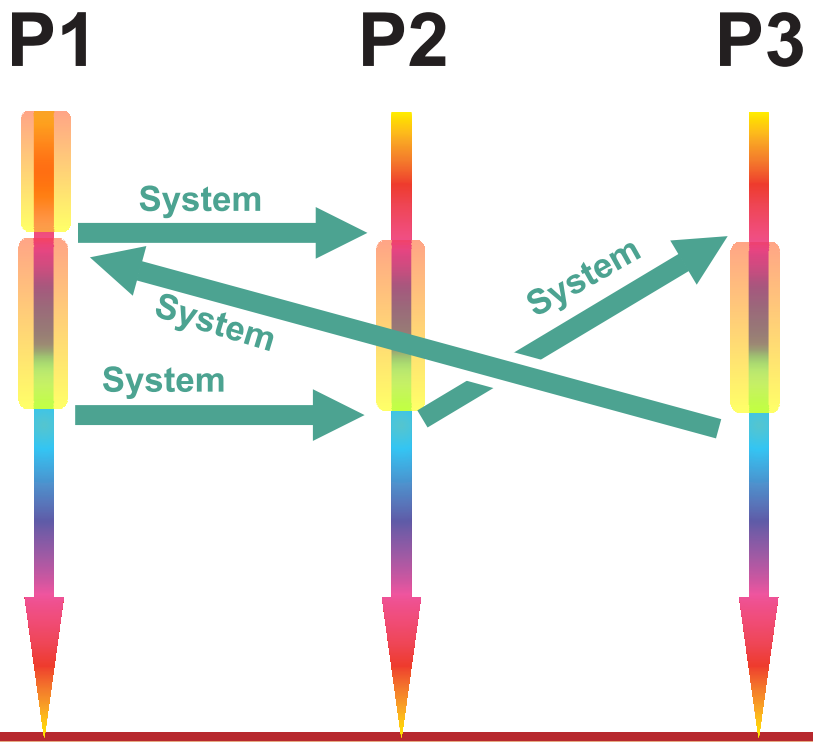

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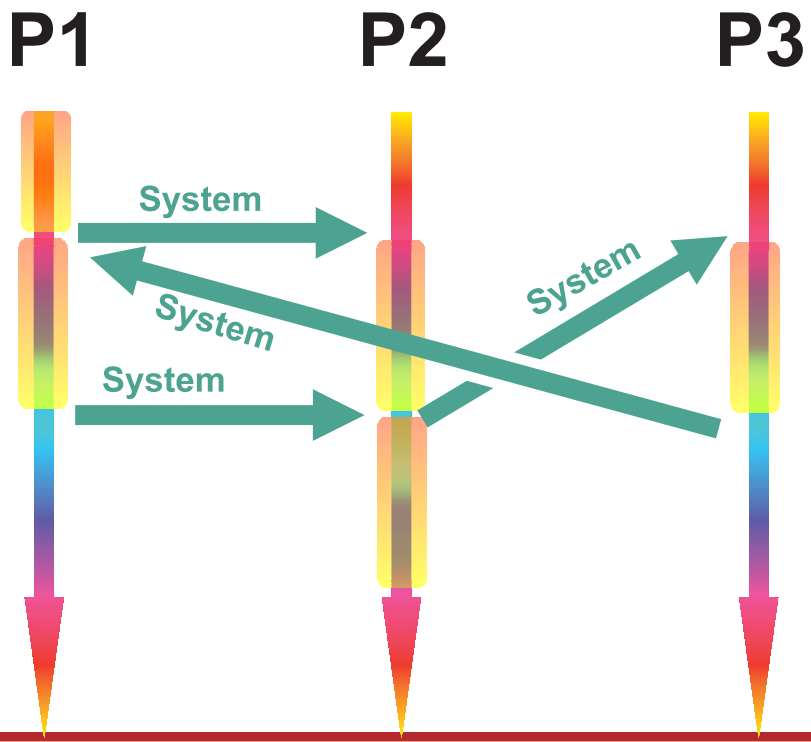

