Technical University Of Varna

Can Mert

Faculty no:21625103

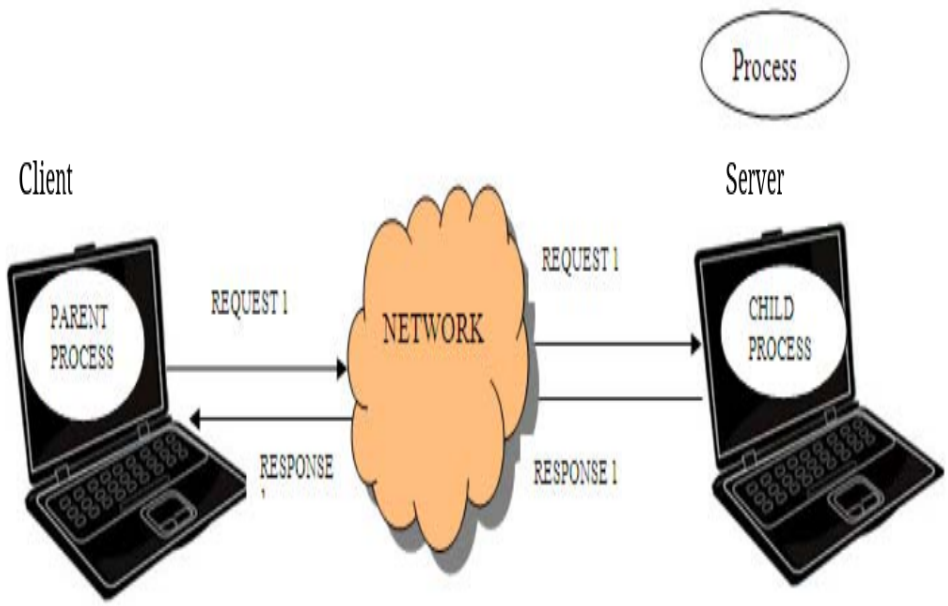
Socket Programming and Threads

1 Introduction to Socket Programming

In the 1980s, the US government's Advanced Research Projects Agency (ARPA) provided funds to the Universiy of California at Berkeley to implement TCP/IP protocols under the UNIX operating system. During this project, a group of Berkeley researches developed an application program interface (API) for TCP/IP network communications called the socket interface. The socket interface is an API TCP/IP networks it defines a variety of routines or software functions for the development of applications for TCP/IP networks. The socket interface designers originally built their interface into the UNIX operating system. However, other operating systems, environments, such as Microsoft Windows, implement the socket interface as software libraries. But it doesnt matter in which of the environment in we program, the code will look much the same. Java is preferred language for socket programming but it socket programming can be done in any language. Java is playform independent, it has exception mechanisms for rebust handling of common problems that occur during I/O and networking operations and its threading facilities provide a way to easily implement powerful servers one of java's major strong suits as a programming language for client-server application development is its wide range of network support. Java has this advantage because it was developed with the Internet in mind. Another advantage of java is that it provides security. The result is that we have a lot of options in regard to network programming in Java. Java performs all of its network communication through sockets.

1.1 Client-Server Communcation

A network is composed of computers which is either a client or server. A server is a program that is offering some services whereas a client is a program that is requesting some service, Servers are powerful computers or processes dedicated to managing disk drives (file servers), printers (print servers), or network traffic (network services) whereas clients are PCs or workstations on which users run applications. Clients need servers for resources, such as files, devices and even processing power. When these programs are executed, as a result, a client and a server process are created simultaneously and this two processes communicate with each other by reading from and writing to sockets.



1.1 Client-Server communications

These sockets are the programming interfaces provided by the UDP and TCP protocols for stream and datagram communication respectively of the transport layer which is a part of the TCP/IP stack. When creating a network application, the developer's main task is to wride code that for the both client and server programs, and the developer needs to complete control over what goes in the code. Code does not implement a public-domain protocol, so other independent developers will not be able to develop code that interoperates with the application. When developing a proprietary application, developer should be careful not to use one of the well-known port numbers defined in RFCs.

1.2 Sockets

The term that 'socket' comes from an electricity/phone socket metaphor where sockets acts as interfaces that plug into each other over a network. Technically, sockets are defined in many ways;

1 According to Wikipedia, a network socket is an endpoint of an inter-process communcation flow across a computer network. A socket is composed of an IP address and a port number.

2 Sockets can be defined as the end-points of a connection between two computers identified by an IP Address and a port number.

3 Also sockets can also be defined as a software abstraction used to represent the "terminals" of a connection between two machines.

4 Socket is the door between the application process and TCP.

5 Socket is an interface between the application and the network.

6 Socket also can be defined as an abstraction that is provided to an application programmer to send or receive data to another process.

