Department of Physics,
Computer Science & Engineering

CPSC 410 – Operating Systems I

Threads

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Adapted from original slides by Dr. Roberto A. Flores

Topics

- Processes & Threads
  - Approaches, States, Processes vs. Threads, Benefits
- Types of Threads
  - User-level, Kernel-level, Hybrid
- Multi-core & Multi-threading
  - Performance, Winners
- Examples
  - ~~Windows 7~~
  - Linux

Multi-Threading

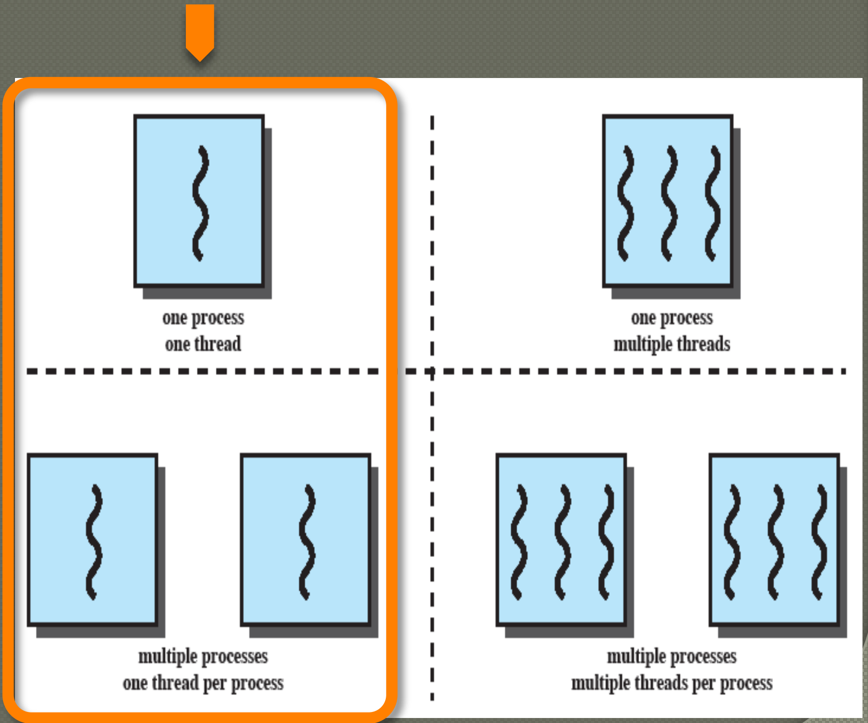
- A process has 2 characteristics
  - Resource ownership
    - virtual address space holding the process image
  - Scheduling & Execution
    - execution state (Running, Ready, etc.)
    - dispatching priority

- Multi-threading
  - ability of an OS to support multiple concurrent paths of execution within a single process

