Condition Variable

Concurrent Programming

Introduction

- What is Condition Variable?
- Pthread Condition Variable API
- Example

What is Condition Variable?

- Synchronization primitive that can be used to block a thread, or multiple threads at the same time, until another thread both modifies a shared variable (the *condition*), and notifies the condition variable

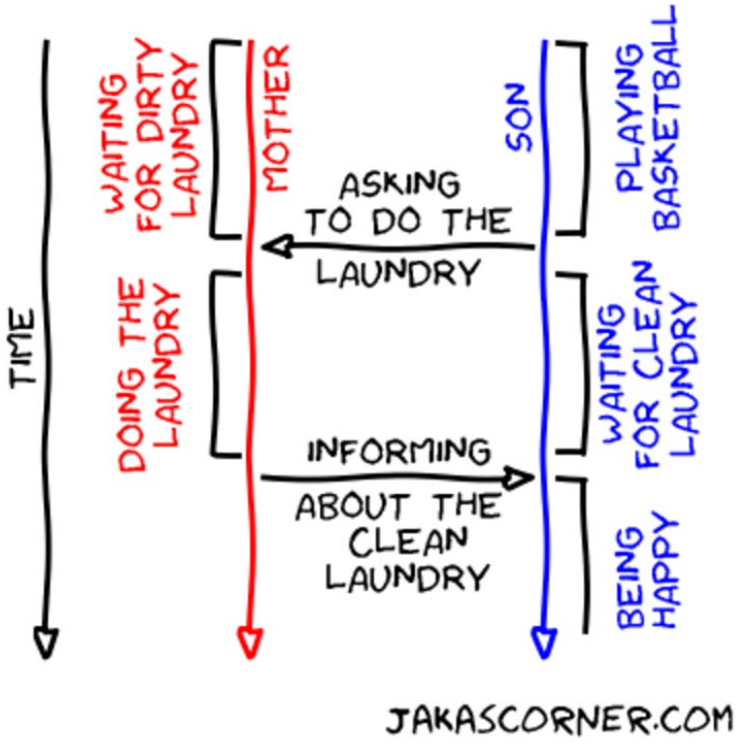


Photo reference: http://jakascorner.com/blog/2016/01/condition-variable.html

Pthread Condition Variable API

- pthread_cond_init
- pthread_cond_wait
- pthread_cond_signal
- pthread_cond_broadcast
- more APIs, but not today

pthread_cond_init

```
int pthread_cond_init(pthread_cond_t *cond,
                      const pthread_condattr_t *attr);
```

- Initialize the condition variable

```
@param[in]  cond        Condition variable to be initialized
@param[in]  attr        Used for setting attributes of a condition variable, Default 0
@return                 0 if initialization success
```

- You can simply use PTHREAD_COND_INITIALIZER
  - ex: pthread_cond_t cond = PTHREAD_COND_INITIALIZER;

pthread_cond_wait

```
int pthread_cond_wait(pthread_cond_t *cond,
                      pthread_mutex_t* mutex);
```

- Atomically release the *mutex* and block the calling thread on the *cond*.
- Always return with the *mutex* acquired

```
@param[in]  cond          Condition variable on which calling thread will block
@param[in]  mutex         Mutex to be released
@return                   0 if complete successfully
```

pthread_cond_signal

```
int pthread_cond_signal(pthread_cond_t *cond);
```

- Unblock one thread that is blocked on the *cond*
- When no threads are blocked on the condition variable, it has no effect

```
@param[in]  cond          Condition variable that the thread to wake is blocking on
@return                   0 if complete successfully
```

pthread_cond_broadcast

```
int pthread_cond_broadcast(pthread_cond_t *cond);
```

- Unblock all threads that is blocked on the *cond*
- When no threads are blocked on the condition variable, it has no effect

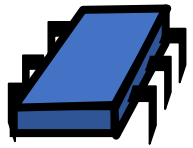
```
@param[in]  cond          Condition variable that the threads to wake is blocking on
@return                   0 if complete successfully
```