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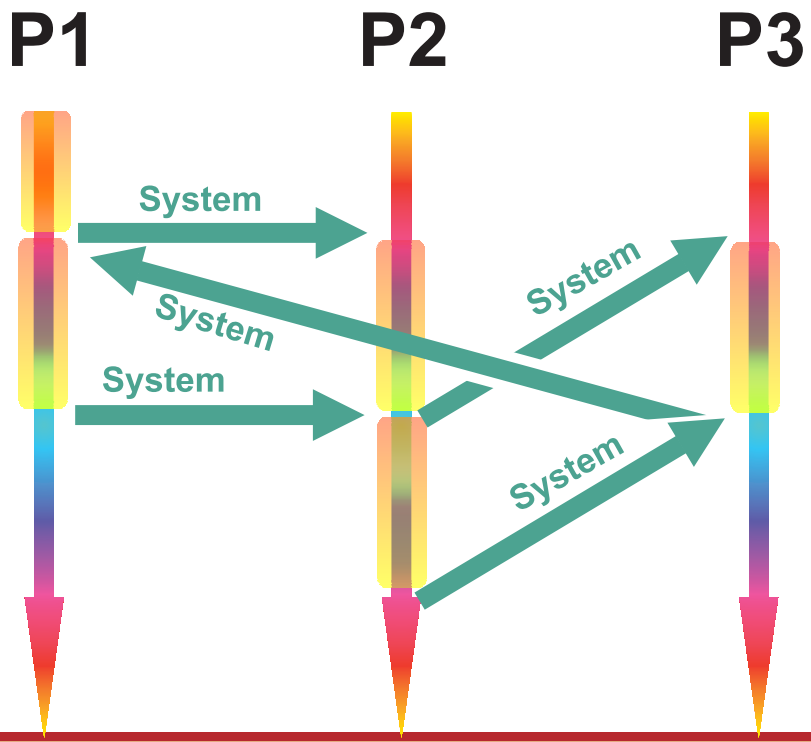

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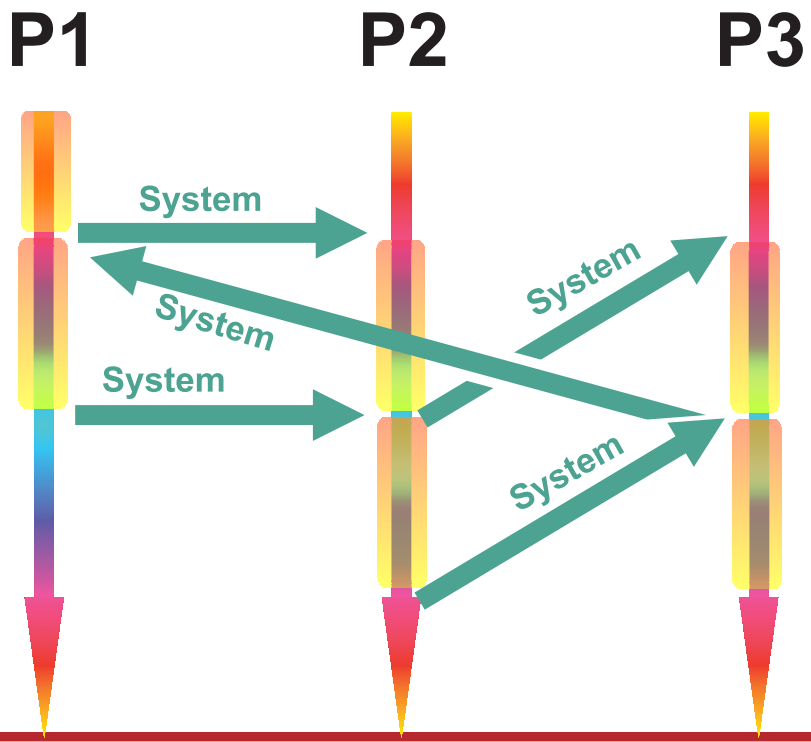