Multi-Threading

- Approaches
  - Single-Threaded

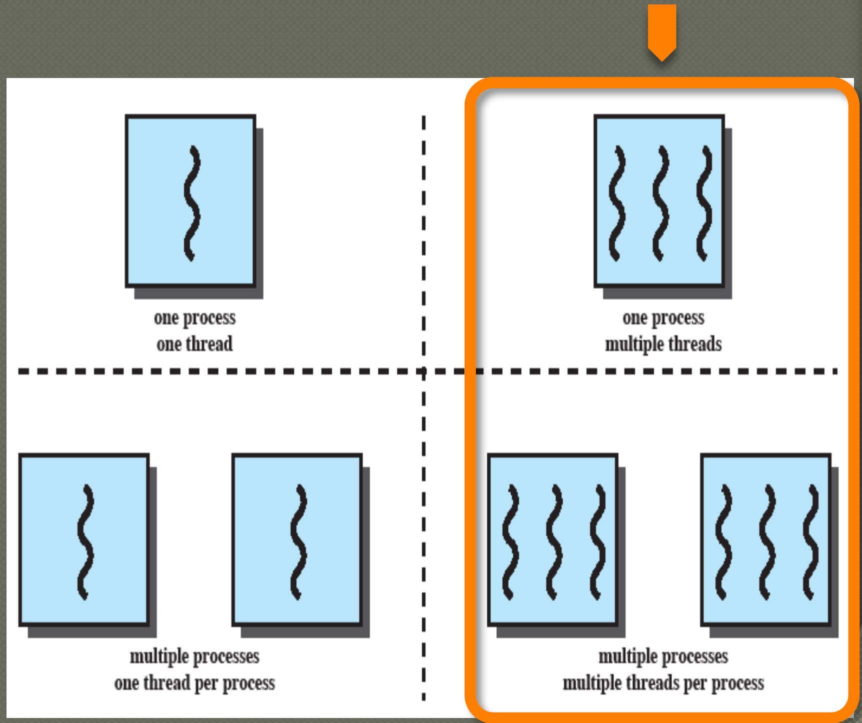
    1 thread per process…



Multi-Threading

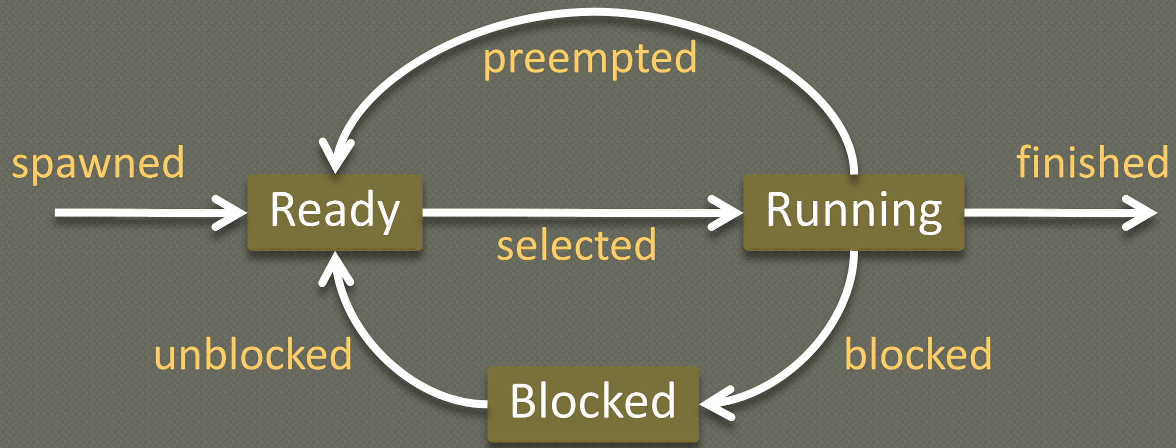
- Approaches
  - Multi-Threaded

    1+ threads per process



Threads

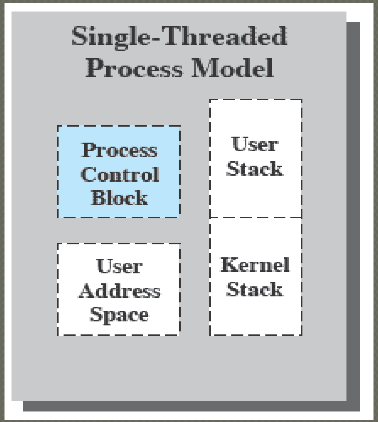
- States



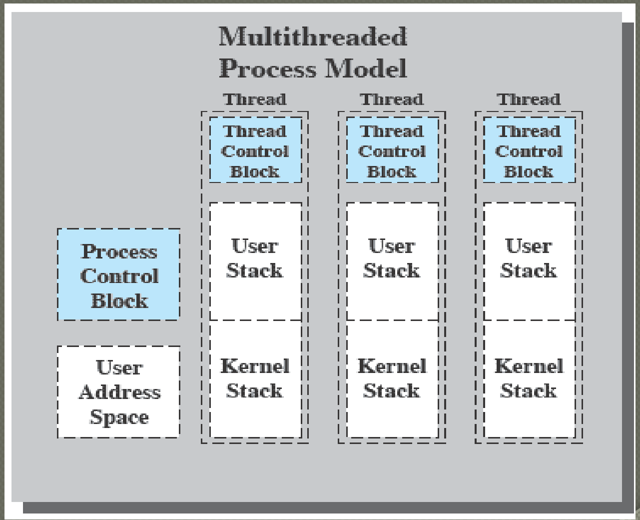
- That all thread info is stored in a process means that…
  - terminating a process
    terminates all its threads.

Processes vs. Threads

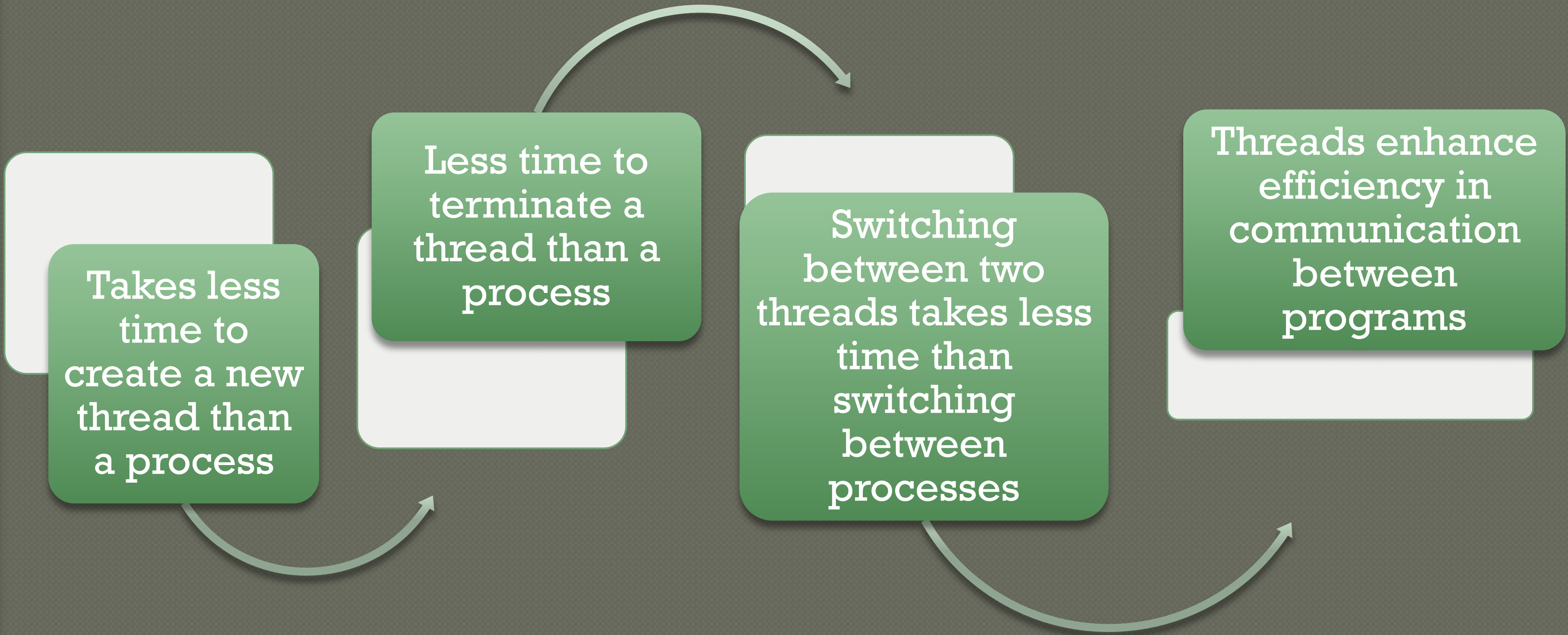
- A process has data structures to run in 1 thread
  - PCB, memory space, user/kernel stacks