1.3 Operations of Socket

A socket performs four main operations:

1 To connect to a remote machine

2 Send data

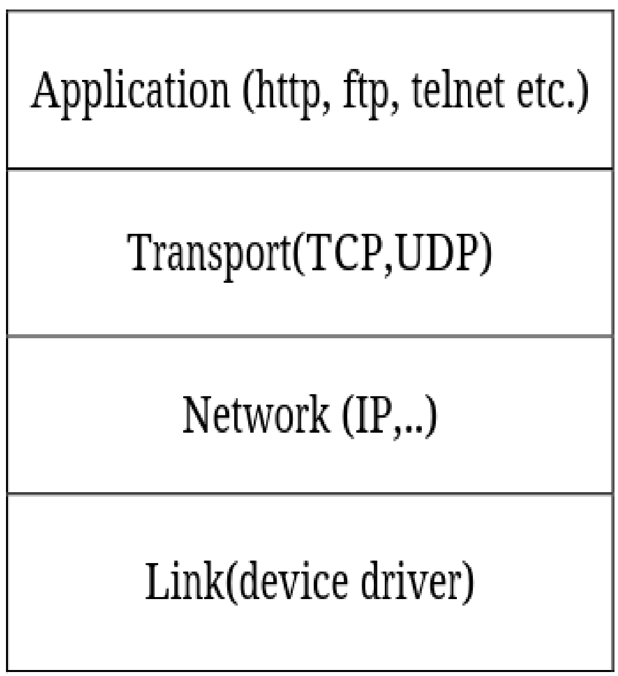
3 Receive data

4 Close the connection

A socket may not be connected to more than one host at a time. However, a socket may both send data to and receive data from the host to which its connected. The java.net.Socket class is Java's interface to a network socket and its allows you to perform all four fundamental socket operations.

1.4 Port

In computer networking, a port is an applicatiton-specific or process-specific software construct serving as a communications endpoint in a computer's host operating system. A port is associated with an IP address of the host, as well as the type of protocol used for communication. The purpose of ports is to uniquely identify different applications or processes running on a single computer. The protocols that primarily use ports are the Transport Layer protocols, such as the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP) of the Internet software stack, often called TCP/IP (Transport Control Protocol/Internet Protocol) stack, as shown in that figure:1.4. They use ports to map incoming data to a particular process running on a computer. So a port will identify a socket on a host.



1.4 TCP/IP software stack

Still, an IP address is not enough to identify a unique server, because many server programs may exist on one machine. So we need a unique identification for each server. This unique identification called as port.

When we are setting up client or a server we must choose a port to where both client and server are gonna meet. This port not a physical port, but a logical port specified by a 16-bit integer number. But some port numbers from 0 to 1024 has been reserved to support common/well known services. And we need to be careful not to use one of that port numbers defined in the RFCs while developoing a proprietary client-server application.

- ftp 21/tcp
- telnet 23/tcp
- smtp 25/tcp
- login 513/tcp
- http 80/tcp,udp
- https 443/tcp,udp

User-level process/services generally use port number value ¿= 1024

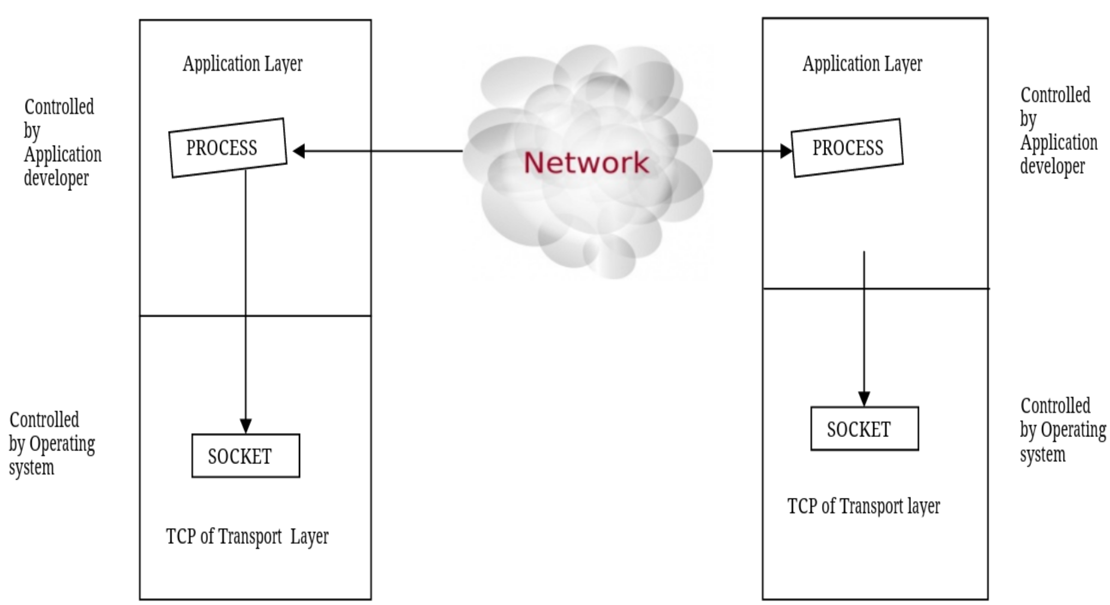
2 Network Programming With Sockets

The Internet has been very popular in the past few years. While its still growing this also increased demand for Internet network software as well. One of the biggest advantages to developing Internet software with Java is in its robust networking support built into the core language. The java.net package provides us with classes that representing URLs, URL connections and sockets. Combined with java.io package, we can quite easily write sophisticated platform-independent applications. Network programming makes use of socket for Interprocess Communication. BSD socket interface supports different domain, the UNIX domain, the Internet Domain and the NS Domain. Java simply supports the Internet domain to maintain cross platform. In Internet domain, the BSD Socket Interface is built on the top of either

TCP/IP or UDP/IP or the raw Socket. Socket programming is important to undderstand how internet based communication work but not at the level program developed but at a higher level that is compiled to set of Socket Programs.

