CSE 3221
Operating System Fundamentals
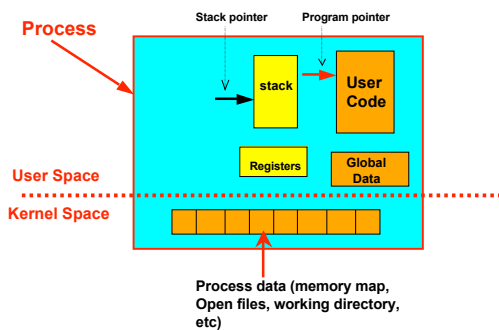
No. 3

Thread

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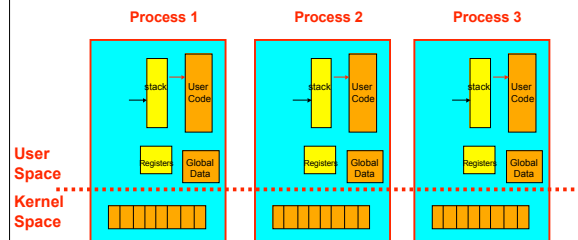*York University*

Thread Concept

- What is thread?
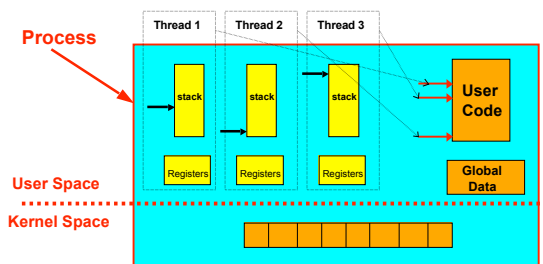
- Difference between a process and a thread

One single-threaded Process

Multiple single-threaded Process

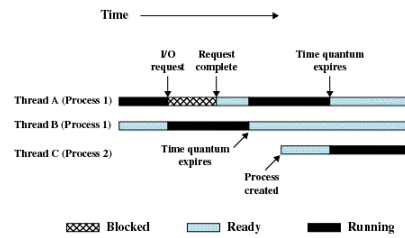# One multi-threaded Process

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Process vs. Thread

- Traditional process contains a single stream of control.
    (one process can do one thing at a time)
- Multithreaded process: contains several different streams of control. Each stream is called a thread of this process.
    (multithreaded process can do multiple jobs simultaneously)
- A multi-threaded process contains several threads.
- All threads in a process share:
    - Code section & data section
    - OS resources (memory map, open devices, accounting, etc.)
- Each thread includes:
    - A thread ID
    - A program counter (PC)
    - A register set
    - A stack & stack pointer

Comparison

- One single-threaded process:
  - can do one thing at a time

- Multiple single-threaded processes:
  - can do many things at the same time

- One multi-threaded process
  - Also can do many things at the same time

- Why multiple thread??
  - Multi-threaded process requires less OS resources (memory)
  - More efficient for OS to handle threads than processes

Multithreading

Multithreading Example on a Uniprocessor

Benefits to use threads

- **Threads occupy less memory than processes.**

- **Takes less time to create a new thread than a process.**

- **Less time to terminate a thread than a process.**

- **Less time to switch context between two threads within the same process.**

- **Since threads within the same process share memory and files, they can communicate with each other without invoking the kernel.**

Thread-safe or Reentrant code

- **To be thread safe, the program must be reentrant:**

  - **Program never modifies itself.**

  - **Each function calling keeps track of its own progress.**

  - **No use of static/global data.**

  - **No use of non-reentrant functions or routines.**

Non-reentrant C code

```
int delta;

int diff (int x, int y)
{

    delta = y - x;

    if (delta < 0) delta = -delta;

    return delta;

}
```

Reentrant C code

```
int diff (int x, int y)
{
    int delta;

    delta = y - x;

    if (delta < 0) delta = -delta;

    return delta;

}
```
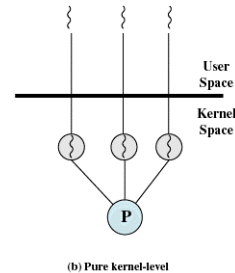
Kernel Threads

- Kernel threads are supported directly by OS.
- The kernel performs thread creation, scheduling, and management in the kernel space.
- Slow to maintain (need system calls to kernel space).
- Each kernel thread can run totally independently:
  - One thread blocks, the kernel will schedule another thread to run.
  - Several kernel threads can run in parallel if many CPU's are available.
  - OS to support kernel thread:
    - Windows NT/2000/XP
    - Solaris 2
    - Linux

Directly Use Kernel Threads

- For each user task, make system call to create a kernel thread.