- A thread duplicates (most of) them to run in its own terms
  - except PCB (replaced by TCB) & memory (which is shared among threads)
  - All in the host process space

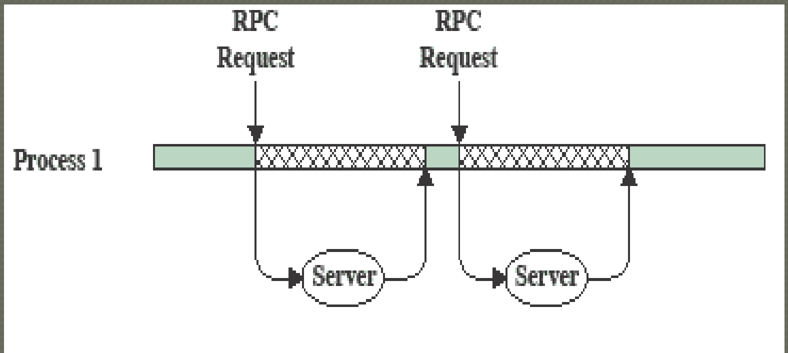


Benefits of Threads

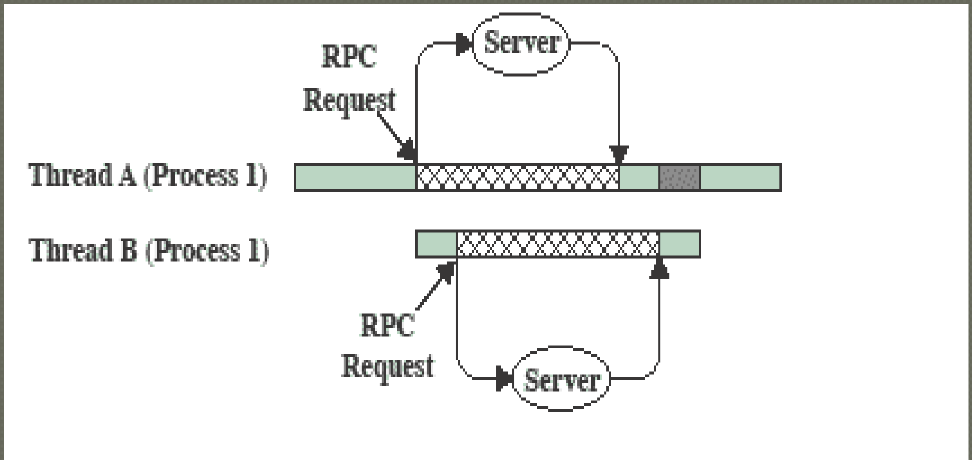


Threads

- Why multi-threading?
  - improved utilization – concurrent waiting rather than sequential



(a) RPC Using Single Thread



(b) RPC Using One Thread per Server (on a uniprocessor)

Threads

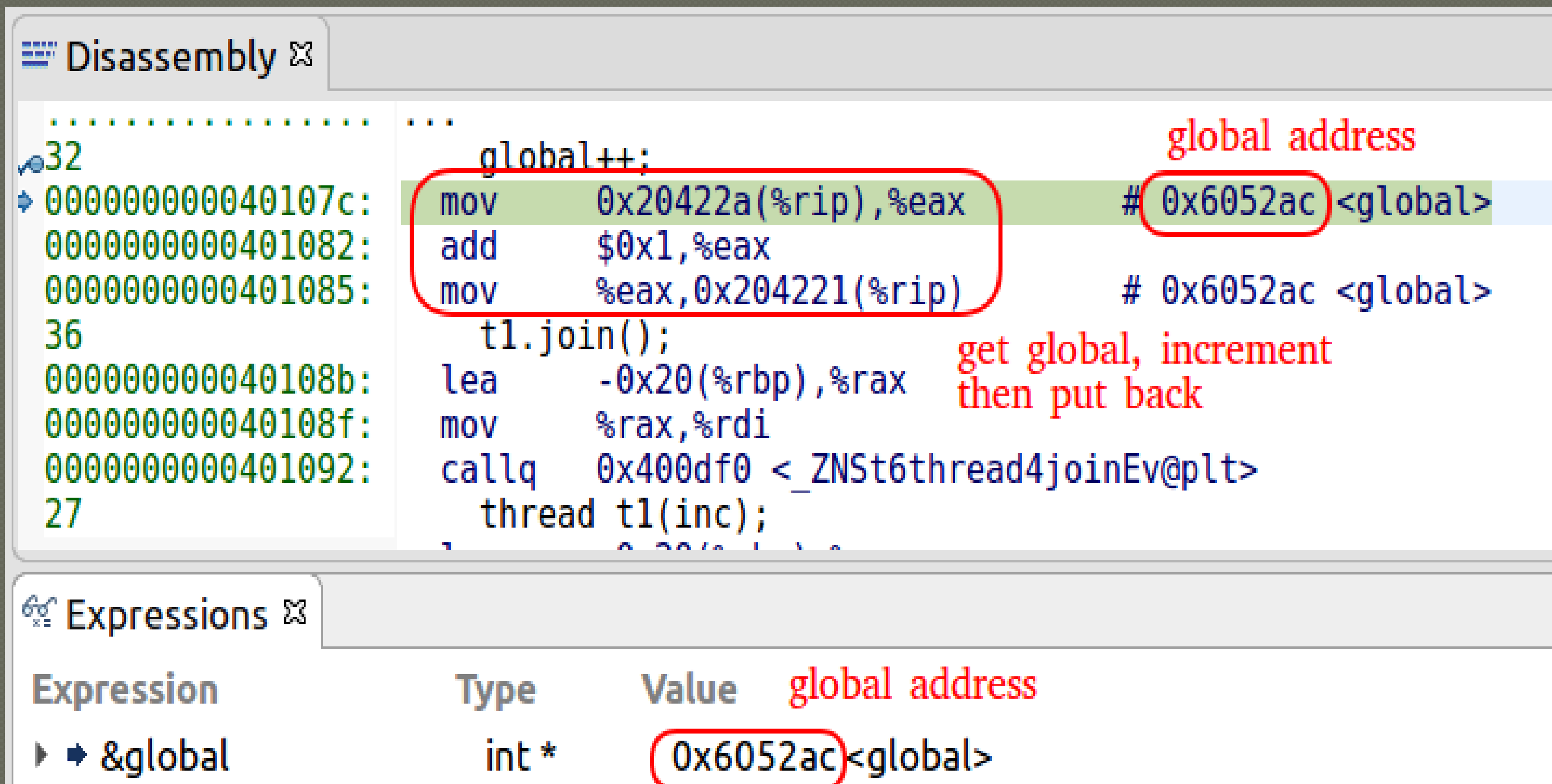
- Why multi-threading?
  - Improves efficiency in asynchronous execution
  Responsiveness
    - 1 thread handles GUI, another background processing
  - Speed of execution (depends on if you can parallelize tasks)
    - e.g., in video games: rendering, AI, physics
  - Modular programming
    - programmers design modular code