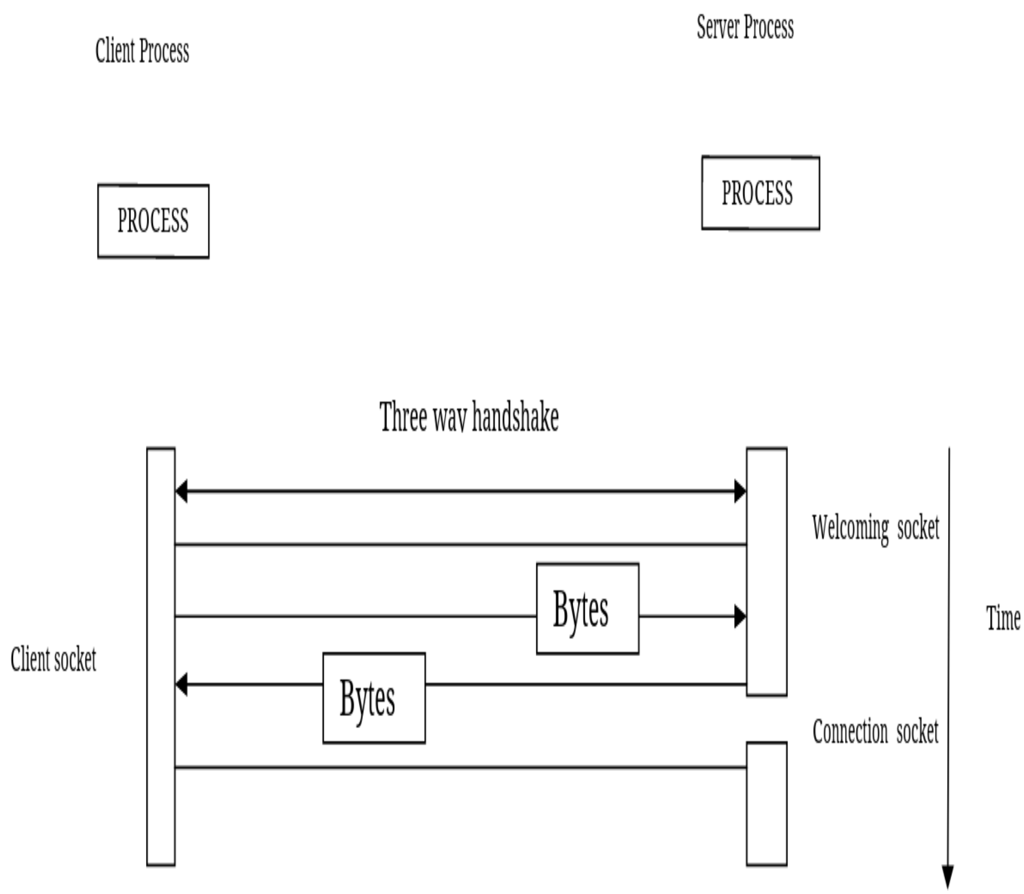
2.1 Socket Programming With TCP

TCP provides a connection oriented service, since it is based on connections between clients and servers. This means that a connection is established before processes can exchange data. The Transmission Control Protocol is also reliable because when a TCP client sends data to the server, it requires an acknowledgement in return. If its not received, then TCP automatically retransmit the data and waits for a longer period of time. The processes running on different machines communicate with each other by sending messages into sockets. Each process is similar to a house and the process's socket is analogous to a door. As you can see in figure 2.1, the socket is the door between the application process and TCP.



2.1 Process communicating through TCP sockets

The application developer has control of everything on application-layer side of the sicket. However it has little control of the transport-layer side. TCP guarantees thatt the server process will receive each byte in the order sent. Furthermore, the client process can also receive bytes from its socket and the server process can also send bytes into its connection socket. This happens in Figure 2.2.