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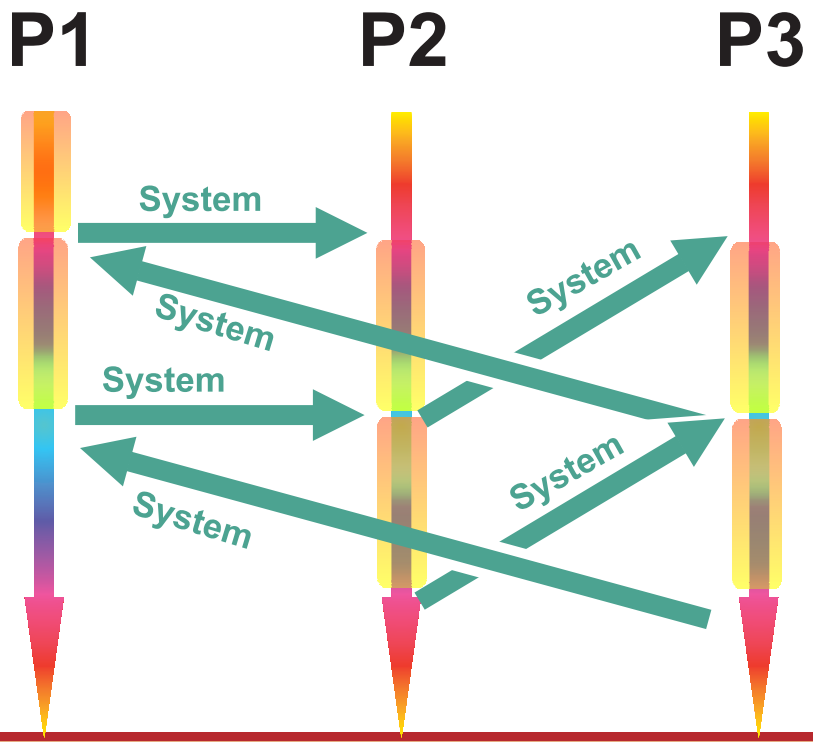

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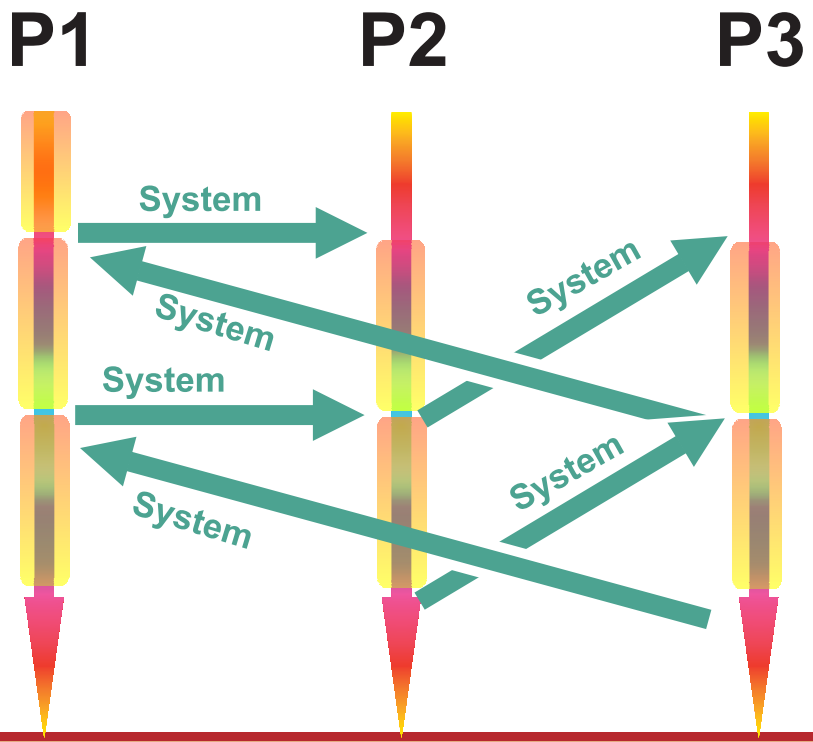