Thread synchronization
- Needed because:
  - all threads of a process share the same memory/resources
    - i.e., any changes by one thread affects other threads in process

My first thread (Eclipse)

```
int global = 0;

void inc()
{
    global++;
}

void thread1()
{
    // constructs threads and runs it
    //it starts by executing function task_inc
    thread t1(inc);

    //Show dissasembly view (window->Show View->Other->debug->Disassembly
    //the following instruction = 3 assembly instructions
    //interrupt can happen after any of those, what happens if
    global++;

    // Makes the main thread wait for the new thread to finish execution,
    // therefore blocks its own execution.
    t1.join();
}
```

Under the hood (Eclipse)



Topics

- Processes & Threads
  - Approaches, States, Processes vs. Threads, Benefits
- Types of Threads
  - User-level, Kernel-level, Hybrid
- Multi-core & Multi-threading
  - Performance, Winners
- Examples
  - ~~Windows 7~~
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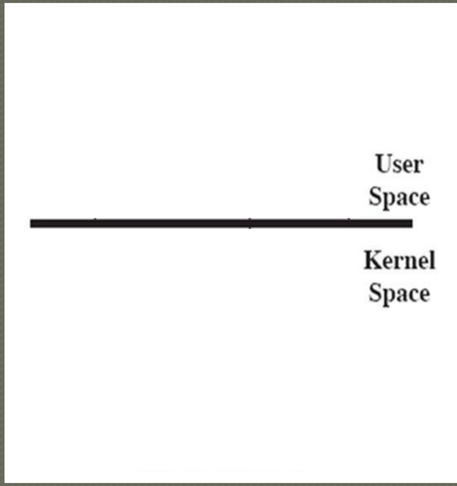
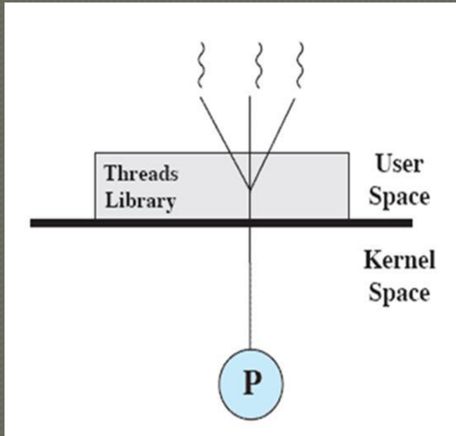
Types of Threads

- Types
  - Thread management is done at
    - The application level (User-level threads)
      - Kernel is aware of process only not its multiple threads (library manages them)
      - Not used much anymore
    - The OS level (Kernel-level threads)
      - processes use an OS API to access threads
      - Used by modern OS (MS Windows, Linux)