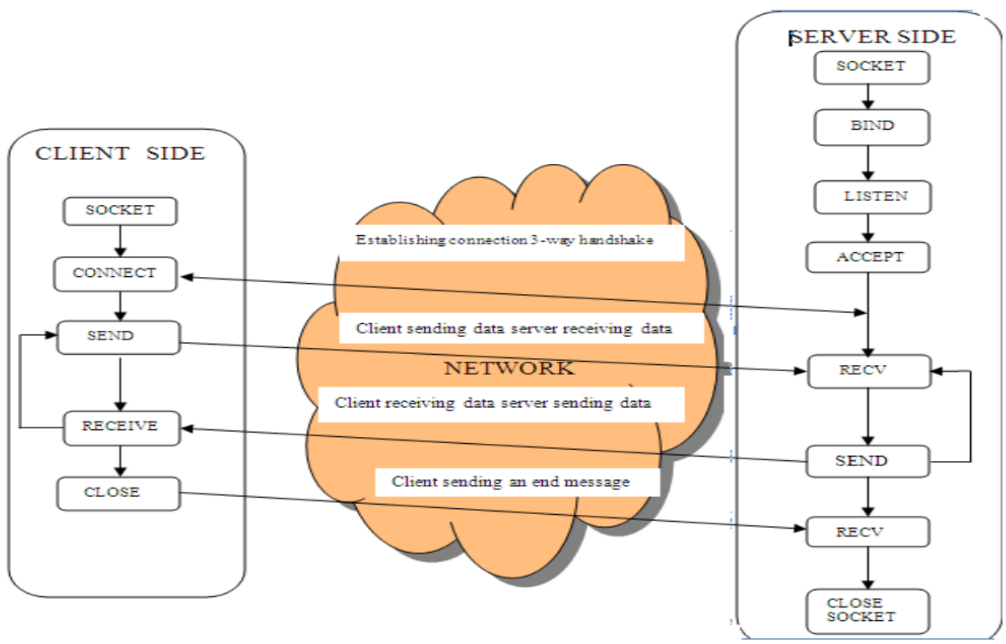


2.2 Client socket, welcoming socket, and connection socket

Because sockets play a central role in client/server applications, client/server application is also called to as socket programming.

2.2 Socket programming over TCP in Java

Java has provided the facility to create sockets for interprocess communication (IPC). So while programming for sockets in java, we have to make sure to import the java.net.package. This package provides a class so that socket implement the client side connection. And a class ServerSocket implements the server side connection. The Server Socket on the server performs the methods "bind" which is to fix to a certain port no. and IP address, "listen" to wait for incoming requests on the port and "accept" for acceptance of connection from the client respectively. Upon acceptance, the server gets a new socket bound to the same local port and also has its remote endpoint set to the name of the machine and port of the client. So the client initiates a three way handshake with the server and creates a TCP connection with the server. So now client and server can communicate by writing or reading from their sockets. And when its done, the close method is called from both client and the server for closing the connection as shown in this figure 2.3 below.



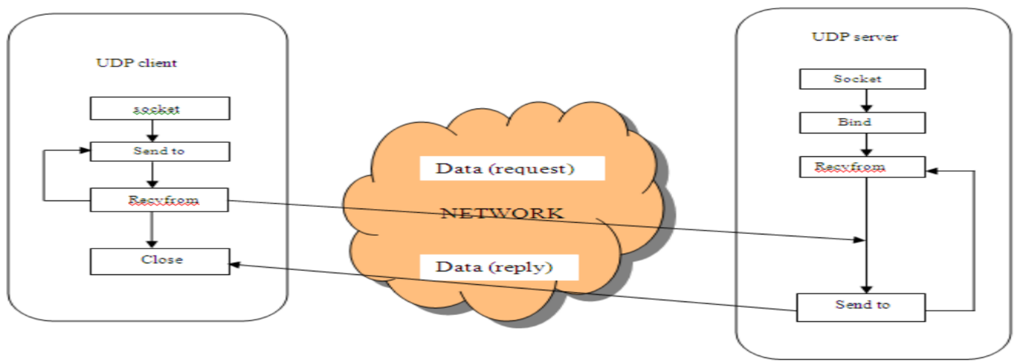
2.3 TCP client-server

List of methods provided by the Berkeley sockets API library:

- socket() creates a new socket of a type, identified by an integer number and allocates resources to it.
- bind() is associates a socket with a socket address structure, a specified local port number and IP address. Its typically used on the server side.
- listen() is used on the server side, and causes a bound TCP socket to enter listening state.
- connect() is used on the client side, and assigns free local port number to a socket. For the TCP socket it attempts to establish a new TCP connection.
- accept() is used on the server side. This accepts a received incoming attempt to create a new TCP connection from remote client, and creates a new socket with the address pair of this connection.
- send(),recv(),write(),read(),sendto() and recvfrom() used for sending and receiving data to/from a remote socket.
- close() makes the system to release resources allocated to a socket. For the TCP, the connection is terminated.

2.3 Socket Programming over UDP

UDP is a connection-less, datagram protocol. The client doesnt establish connection with the server like in case of TCP. Instead, the client just sends a datagram to the server using the sendto function and this requires address of the destination as a parameter. Similarly, the server does not accept a connection from a client. Instead, the server just calls the recvfrom function, which waits until data arrives from some client. Recvfrom returns the IP address of the client, along with the datagram, so the server can send a response to the client as shown in figure below 2.4.