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- No security threat: all threads in one process are part of the same program

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- Multi-threaded servers:
  - multiple threads process client requests in parallel
  - faster
  - less secure/safe: 1 compromised thread can compromise the whole server process

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  - we can wait until it is finished with `void join()`
- Interface `Runnable`
  - has method `void run()` which may do some work
  - can be passed into the constructor of `Thread`, thread will then execute `run()` when started

Listing: MinHTTPServerMultiThread.java Multi-Threaded HTTP Server / Java

```
import java.io.BufferedReader;      import java.io.File;        import java.io.FileInputStream;   import java.io.InputStreamReader;
import java.io.OutputStreamWriter;  import java.io.PrintWriter; import java.net.ServerSocket;     import java.net.Socket;

public class MinHTTPServerMultiThread {
  public static final void main(final String[] args) {
    ServerSocket    server;     Socket          client;
    try {
      server = new ServerSocket(9995); //create server socket 1 + 2)

      for (;;) {  //forever...
        client = server.accept(); //wait for and accept incoming connection 3)
        new Thread(new Job(client)).start(); //create and start a new thread to process the request

      }
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }

  private static final class Job implements Runnable { //the job class: process one request; Runnable is the key interface
    private final Socket m_client; //the client socket to process
    Job(final Socket client){ //create a job for a given socket
      this.m_client=client;
    }

    @Override //this method is executed by the thread that was created with this object as constructor parameter
    public final void run(){ //process the client socket: exactly the same as in the MinHTTPServer example
      BufferedReader  br;   PrintWriter     pw;   String    s;    File  f;
      byte[]          bs;   FileInputStream fis;  Throwable x;    int   i;

      try{
      br = new BufferedReader(new InputStreamReader(this.m_client.getInputStream())); // read character data
      pw = new PrintWriter(new OutputStreamWriter(this.m_client.getOutputStream(), "ISO_8859-1")); //chose the right encoding! [17, 18]

      process: { //4 + 3)
        x = null;
        try {
          while ((s = br.readLine()) != null) { //read text from connection line-by-line until end
            if (s.startsWith("GET ")) {  // try to find the GET command in the HTTP request [17, 18]
              f   = new File(s.substring(4, s.indexOf(' ', 4)).replace('/', File.separatorChar)); //in a very crude way, extract the requested path from that command
              bs  = new byte[(int) (f.length())];  //allocate a buffer of the right size
              fis = new FileInputStream(f);        //open the file
              i   = fis.read(bs);                  //read the complete file into memory
              fis.close();                         //close the file
              pw.write("HTTP/1.1 200 OK\r\n\r\n");  pw.flush(); //send "success" according to [17, 18]
              this.m_client.getOutputStream().write(bs, 0, i); //...and the file content  (4 + 3))
              break process;                       //ok, we are finished here
            }
          }
        } catch (Throwable t) { x= t; } //if request fails, remember why

        //hm, we did not find the file or had an error [17, 18]
        pw.write("HTTP/1.1 404 Not Found\r\n\r\n<html><head><title>404</title></head><body><h1>404 - Not found</h1><pre>");
        if(x != null) { x.printStackTrace(pw); } //write the error message (notice the <pre>...</pre> wrapper)
        pw.write("</pre></body></html");         //end the html body
        pw.flush(); //and flush (4 + 3))
      }

      this.m_client.close(); }//4)
      catch(Throwable error) { error.printStackTrace(); }
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- `ExecutorService` is an interface of classes that can execute `Runnable`s
- `Executors.newFixedThreadPool(n)` creates a thread-pool based `ExecutorService`

Listing: MinHTTPServerThreadPool.java Thread-Pooled HTTP Server / Java

