CS420: Operating Systems

Threading Issues

James Moscola
Department of Engineering & Computer Science
York College of Pennsylvania

YORK COLLEGE OF PENNSYLVANIA

Threading Issues

- **There are a variety of issues to consider with multithreaded programming**
  - Semantics of `fork()` and `exec()` system calls
  - Signal handling
    - Synchronous and asynchronous
  - Thread cancellation
    - Asynchronous or deferred
  - Thread-specific data
    - Create facility needed for data private to thread

Semantics of `fork()` and `exec()`

- **Recall that when `fork()` is called, a separate, duplicate process is created**
- **How should `fork()` behave in a multithreaded program?**
  - Should all threads be duplicated?
  - Should only the thread that made the call to `fork()` be duplicated?
- **In some systems, different versions of `fork()` exist depending on the desired behavior**
  - Some UNIX systems have `fork1()` and `forkall()`
    - `fork1()` only duplicates the calling thread
    - `forkall()` duplicates all of the threads in a process
  - In a POSIX-compliant system, `fork()` behaves the same as `fork1()`

Semantics of `fork()` and `exec()`

- **The `exec()` system call continues to behave as expected**
  - Replaces the entire process that called it, including all threads

- **If planning to call `exec()` after `fork()`, then there is no need to duplicate all of the threads in the calling process**
  - All threads in the child process will be terminated when `exec()` is called
  - Use `fork1()`, rather than `forkall()` if using in conjunction with `exec()`

Signal Handling

- **Signals are used in UNIX systems to notify a process that a particular event has occurred**
  - CTRL-C is an example of an asynchronous signal that might be sent to a process
    - An asynchronous signal is one that is generated from outside the process that receives it
  - Divide by 0 is an example of a synchronous signal that might be sent to a process
    - A synchronous signal is delivered to the same process that caused the signal to occur
- **All signals follow the same basic pattern:**
  - A signal is generated by particular event
  - The signal is delivered to a process
  - The signal is handled by a signal handler (all signals are handled exactly once)

Signal Handling

- **Signal handling is straightforward in a single-threaded process**
  - The one (and only) thread in the process receives and handles the signal

- **In a multithreaded program, where should signals be delivered?**
  - Options:

    (1) Deliver the signal to the thread to which the signal applies

    (2) Deliver the signal to every thread in the process

    (3) Deliver the signal only to certain threads in the process

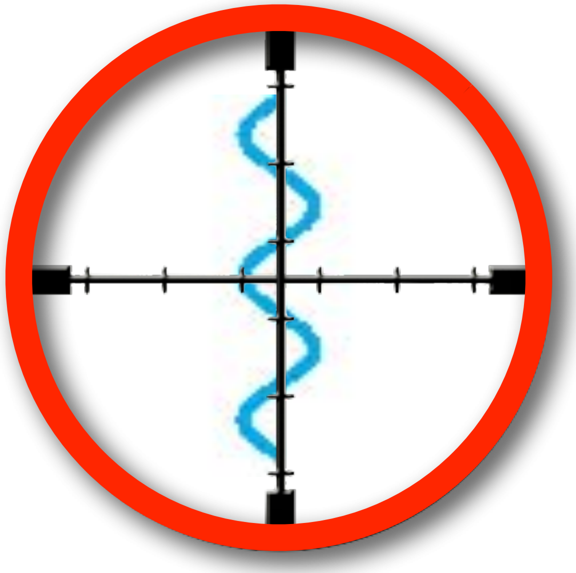
    (4) Assign a specific thread to receive all signals for the process

Signal Handling

- **Option 1 - Deliver the signal to the thread to which the signal applies**
  - Most likely option when handling synchronous signals (e.g. only the thread that attempts to divide by zero needs to know of the error)
- **Option 2 - Deliver the signal to every thread in the process**
  - Likely to be used in the event that the process is being terminated (e.g. a CTRL-C is sent to terminate the process, all threads need to receive this signal and terminate)

Thread Cancellation

- **Thread cancellation is the act of terminating a thread before it has completed**
  - Example - clicking the stop button on your web browser will stop the thread that is rendering the web page
- **The thread to be cancelled is called the target thread**
- **Threads can be cancelled in a couple of ways**
  - **Asynchronous cancellation** terminates the target thread immediately
    - Thread may be in the middle of writing data ... not so good
  - **Deferred cancellation** allows the target thread to periodically check if it should be cancelled
    - Allows thread to terminate itself in an orderly fashion