2.4 UDP client-server

There is no any initial handshaking. When you send a data or message, you dont know if it will get there, it could get lost on the way so it lacks reliability. There also may be corruption while transferring a message. UDP Socket's list of functions down below:

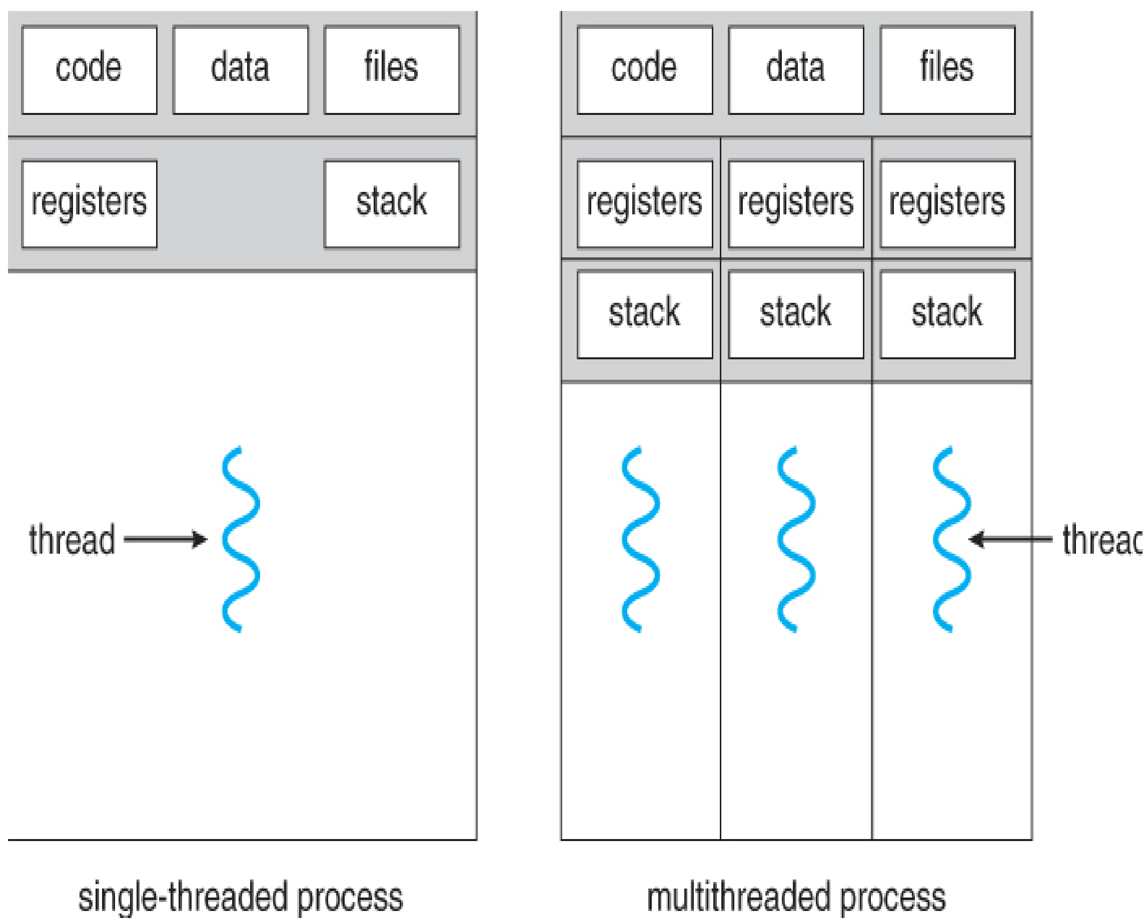
- socket() both client and the server creates the function.
- bind() its usually used on the server side and bounds socket with a socket address structure, specified local port.
- listen() This typically used on the server side waiting for incoming connections from client as passive.
- sendto() It is on both sides used to send a datagram to another UDP socket.
- recvfrom() It is on both client side and server side. It is used to receive a datagram from another UDP socket.
- close() closes a socket.

3 References

- http://en.wikipedia.org/wiki/Berkeley Sockets.
- Joseph M. Dibella , "Socket Programming with Java"
- http://www.tutorialspoint.com/java/javanetworking.htm

4 Threads

A thread is a basic unit of CPU utilization, consisting of a program counter, a stack, and a set of registers,(and a thread ID). Traditional(heavyweight) processess have a single thread of control-There is one program counter, and one sequence of instructions that can be carried out at any given time. If you look at the figure below, multi-threaded appliciations have multiple threads within single process, each having their own program counter, stack and set of registers, but sharing common code,data, and certain structures like open files.