Types of Threads

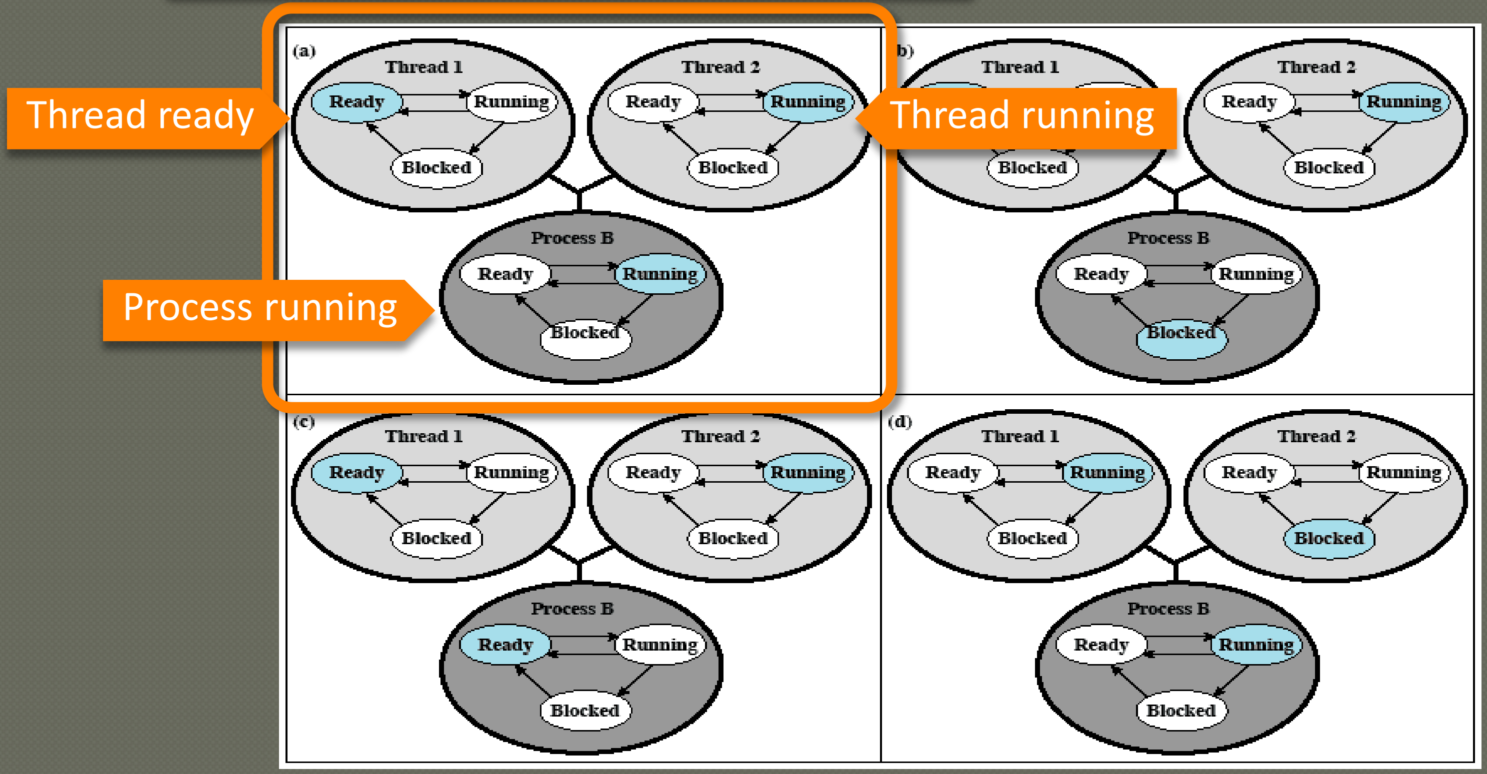
- User-level Threads (ULT)
  - All management done by a threads library
    - Program & library run in a one-thread process.
    - A program spawning a new thread (within the same process) invokes the library, which creates data structures for the thread.
    - When the library is given control, it executes threads using its own scheduling algorithm, saving threads states as it switches execution from one to the next.



(a) Pure user-level

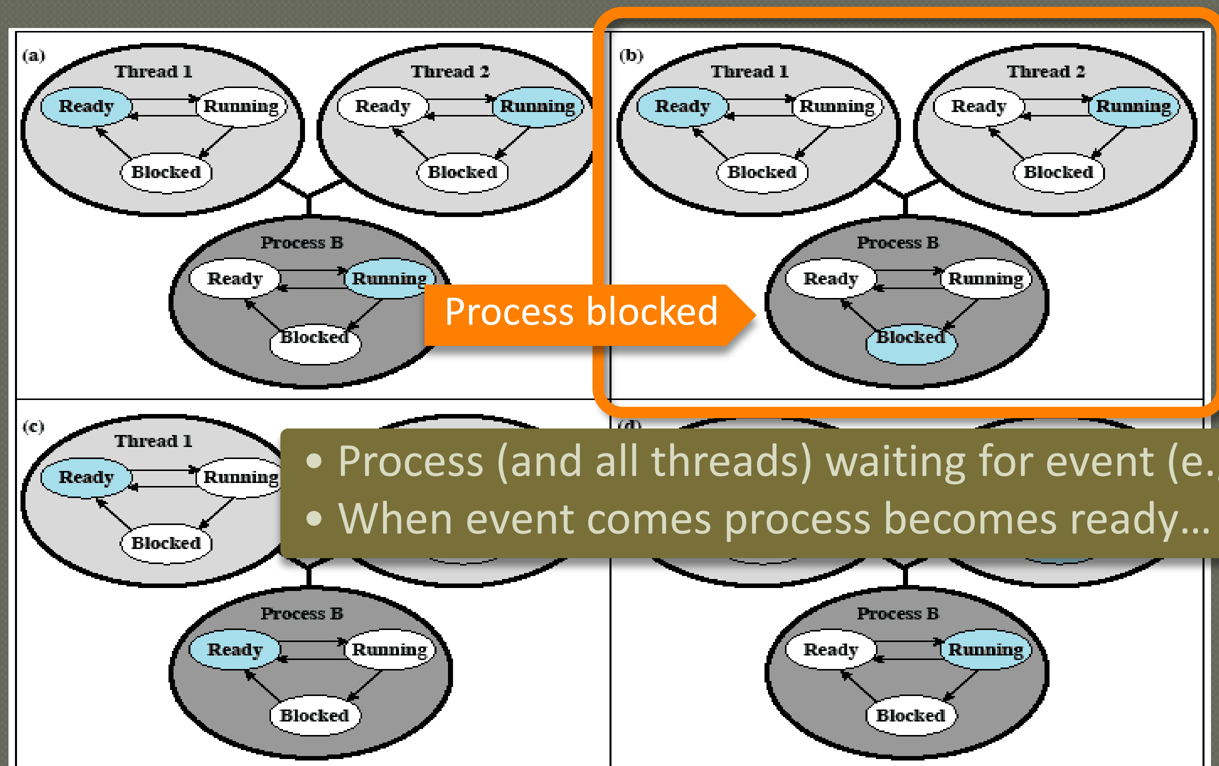
Types of Threads

- User-level Threads (ULT) in context
  - Thread requests system call (e.g., I/O)
  - Entire process is blocked by OS