(b) Pure kernel-level

Example of Kernel Thread: Linux Thread

- Linux kernel support kernel threads, system call *clone()*.
- *fork()* creates a new process
  - Create a new memory space for new process
  - Copy from the address space of the calling process
- *clone()* simulates *fork(),* but
  - It does not create new memory space.
  - The new process shares the same address space of the original process.
  - → two processes sharing the same memory space.
    (something like thread)

Linux Thread

- Linux use `clone()` to create kernel threads.

```
#include <sched.h>
 int clone(int (*fn)(void *), void
 *child_stack, int flags, void *arg);
```

`fn`: starting function
`child_stack`: stack memory space for child thread.
`flags`: what to share.
  for thread creation:
  flags = CLONE_FS | CLOSE_VM | CLONE_SIGHAND | CLONE_FILES
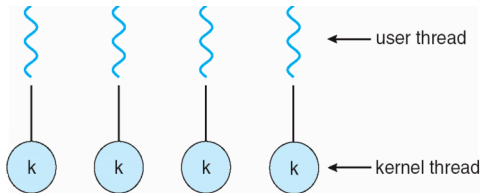`arg`: arguments to pass.

User Thread

- User thread: supported above the kernel and implemented by a thread library in user space.
  - The library supports thread creation, scheduling, management in user space.
  - User threads are fast to create and manage (no need to make a system call to trap to the kernel).
  - User threads for better compatibility across OS platforms.
- Problems with user threads:
  - The kernel is not aware of the existence of users threads.
  - User thread must be mapped to the kernel to execute in CPU.
- Examples:
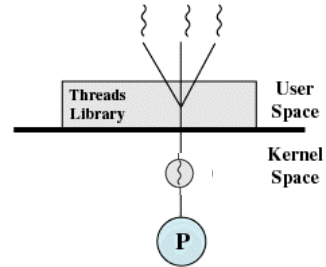 - POSIX Threads (Pthreads), Java Threads, Win32 Threads, Solaris UI-threads

Three Models for User Thread

- One-to-One mapping

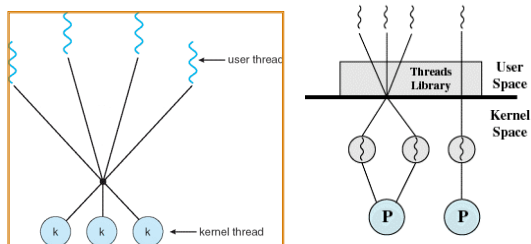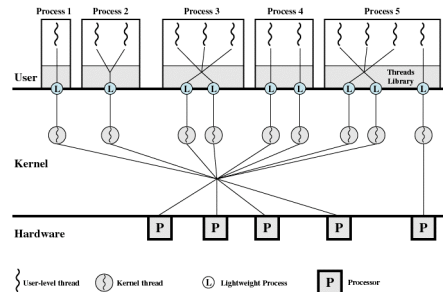- Many-to-One Mapping

- Many-to-Many Mapping

One-to-One Mapping

← user thread

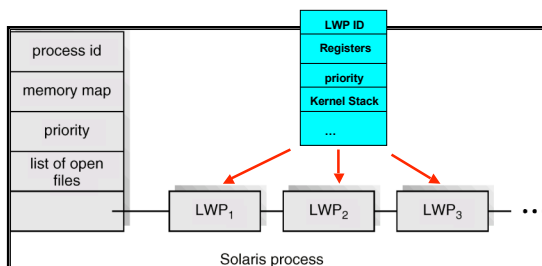← kernel thread

Many-to-One Mapping

Threads Library

User Space

Kernel Space

P

Combined Model: many-to-many mapping

← user thread

Threads Library

User Space

Kernel Space

P   P

← kernel thread

Solaris Threads

Process 1   Process 2   Process 3   Process 4   Process 5

User

Threads Library

Kernel

Hardware   P   P   P   P   P

User-level thread   Kernel thread   Lightweight Process   P Processor

Thread data structure in Solaris

process id

memory map

priority

list of open files

LWP ID
Registers
priority
Kernel Stack
...

LWP₁   LWP₂   LWP₃   • • •

Solaris process

Threading Issues

- *fork()* **and** *exec()* **implementation**
  - **One thread calls** *exec(),* **it will replace the entire process.**
  - **One thread in a process call** *fork(),* **it duplicates all threads in the process or just one calling thread.**

- **Thread cancellation: terminating a thread before it finishes.**
  - **Asynchronous cancellation**
  - **Deferred cancellation**

- **Unix Signal Handling**
  - **Deliver the signal to the thread to which the signal applies.**
  - **Deliver the signal to every thread in the process**
  - **Deliver the signal to certain threads in the process**
 - **Assign a specific thread to receive all signals for the process**

Thread Pools

- Create a number of threads at process start-up, place them into a pool, where they sit and wait for work.
- When the process receives a request, it awakens a thread from the pool, and serves the request immediately.
- Once the thread completes, it returns to the pool.
- If the pool contains no available thread, the process waits until one becomes free.
- Benefits of thread pools:
  - Faster to service a request.
 - Thread pool limits the total number of threads in system (no overload).

Three Models to use Threads

- Pipeline
  - Assembly line: each thread repeatedly performs the same operation on a sequence of data sets, passing each result to another thread for next step.