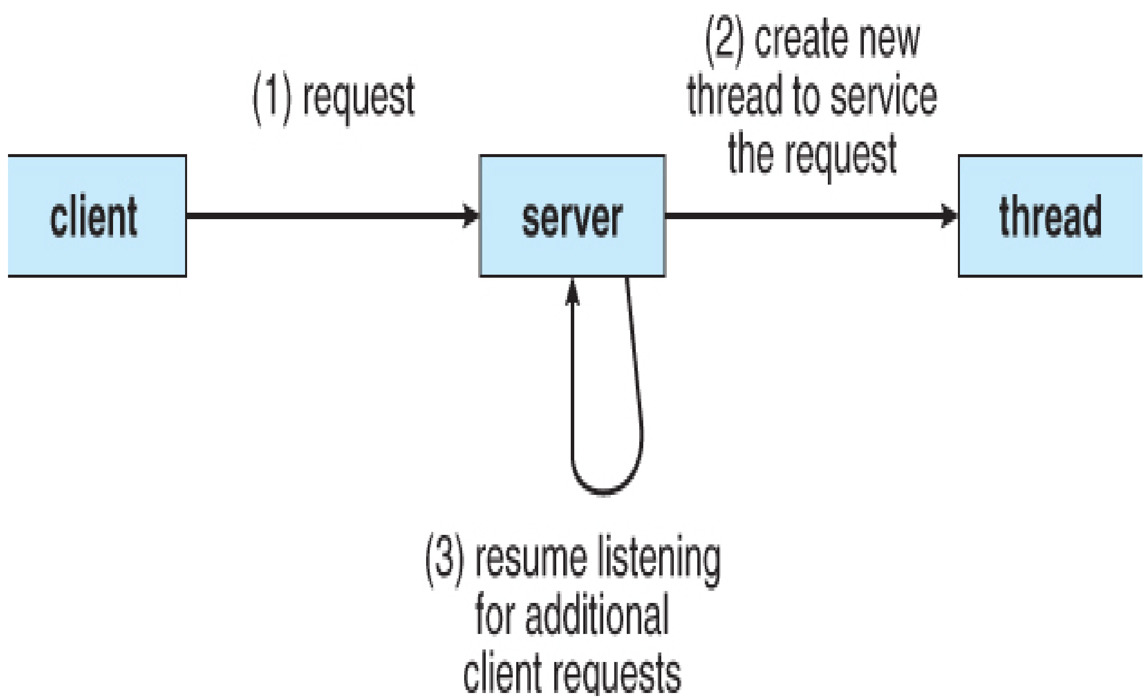
4.1 Why Threads?

- Threads are very useful in modern programming whenever a process has multiple tasks to perform independently of the others.

- This is particularly true when one of the tasks may block, and it is desired to allow the other tasks to proceed without blocking.

- For example in a word processor, a background thread may check spelling and grammar while a foreground thread processes user input (keystrokes), while yet a third thread loads images from the hard drive, and a fourth does periodic automatic backups of the file being edited.

- Another example is a web server - Multiple threads allow for multiple requests to be satisfied simultaneously, without having to service requests sequentially or to fork off separate processes for every incoming request. (The latter is how this sort of thing was done before the concept of threads was developed. A daemon would listen at a port, fork off a child for every incoming request to be processed, and then go back to listening to the port.)



4.2 Benefits

There are four main categories of benefits to multi-threading

- Responsiveness - One thread may provide rapid response while other threads are blocked or slowed down doing intensive calculations.
- Resource Sharing - By default threads share common code, data, and other resources, which allows multiple tasks to be performed simultaneously in a single address space.
- Economy - Creating and managing threads is much faster than performing the same tasks for processes.
- Scalability and Utilization of multiprocessor architectures - A single threaded process can only run on one CPU, no matter how many may be available, whereas the execution of a multi-threaded application may be split amongst available processors.

4.3 Thread States

Primary States:

- Running, Ready and Blocked.

Operations to change state:

- Spawn: new thread provided register context and stack pointer.
- Block: event wait, save user registers, PC and stack pointer.
- Unblock: moved to ready state.
- Finish: deallocate context and stacks.

5 User and Kernel Level Threads

5.1 Kernel-Level Threads

To make concurrency cheaper, the execution aspect of process is separated out into threads. As such, the OS now manages threads and processes. All thread operations are implemented in the kernel and the OS schedules all threads in the system. OS managed threads are called kernel-level threads or light weight processes. In this method, kernel knows about and manages the threads. No runtime system is needed. OS kernel provides system call to create and manage threads.

Advantages:

- Because kernel has full knowledge of all threads, Scheduler may decide to give more time to a process having large number of threads than process having small number of threads.
- Kernel-level threads are especially good for applications that frequently block.

Disadvantages:

- The kernel-level threads are slow and inefficient. For instance, threads operations are hundreds of times slower than that of user-level threads.
- Since kernel must manage and schedule threads as well as processes. It require a full thread control block (TCB) for each thread to maintain information about threads. As a result there is significant overhead and increased in kernel complexity.

5.2 User-Level Threads

Kernel-Level threads make concurrency much cheaper than process because, much less state to allocate and initialize. However, for fine-grained concurrency, kernel-level threads still suffer from too much overhead. Thread operations still require system calls. Ideally, we require thread operations to be as fast as a procedure call. Kernel-Level threads have to be general to support the needs of all programmers, languages, runtimes, etc. For such fine grained concurrency we need still "cheaper" threads.

Advantages:

- The most obvious advantage of this technique is that a user-level threads package can be implemented on an Operating System that does not support threads.

- Simple Representation: Each thread is represented simply by a PC, registers, stack and a small control block, all stored in the user process address space.