Types of Threads

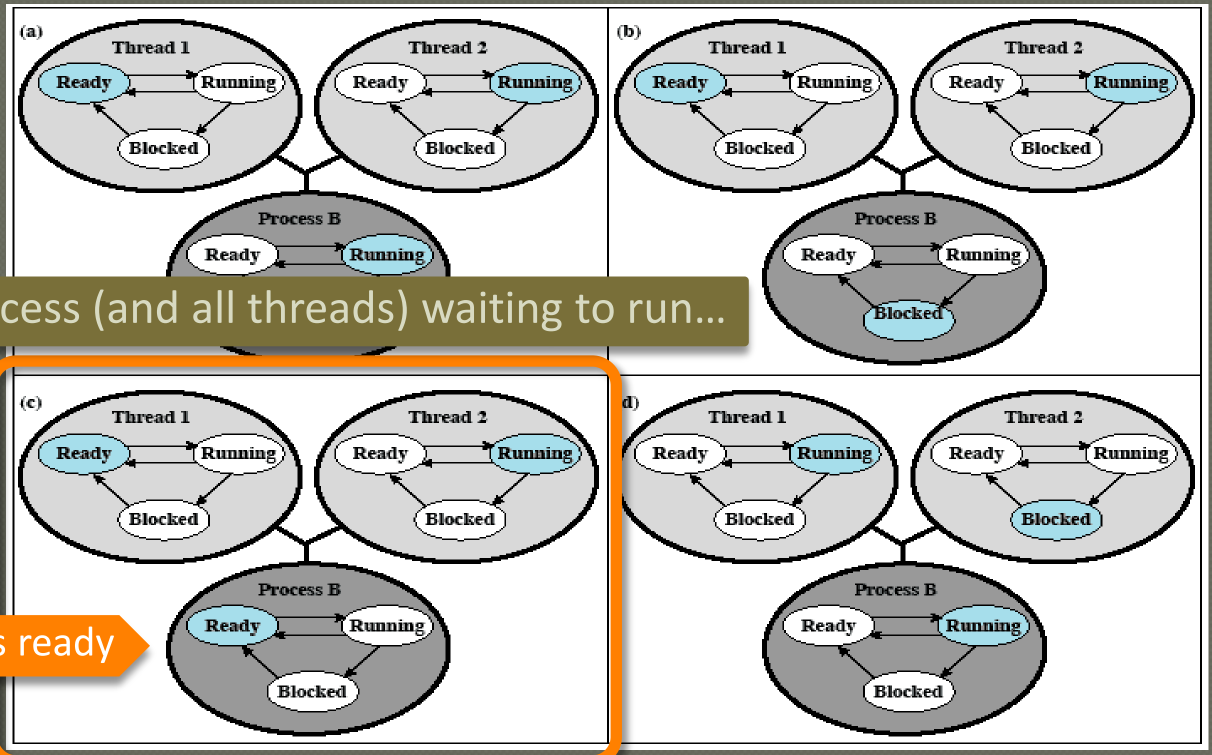
- User-level Threads (ULT) in context



- Process (and all threads) waiting for event (e.g., I/O interrupt)
- When event comes process becomes ready…