```
import java.io.BufferedReader;    import java.io.File;            import java.io.FileInputStream;   import java.io.InputStreamReader;            import java.io.OutputStreamWriter;
import java.io.PrintWriter;       import java.net.ServerSocket;   import java.net.Socket;           import java.util.concurrent.ExecutorService; import java.util.concurrent.Executors;

public class MinHTTPServerThreadPool {
  public static final void main(final String[] args) {
    ServerSocket    server;     Socket          client;   ExecutorService pool;
    try {
      pool = Executors.newFixedThreadPool(10); //create a pool of 10 threads waiting to execute something
      server = new ServerSocket(9994); //(1 + 2)

      for (;;) {
        client = server.accept(); //wait for and accept new connection (3)
        pool.execute(new Job(client)); //enqueue the job into the pool's job queue, it will be executed when a thread is ready
      }
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }

  private static final class Job implements Runnable { //the job class: process one request; Runnable is the key interface
    private final Socket m_client; //the client socket to process
    Job(final Socket client){ //create a job for a given socket
      this.m_client=client;
    }

    @Override //this method is executed by a thread in the thread pool
    public final void run(){
      BufferedReader  br;   PrintWriter     pw;   String    s;    File  f;
      byte[]          bs;   FileInputStream fis;  Throwable x;    int   i;

      try{
      br = new BufferedReader(new InputStreamReader(this.m_client.getInputStream())); // read character data
      pw = new PrintWriter(new OutputStreamWriter(this.m_client.getOutputStream(), "ISO_8859-1")); //chose the right encoding! [17, 18]

      process: { //(4 + (3))
        x = null;
        try {
          while ((s = br.readLine()) != null) { //read text from connection line-by-line until end
            if (s.startsWith("GET␣")) {  // try to find the GET command in the HTTP request [17, 18]
              f   = new File(s.substring(4, s.indexOf('␣', 4)).replace('/', File.separatorChar)); //in a very crude way, extract the requested path from that command
              bs  = new byte[(int) (f.length())];  //allocate a buffer of the right size
              fis = new FileInputStream(f);        //open the file
              i   = fis.read(bs);                  //read the complete file into memory
              fis.close();                         //close the file
              pw.write("HTTP/1.1␣200␣OK\r\n\r\n");  pw.flush(); //send "success" according to [17, 18]
              this.m_client.getOutputStream().write(bs, 0, i); //...and the file content  (4 + (3))
              break process;                       //ok, we are finished here
            }
          }
        } catch (Throwable t) { x= t; } //if request fails, remember why

        //hm, we did not find the file or had an error [17, 18]
        pw.write("HTTP/1.1␣404␣Not␣Found\r\n\r\n<html><head><title>404</title></head><body><h1>404␣-␣Not␣found</h1><pre>");
        if(x != null) { x.printStackTrace(pw); } //write the error message (notice the <pre>...</pre> wrapper)
        pw.write("</pre></body></html");         //end the html body
        pw.flush(); //and flush (4 + (3))
      }

      this.m_client.close(); }//(4)
      catch(Throwable error) { error.printStackTrace(); }
    }
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}
```

Summary

- Parallelism may increase server performance significantly.
- The concept of threads allows for pre-emptive multi-tasking of different (quasi-)parallel strands of a process.
- The class `Thread` implements this in Java.
- Each client of a server can be processed by a different thread.
- Since `Thread`s are expensive system resources, thread pools can hold a set of threads to be re-used for future clients after having completed a task.

谢谢

Thank you

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Caspar David Friedrich, “Der Wanderer über dem Nebelmeer”, 1818
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