- Simple Management: This simply means that creating a thread, switching between threads and synchronization between threads can all be done without intervention of the kernel.

- Fast and Efficient: Thread switching is not much more expensive than a procedure call.

  Disadvantages:

- User-Level threads are not a perfect solution as with everything else, they are a trade off. Since, User-Level threads are invisible to the OS they are not well integrated with the OS.

6 Multithreading Models

- There are two types of threads to be managed in a modern system:User threads and kernal threads.

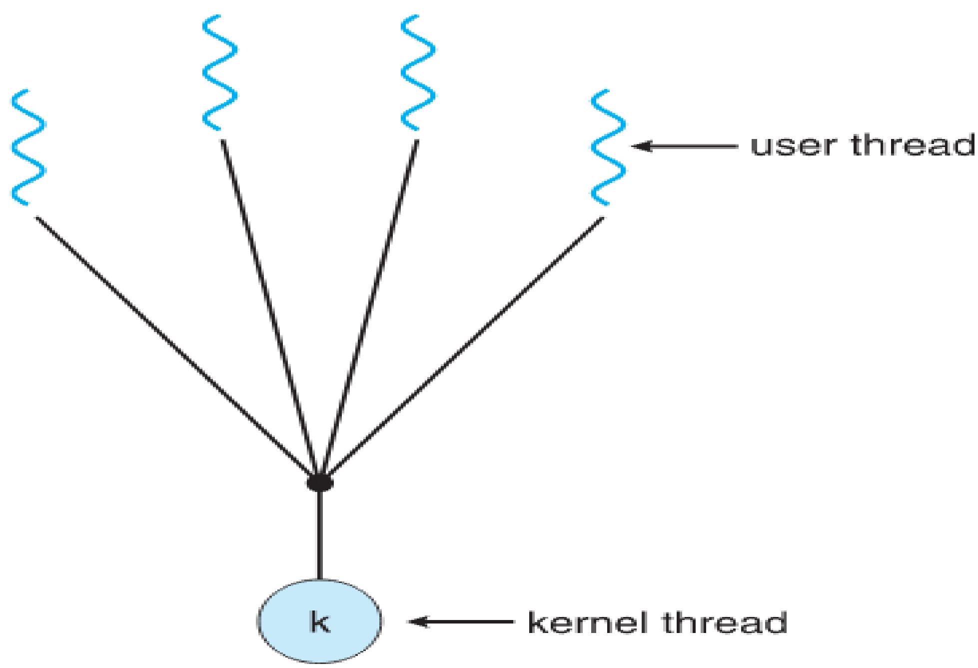
- User threads are supported above the kernel, without kernel support. These are the threads that application programmer would put into their programs.

- Kernel threads are supported within the kernel of the OS itself. All modern OSes support kernel level threads, allowing the kernel to perform multiple simultaneous taks and/or to service multiple kernel system calls simultaneously.

- In a specific implementation, the user threads must be mapped to kernel threads, using one of the following strategies.

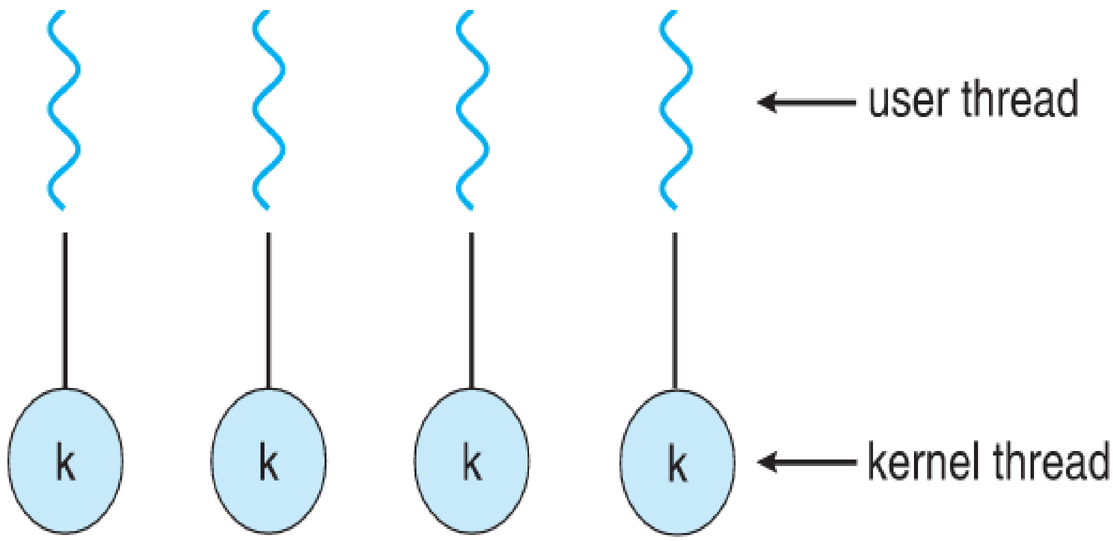
6.1 Many-To-One Model

- In this model many user-level threads all mapped to onto a single kernel thread.
- Thread library handled thread management in the user space, which is very efficient.
- But if a blocking system call is made, then entire process blocks, even if the other user threads would otherwise be able to continue.
- Because a single kernel thread can operate only on a single CPU, the many-to-one model does not allow individual processes to be split across multiple CPUs.
- Few systems uses this model like Solaris Green Threads, Gnu Portable Threads