Types of Threads

- User-level Threads (ULT) in context

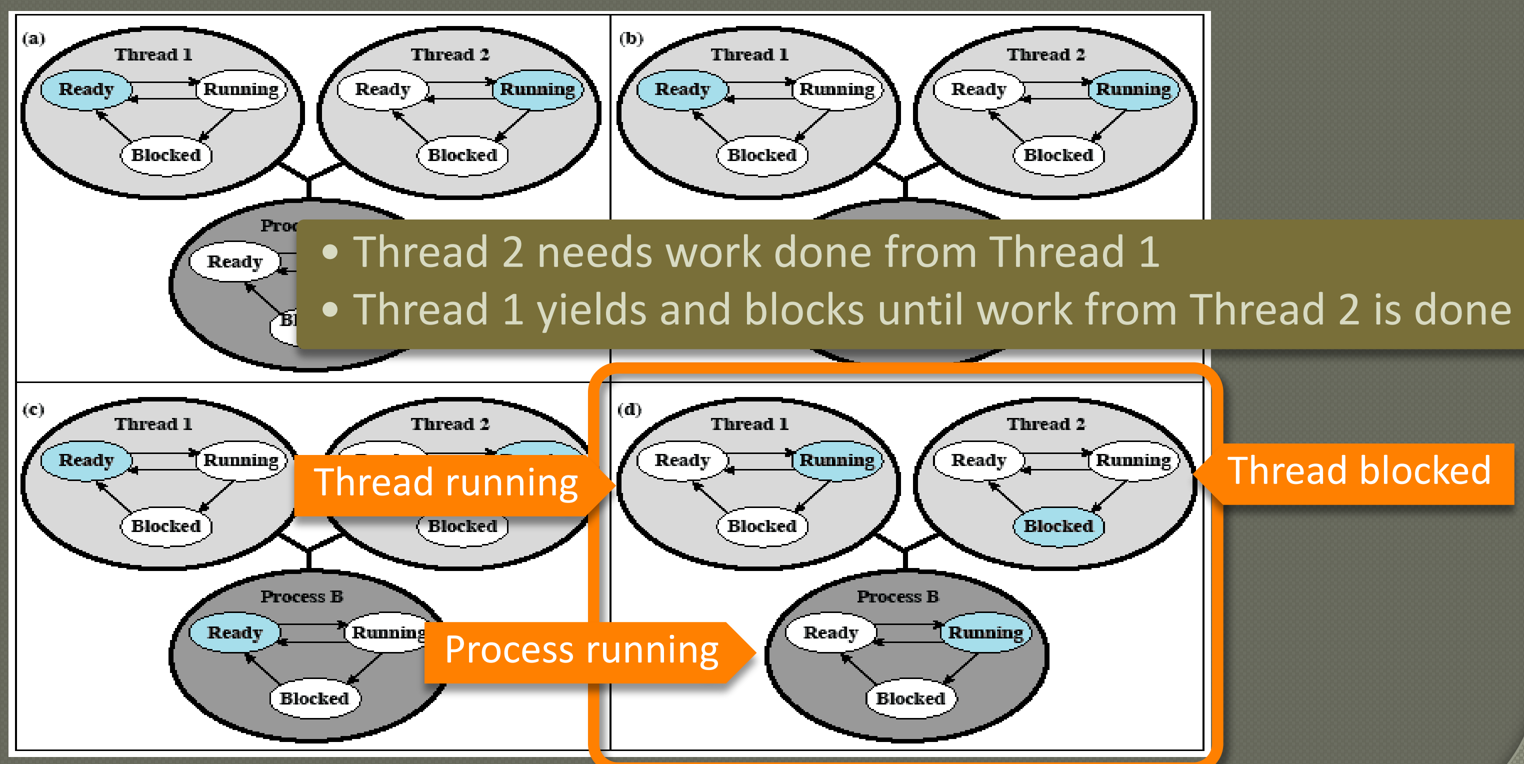


- Process (and all threads) waiting to run…

Process ready

Types of Threads

- User-level Threads (ULT) in context



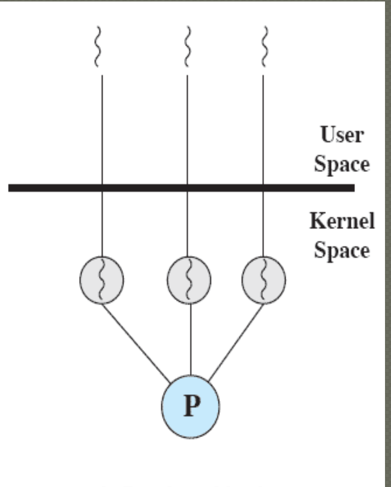
- Thread 2 needs work done from Thread 1
- Thread 1 yields and blocks until work from Thread 2 is done

Types of Threads

- User-level Threads (ULT)
  - Advantages
    - Switching threads does not require Kernel mode.
    - Scheduling can be application-specific.
    - Threads can run on any OS.
  - Disadvantages
    - If a thread requests a system call, then the process (and all threads) are blocked. (A big problem!)
    - ULT cannot take advantage of (OS scheduled) multi-processing. (A really big problem!)

Types of Threads

- Kernel-level Threads (KLT)
  - All management done by OS
    - Threads like processes (with shared memory)
  - Advantages
    - Threads from the same process can…
      - …run on multiple processors.
      - …keep running if one gets blocked.
  - Disadvantages
    - Transferring control from one thread to another (even from the same process) requires a switch to kernel mode.



(b) Pure kernel-level

Operation	User-Level Threads	Kernel-Level Threads	Processes
Null Fork	34	948	11,300
Signal Wait	37	441	1,840

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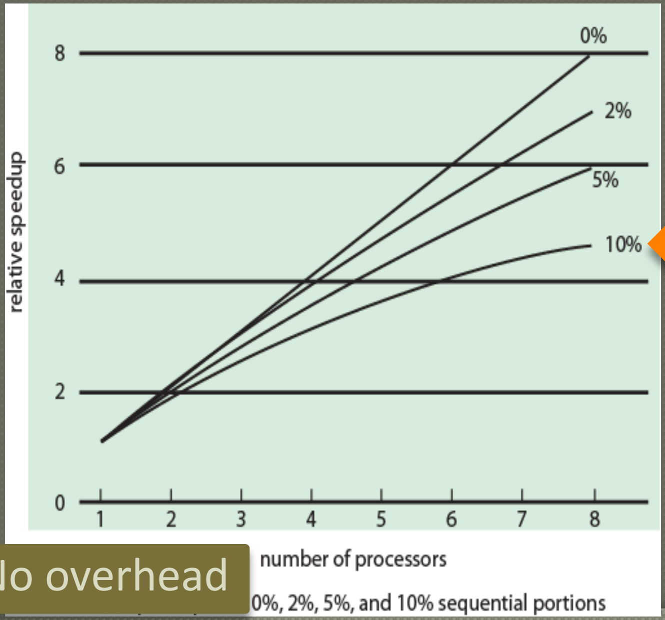
Multi-core & Multi-threading

- Performance
  - Benefits depend on program design
  - Amdahl's law

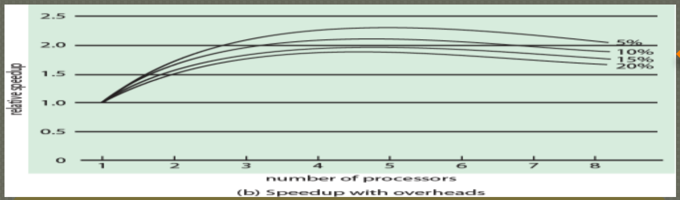
f = % parallelism

$$\text{Speedup} = \frac{\text{Time to run in 1 processor}}{\text{Time to run on N parallel processors}} = \frac{1}{(1 - f) + (f / N)}$$



f=90%, speedup=4.7

No overhead



f=90%, speedup=1.9

With synchronization overhead

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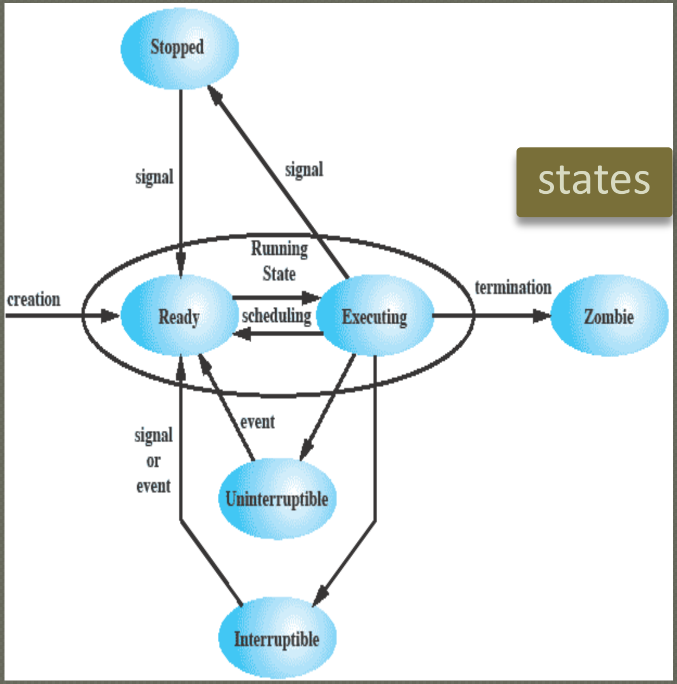
Linux

