Software Lab

Advanced IPC

Roberto Farina
roberto.farina@cefriel.it

Summary

- Futex
  - General concepts
  - Futex in practice
- Barriers
  - General concepts
  - How they can be implemented

Futex

- **F**ast **U**serspace mu**TEX**: a basic tool to realize locking and building higher-level locking
  - First appearance in the development kernel version 2.5.7
- A piece of memory (an aligned integer) that can be shared between processes
  - It can be incremented and decremented by atomic instructions
  - Processes can wait for the value to become positive

Why a new lock mechanism

- Classic mechanisms (Sys V semaphores, fcntl lock) represent **heavy weight** kernel approaches
- Kernel based mechanisms imply syscalls
  - Significant overhead when low contention rates
- Futex operations are done almost entirely in **userspace**
  - The kernel is only involved when a contended case needs to be arbitrated
  - Locking primitives implementing used futexes to be very efficient

Goals and requirements

- Goals
  - Avoid syscalls
  - Avoid unnecessary context switches
- Requirements
  - Fairness in the locking and release policies
  - Avoid the convoy problem when using FIFO policy

Implementation aspects

- A variable of type `int` at the user level
  - A size of 4 bytes on all platforms
- Kernel object mapped at `different virtual addresses` in different processes
  - A lookup has to be performed
- A queue for waiting threads
- A `single` multiplexed syscall
  - `long sys_futex(void* addr1, int val1, …)`
  - Avoid problems with syscall number allocation
- Two basic operations: `FUTEX_UP` and `FUTEX_DOWN`

Recent implementation

- **FUTEX_WAIT**
  - Thread suspended in the kernel until notified
  - It is possible to specify a timeout
- **FUTEX_WAKE**
  - Wake up one or more threads waiting for the futex
  - It is possible to specify how many threads to wake up
- **FUTEX_FD**
  - The kernel generates a file descriptor to refer to the futex
  - It is possible to request asynchronous notification
    - A signal associated to the fd

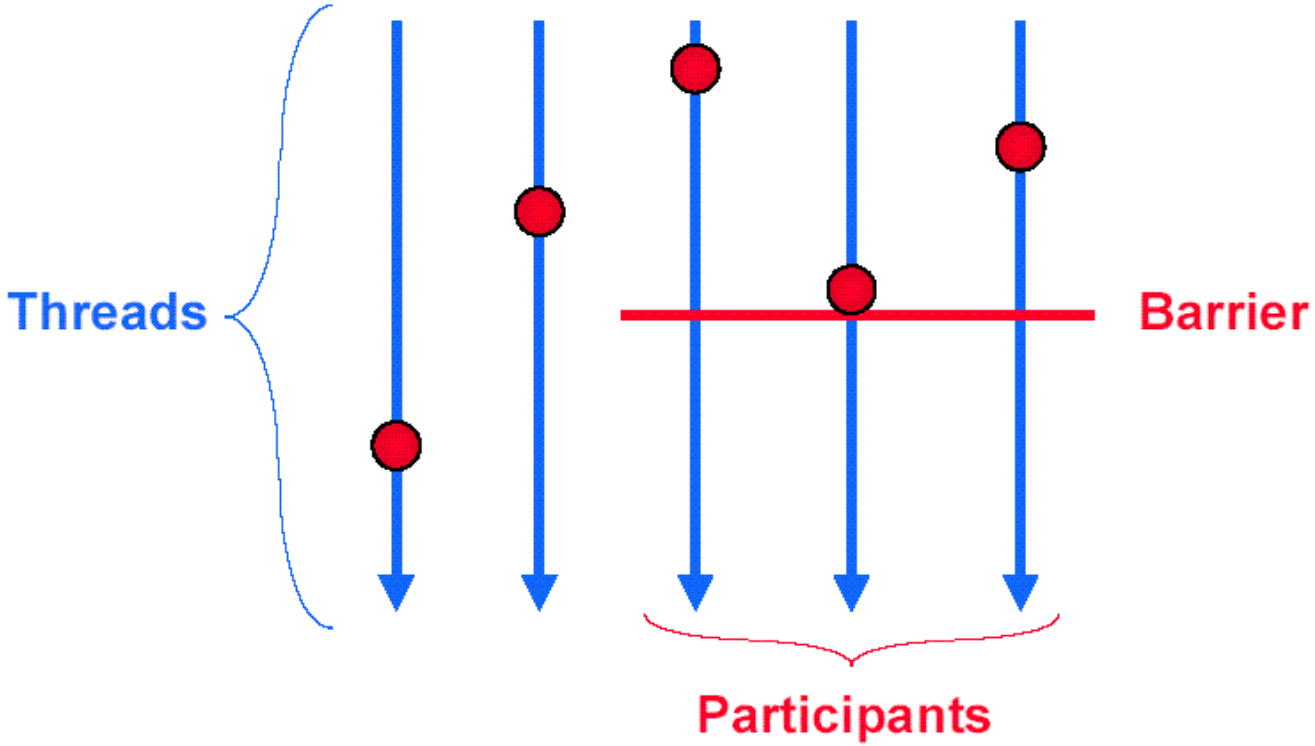
Details

- Futexes are `non RT`
  - The kernel doesn't look through the queue of waiting threads to find the one with highest priority when a wake operation is requested
- `Contrast` with Sys V IPC mechanism
  - They merely export an handle to the user
  - All operations are performed in the kernel

Barriers

- All processes have to reach a **`specific point`** before any one can proceed further
  - Rendezvous
- To ensure the computation has reached a **`steady state`**
- There's no data exchange or communication between processes

Synchronization Barriers



Barriers

- The number of threads synchronizing at a barrier is specified at initialization time
  - It cannot be changed at run time
- A thread calls `barrier_wait` (or `barrier_sync`) to synchronize with the barrier
  - The barrier keeps track about the number of threads that invoked this primitive
  - Returns –1 to the last thread that arrives, 0 otherwise

Bibliography

- "Fuss, Futexes and Furwocks: Fast Userlevel Locking in Linux" - Hubertus Franke, Rusty Russel, Matthew Kirkwood
- "Futexes are tricky" - Ulrich Drepper
- ftp://ftp.kernel.org/pub/linux/kernel/people/rusty