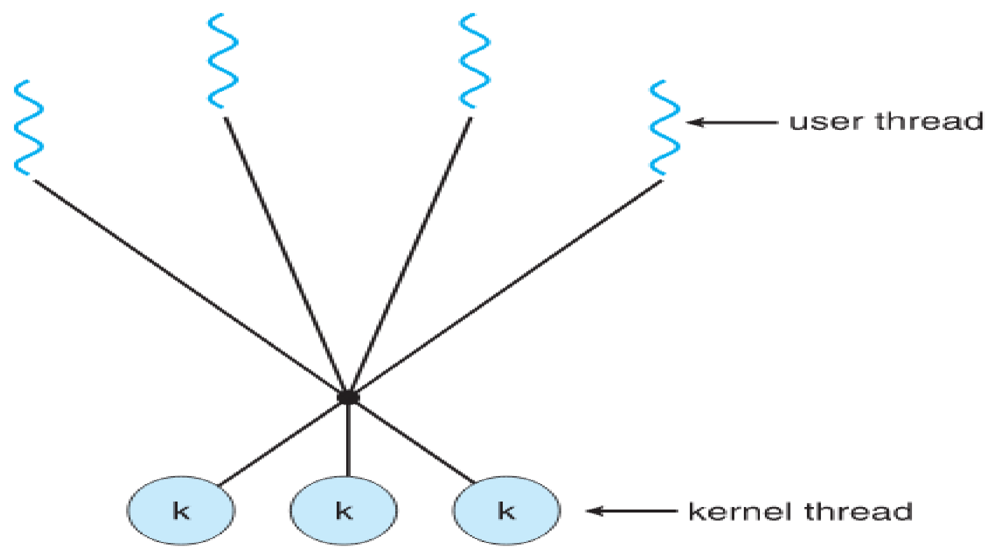
6.2 One-To-One Model

- Each user-level thread maps to kernel thread.
- Creating a user-level thread creates a kernel thread.
- More concurrency than many-to-one.
- Number of threads per process sometimes restricted due to overhead.
- Examples; Windows,Linux,Solaris 9 and later.



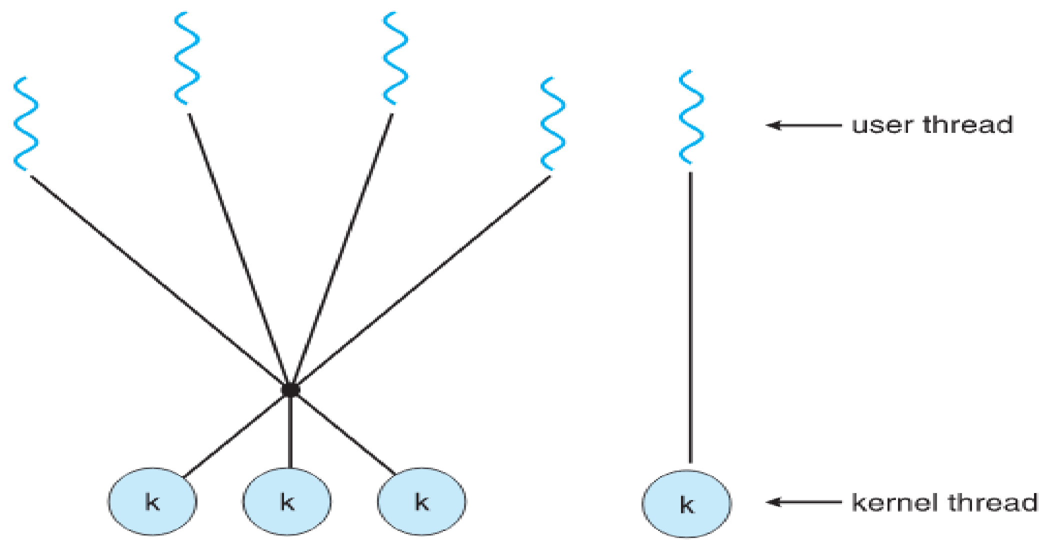
6.3 Many-To-Many Model

- Allows many user to level threads to be mapped to many kernel threads.
- Allows the operating system to create a sufficient number of kernel threads.
- Solaris prior to version 9
- Windows with the ThreadFiber package.



6.4 Two-Level-Model

- Similar to M:M, except that it allows a user thread to be bound to kernel thread.
- Examples: IRIX, HP-UX, Tru64 UNIX, Solaris 8 and earlier.



7 References

- Abraham Silberschatz, Greg Gagne, and Peter Baer Galvin, "Operating System Concepts, Ninth Edition ", Chapter 4
- https://www.geeksforgeeks.org/threads-and-its-types-in-operating-system/