Thread-Specific Data

- **Thread-specific data - in some applications it may be useful for each thread to have its own copy of data**
  - May also be referred to as Thread-local storage or Thread-static variables
  - The errno variable is thread-specific

```
// In C#
class FooBar {
   [ThreadStatic] static int foo;
}
```

```
// In Java
private static ThreadLocal<Integer> threadLocalInt =
      new ThreadLocal<Integer>();
```

```
// In a POSIX-compliant system
// see pthread_key_create()
//     pthread_setspecific()
//     pthread_getspecific()
```

Thread Examples - Windows Threads

- **Uses the one-to-one thread model to implement threads**

- **Each thread contains**
  - A thread id
  - Register set (including a program counter)
  - Separate user and kernel stacks (for user-mode and kernel-mode activity)
  - Private data storage area

- **Also implements a fiber — a unit of execution that must be manually scheduled by the application**
  - Every thread can have multiple fibers
  - Fibers run in the context of the thread that created them

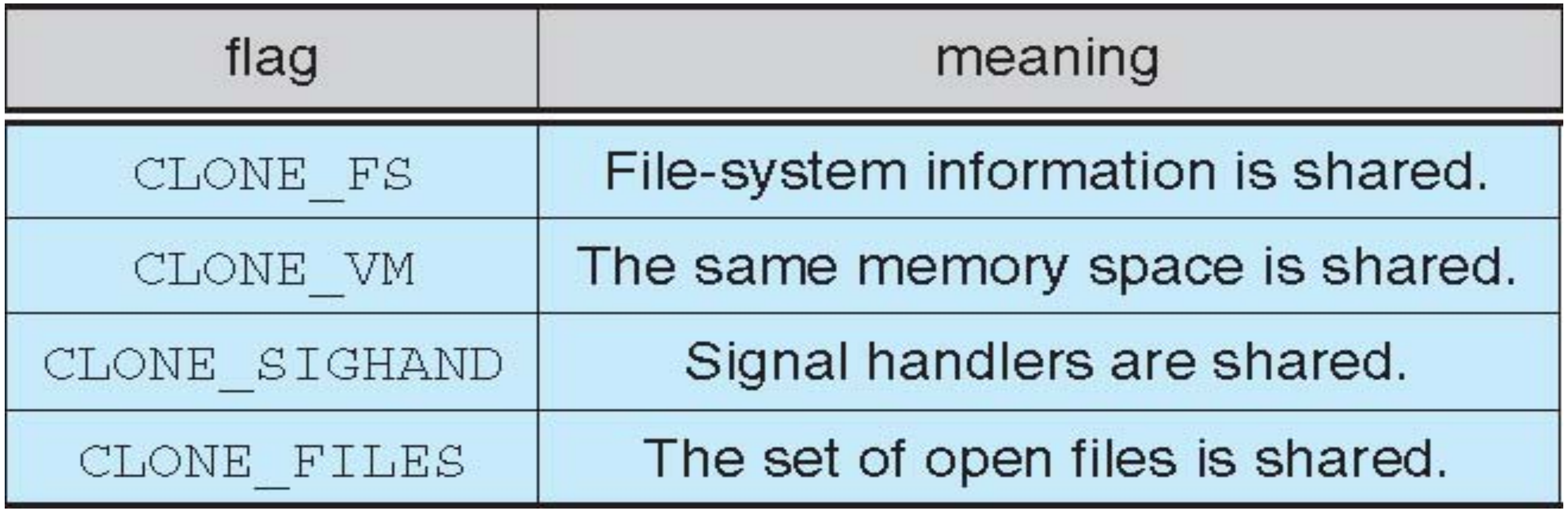
Linux Threads

- **Linux oftentimes uses the term task rather than process or thread**
  - Doesn't really distinguish between processes and threads

- **Thread creation is done through the `clone()` system call**
  - The `clone()` can create either 'threads' or 'processes' depending on the options passed to `clone()`
    - The options passed to clone determine how much sharing is taking place between the parent and the child
  - A 'process' can still be created using the `fork()` system call
  - Provide a specific set of options and the `clone()` and `fork()` systems calls behave identically

Linux Threads (Cont.)

- **The following table shows the various flags that can be passed to clone to determine how much sharing is taking place between the parent and the child**



flag	meaning
CLONE_FS	File-system information is shared.
CLONE_VM	The same memory space is shared.
CLONE_SIGHAND	Signal handlers are shared.
CLONE_FILES	The set of open files is shared.

  - If ALL these flags are passed to `clone()`, the task is equivalent to a thread
    - Shared memory space, shared list of open files, etc.
  - If NONE of these flags are passed to `clone()`, it behaves more like `fork()`
    - NO shared memory space, NO shared list of open files, etc.