

Operating Systems: Synchronization Tools and examples – Part III

Neerja Mhaskar

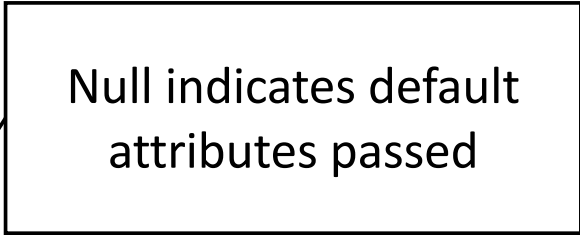
Department of Computing and Software, McMaster University, Canada

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POSIX Condition Variables

- **Condition variables** in Pthreads behave similarly to those described under Monitors.
- Since Pthreads is typically used in C programs—and since C does not have a monitor—we accomplish locking by associating a condition variable with a mutex lock.
- Condition variables in Pthreads use the
 - `pthread_cond_t` data type, and
 - `pthread_cond_init()` function to initialize it.
- The following code creates and initializes a condition variable as well as its associated mutex lock:

```
pthread_mutex_t mutex;  
pthread_cond_t cond_var;  
pthread_mutex_init(&mutex, NULL);  
pthread_cond_init(&cond_var, NULL);
```



Null indicates default
attributes passed

POSIX Condition Variables Contd...

- `pthread_cond_wait()` function – used to wait/block on a condition variable. It takes two parameters
 - Pointer to condition variable
 - Pointer to mutex.
 - This mutex must be locked by the calling thread before the `pthread_cond_wait()` is used, or undefined behaviour will result.
- `pthread_cond_wait()` atomically unlocks the mutex and wait on the condition variable.
- When condition variable is signaled, before returning to the calling thread, the the mutex lock is acquired on entrance to **`pthread_cond_wait()`**

POSIX Condition Variables Contd...

- Example: A thread waiting for the condition $a == b$ to become true using a Pthread condition variable:

```
pthread_mutex_lock(&mutex);  
while (a != b)  
    pthread_cond_wait(&cond_var, &mutex);  
pthread_mutex_unlock(&mutex);
```

POSIX Condition Variables Contd...

- `pthread_cond_signal()` function
 - Takes in a pointer to the condition variable.
 - used to signal any one thread waiting on the condition variable.
 - If no thread waiting on the condition variable nothing happens.

- Example:

```
pthread_mutex_lock(&mutex);  
  
a = b;  
  
pthread_cond_signal(&cond_var);  
  
pthread_mutex_unlock(&mutex);
```

Hardware Support for Synchronization

- Hardware Support for Synchronization is typically for kernel developers and implementation of high-level Synchronization tools.
- Some of them are
 - Memory barriers or Memory Fences
 - Atomic hardware instructions
 - `Test_and_Set()`
 - `Compare_and_swap()`
 - Atomic variables

Memory Barriers or Memory Fences

- System can reorder instructions for efficiency - leads to data inconsistency.
- **Memory model** – explains how a computer architecture determines what memory guarantees it will provide to an application program.
 - Varies by processor type and kernel developers cannot make any assumptions about it.
 - To address this issues computer architectures, provide memory barriers or memory fences.
- **Memory barriers** or **Memory Fences**
 - Computer instructions that force any changes in memory to be propagated to all other processors in the system.
 - Example:

```
x = 100;  
memory_barrier();  
flag = true;
```

Hardware Support for Synchronization

- Modern machines provide special atomic hardware instructions
 - `Test_and_Set()`
 - `Compare_and_swap()`
- They are Executed atomically. For instance, two `test_and_set()` instructions are executed simultaneously (each on a different CPU), they will be executed sequentially in some arbitrary order.

Synchronization Hardware

`Test_and_Set():`

```
boolean test_and_set (boolean *target)
{
    boolean rv = *target; //stores the target/
                           //locked value

    *target = TRUE; //sets it to true


    return rv: //returns the old value!
}
```

- Returns the original value of the passed parameter and sets its value to "TRUE".

Solution using test_and_set()

- Shared Boolean variable `lock`.
- Initially `locked = FALSE` (lock is available)
- Suppose a process P_i wants to enter its CS

```
do {  
    while (test_and_set(&locked));  
        /* do nothing */  
        /* critical section */  
        locked = false;  
        /* remainder section */  
} while (true);
```



Sets `locked = True`
and returns `False`

Solution using test_and_set() - Mutual Exclusion

- Suppose process P_j wants to enter its CS, while P_i is executing in its CS. It sees $lock=True$.

```
do {
```

```
    while (test_and_set(&locked))
```



Returns True, and also, $locked=True$, so waits.

```
    ; /* do nothing */
```

```
        /* critical section */
```

```
    lock = false;
```

```
        /* remainder section */
```

```
    } while (true);
```

- Process waits to get the lock at the while loop.
- Therefore, when any process P_i is executing in its CS, another process cannot enter its CS and mutual exclusion is achieved.

Solution using test_and_set() - Progress and Bounded waiting

- Initially `locked=FALSE`,
 - If multiple processes want to enter CS, only one of them gets to execute `test_and_set()` (also in finite time)
 - A process executing in its remainder section does not get to block another process from entering the CS, since it has already released the lock.
- However, the same process can enter CS repeatedly, without giving a turn to other processes. Hence, bounded wait is not achieved.

compare_and_swap Instruction

```
int compare_and_swap(int *value, int expected, int
    new_value)
{
    int temp = *value;
    if (*value == expected)
        *value = new_value;
    return temp;
}
```

- Executed atomically
- Returns the original value of passed parameter “value”.
- Compares the integer stored in “value” to the integer value stored in expected. If they are equal, then stores the integer value of “new_value” in “value”.

Solution using compare_and_swap

- Shared integer “lock” initialized to 0; (lock is available)
- Expected value = 0 (lock is available)
- New value = 1 (lock is unavailable)
- Suppose lock is available and process P_i wants to enter its CS
- Solution:

```
do {  
    while (compare_and_swap(&lock, 0, 1) != 0)  
        ; /* do nothing */  
    /* critical section */  
    lock = 0;  
    /* remainder section */  
} while (true); s
```

Checks if lock=0,
in this case it is,
therefore resets
lock = 1 and returns
0

Alternative Approaches

- Transactional Memory
 - A **memory transaction** is a sequence of read-write operations to memory that are performed atomically.
- OpenMP
 - OpenMP is a set of compiler directives and API that support parallel programming.
 - The code contained within the `#pragma omp critical` directive is treated as a critical section and performed atomically.
- Functional Programming Languages
 - Do not maintain state. Variables are treated as immutable and cannot change state once they have been assigned a value.