- Work Crew
  - Each thread performs an operation on its own data independently, then combine all results to get the final.

- Client/Server
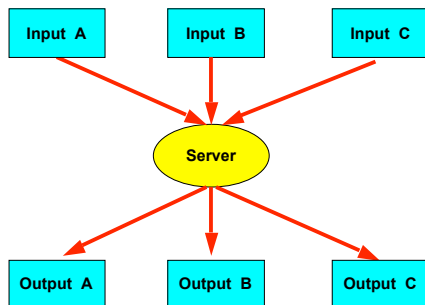 - A client contacts with an independent server for each job.
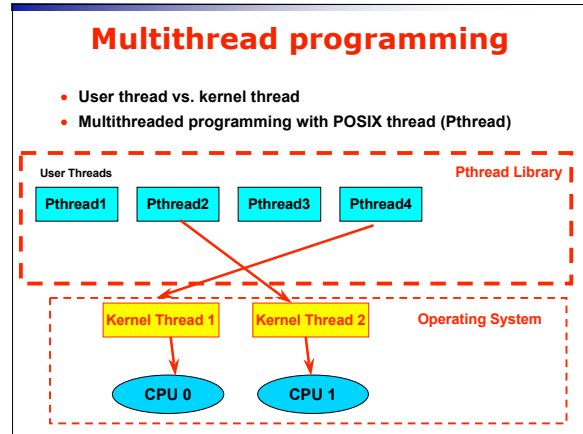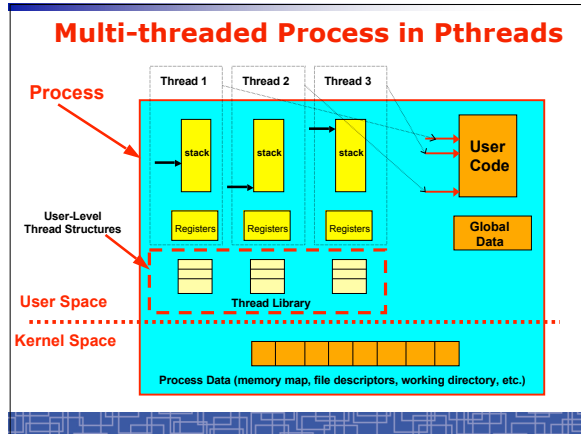
Pipeline
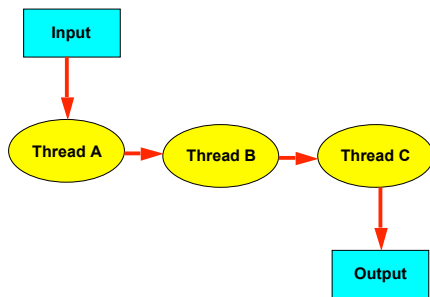
Work Crew
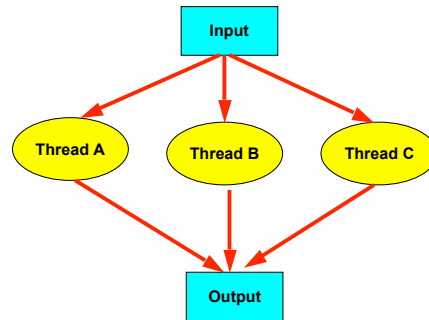
Client/Server

User Threads: Pthreads

- A POSIX standard (IEEE 1003.1c) API for thread creation and synchronization.

- 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).

Multi-threaded Process in Pthreads

Process

Thread 1 | Thread 2 | Thread 3

stack | stack | stack

User Code

User-Level Thread Structures

Registers | Registers | Registers

Global Data

Thread Library

User Space

Kernel Space

Process Data (memory map, file descriptors, working directory, etc.)

Multithread programming

- User thread vs. kernel thread
- Multithreaded programming with POSIX thread (Pthread)

User Threads | Pthread Library

Pthread1 | Pthread2 | Pthread3 | Pthread4

Kernel Thread 1 | Kernel Thread 2 | Operating System

CPU 0 | CPU 1

POSIX Thread (1)

- **Thread creation and termination:**

```
#include <pthread.h>

pthread_create(pthread_t *thread, const pthread_attr_t
        *attr, void *(*start) (void *), void *argv) ;


        pthread_exit(void *value_ptr) ;
```

POSIX thread(2)

- **Wait for another thread to terminate**

```
pthread_join(pthread_t thread, void **value_ptr) ;
```

- **Cancellation**

```
pthread_cancel(pthread_t thread) ;
```

- **Others**

```
pthread_self(void) ;
pthread_detach(pthread_t thread) ;
pthread_attr_init(pthread_attr_t *attr) ;
```

Example 1: thread.c

- **Example: thread.c (How to use pthread)**

- **Two threads:**
  - *main*() **thread**
  - *runner*() **thread**

Example 2: alarm.c

- **Example 1: alarm.c (no process/thread)**

- **Example 2: alarm_fork.c (multiple process)**

- **Example 3: alarm_thread.c (multiple thread)**