User Threads Lab Primer and Sockets

2025 Winter ECE353: Systems Software

Lecture 12

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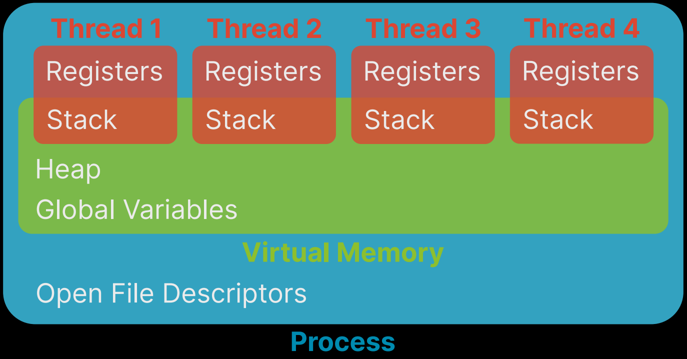
A Process with 4 Threads



Remember, You Can Access These Examples!

Look at the `materials` repository, today:
`lectures/12-user-threads-lab-primer-and-sockets`

First Example

`ucontext-example.c`

Done live, please see the recording

Second Example

`tailq-example.c`

Done live, please see the recording

ucontext Question

Global variables:

```
int i = 0;
ucontext_t uA; // Initialized to execute thread_a()
ucontext_t uB; // Initialized to execute thread b()
```

One kernel thread calls `set_context(&uA)`, what happens?

```
void thread_a() {
    int d = 0;
    while (i < 3) {
        i++;
        printf("A: %d\n", i);
        d = 0;
        getcontext(&uA);
        if (d == 0) {
            d = 1;
            setcontext(&uB);
        }
    }
}
```

```
void thread_b() {
    int d = 1;
    while (i < 3) {
        i++;
        printf("B: %d\n", i);
        d = 1;
        getcontext(&uB);
        if (d == 1) {
            d = 0;
            setcontext(&uA);
        }
    }
}
```

Sockets are Another Form of IPC

We’ve seen pipes and signals

- We also talked about shared memory

Previous IPC assume that the processes are on the same physical machine

Sockets enable IPC between physical machines, typically over the network

Servers Follow 4 Steps to Use Sockets

These are all system calls, and have the usual C wrappers:

1. `socket`
   Create the socket
2. `bind`
   Attach the socket to some location (a file, IP:port, etc.)
3. `listen`
   Indicate you're accepting connections, and set the queue limit
4. `accept`
   Return the next incoming connection for you to handle

Clients Follow 2 Steps to Use Sockets

Clients have a much easier time, they use one socket per connection

1. `socket`
   Create the socket
2. `connect`
   Connect to some location, the socket can now send/receive data

The socket System Call Sets the Protocol and Type of Socket

```c
int socket(int domain, int type, int protocol);
```

domain is the general protocol, further specified with protocol (mostly unused)

- AF_UNIX is for local communication (on the same physical machine)
- AF_INET is for IPv4 protocol using your network interface
- AF_INET6 is for IPv6 protocol using your network interface

type is (usually) one of two options: stream or datagram sockets

Stream Sockets Use TCP

All data sent by a client appears in the same order on the server

Forms a persistent connection between client and server

Reliable, but may be slow

Datagram Sockets Use UDP

Sends messages between the client and server

No persistent connection between client and server

Fast but messages may be reordered, or dropped

The `bind` System Call Sets a Socket to an Address

```
int bind(int socket, const struct sockaddr *address,
         socklen_t address_len);
```

`socket` is the file descriptor returned from the `socket` system call

There's different `sockaddr` structures for different protocols

- `struct sockaddr_un` for local communcation (just a path)
- `struct sockaddr_in` for IPv4, a IPv4 address (e.g. 8.8.8.8)
- `struct sockaddr_in6` for IPv6, a IPv6 address (e.g. `2001:4860:4860::8888`)

The `listen` System Call Sets Queue Limits for Incoming Connections

```
int listen(int socket, int backlog);
```

`socket` is still the file descriptor returned from the `socket` system call

`backlog` is the limit of the outstanding (not accepted) connections

- The kernel manages this queue, and if full will not allow new connections

We’ll set this to `0` to use the default kernel queue size

The `accept` System Call Blocks Until There's a Connection

```c
int accept(int socket, struct sockaddr *restrict address,
           socklen_t *restrict address_len);
```

`socket` is *still* the file descriptor returned from the `socket` system call

`address` and `address_len` are locations to write the connecting address
- Acts as an optional return value, set both to `NULL` to ignore

This returns a new file descriptor, we can `read` or `write` to as usual

The `connect` System Call Allows a Client to Connect to an Address

```
int connect(int sockfd, const struct sockaddr *addr,
            socklen_t addrlen);
```

`sockfd` is the file descriptor returned by the `socket` system call

- The client would need to be using the same protocol and type as the server

`addr` and `addrlen` is the address to connect to, exactly like `bind`

If this call succeeds then `sockfd` is may be used as a normal file descriptor

Our Example Server Sends “Hello there!” to Every Client and Disconnects

Please see `lectures/19-sockets` in your `materials` repository

- Relevant source files: `client.c` and `server.c`

We use a local socket just for demonstration, but you could use IPv4 or IPv6

- We use `example.sock` in the current directory as our socket address

Our server uses signals to clean up and terminate from our infinite `accept` loop

Instead of `read`/`write` There's Also `send`/`recv` System Calls

These system calls are basically the same thing, except they have `flags`

Some examples are:
- `MSG_OOB` — Send/receive out-of-band data
- `MSG_PEEK` — Look at data without reading
- `MSG_DONTROUTE` — Send data without routing packets

Except for maybe `MSG_PEEK`, you do not need to know these

`sendto`/`recvfrom` take an additional address
- The kernel ignores the address for stream sockets (there's a connection)

You Perform Networking Through Sockets

Sockets are IPC across physical machines, the basics are:

- Sockets require an address (e.g. local and IPv4/IPv6)
- There are two types of sockets: stream and datagram
- Servers need to bind to an address, listen, and accept connections
- Clients need to connect to an address