- Processes & Threads
  - No difference in Linux
  - ULT are mapped into KLT processes.
  - New processes are created…
    - …by forking or cloning
      - fork calls clone with flags cleared to create new process
      - Otherwise flags determine level of sharing
      - tgid of parent is copied
      - resources are shared
      - parent/child have separate stacks
  - When switching processes
    - If they have same ID (tgid), then Linux Does not switch address space. Just process state



states

Linux Threads

Linux does not recognize a distinction between threads and processes

User-level threads are mapped into kernel-level processes

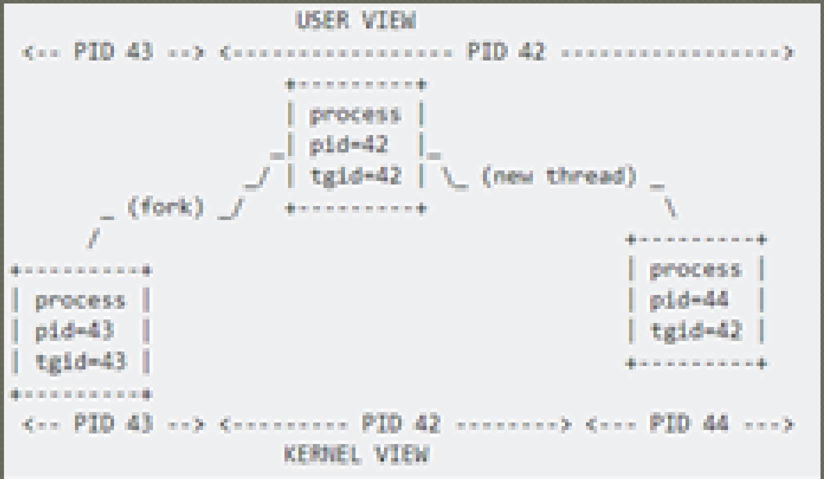
A new process is created by copying the attributes of the current process

The new process can be *cloned* so that it shares resources

The clone() call creates separate stack spaces for each process

Linux Processes and Threads

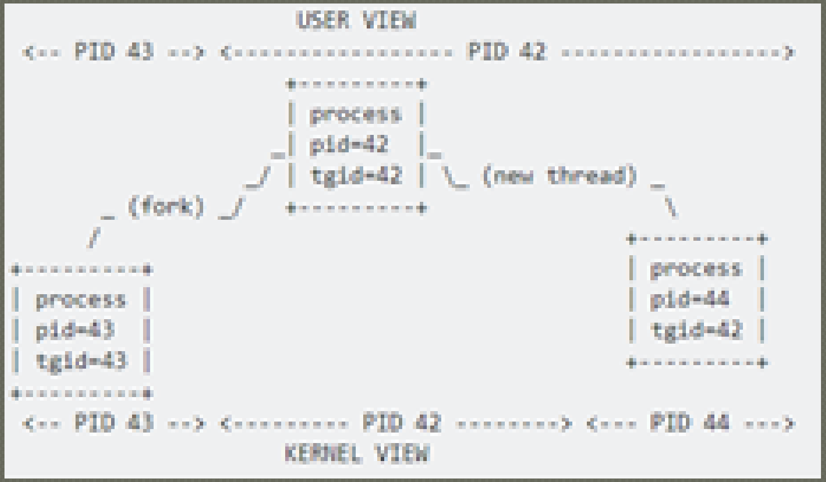
- Linux treats threads as processes
  - Parent process pid==tgid
  - Launched threads have new pid and **Parents** tgid
  - So scheduler sees different pids (for scheduling)
  - But same tgid means don’t swap memory if swapping to same tgid



Graphic from https://stackoverflow.com/questions/9305992/if-threads-share-the-same-pid-how-can-they-be-identified

Viewing

- Also means you can just show processes (not their internal threads) by displaying tgid only
- Show how HTOP tracks processes and threads
  - F2 to setup columns (PID, TGID)
  - Show tree view (Display options->to see parent process



Graphic from https://stackoverflow.com/questions/9305992/if-threads-share-the-same-pid-how-can-they-be-identified

Summary 1

- User-level threads
  - created and managed by a threads library that runs in the user space of a process
  - a mode switch is not required to switch from one thread to another
  - only a single user-level thread within a process can execute at a time
  - if one thread blocks, the entire process is blocked
- Kernel-level threads
  - threads within a process that are maintained by the kernel
  - a mode switch is required to switch from one thread to another
  - multiple threads within the same process can execute in parallel on a multiprocessor
  - blocking of a thread does not block the entire process

Summary 2

Threads vs. Processes

- A thread has no data segment or heap
- A thread cannot live on its own, it must live within a process
- *There can be more than one thread in a process, the first thread calls main & has the process's stack*
- Inexpensive creation
- Inexpensive context switching
- Efficient communication
- If a thread dies, its stack is reclaimed

- A process has code/data/heap & other segments
- A process has at least one thread
- *Threads within a process share code/data/heap, share I/O, but each has its own stack & registers*
- Expensive creation
- Expensive context switching
- Interprocess communication can be expressive
- If a process dies, its resources are reclaimed & all threads die

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Done!