pthread_cond_wait

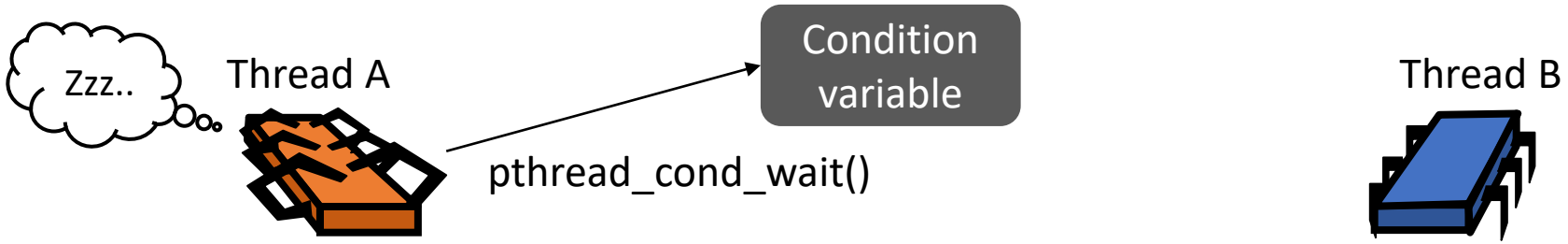
Thread A

Condition variable

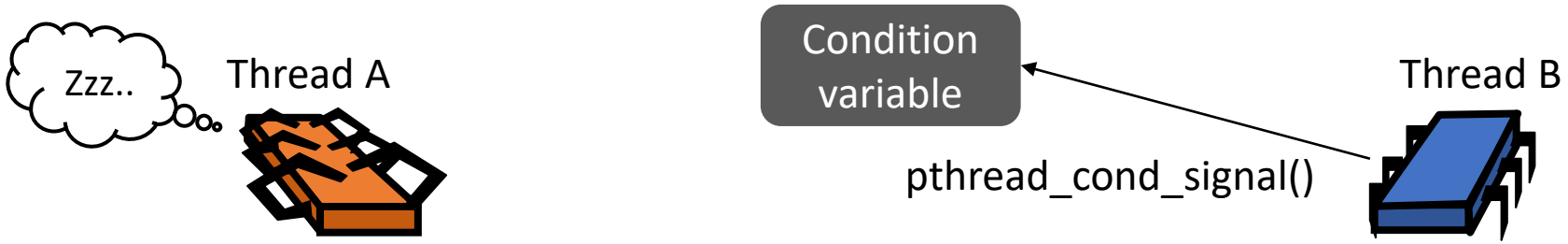
Thread B



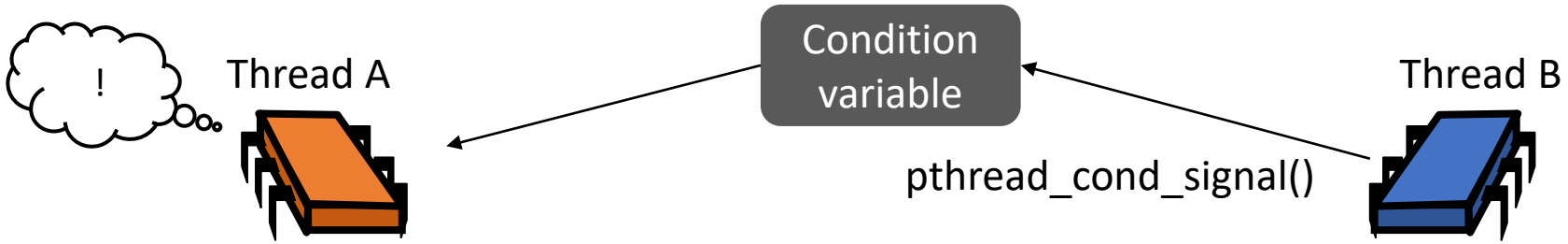
pthread_cond_wait



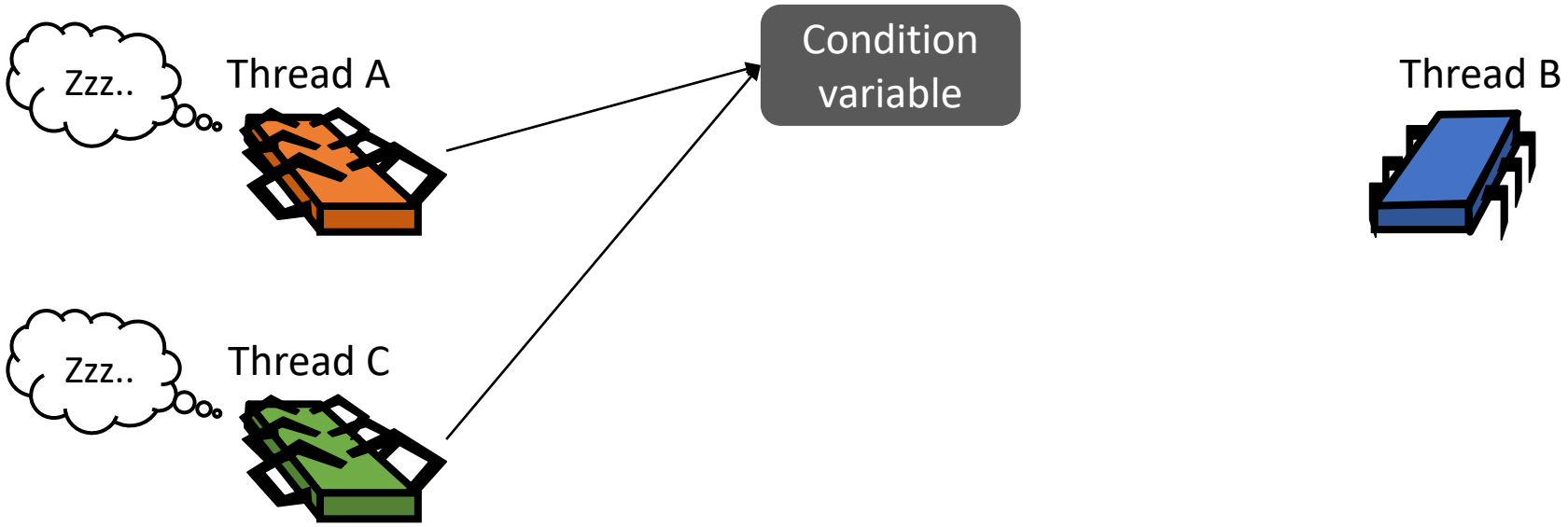
pthread_cond_signal



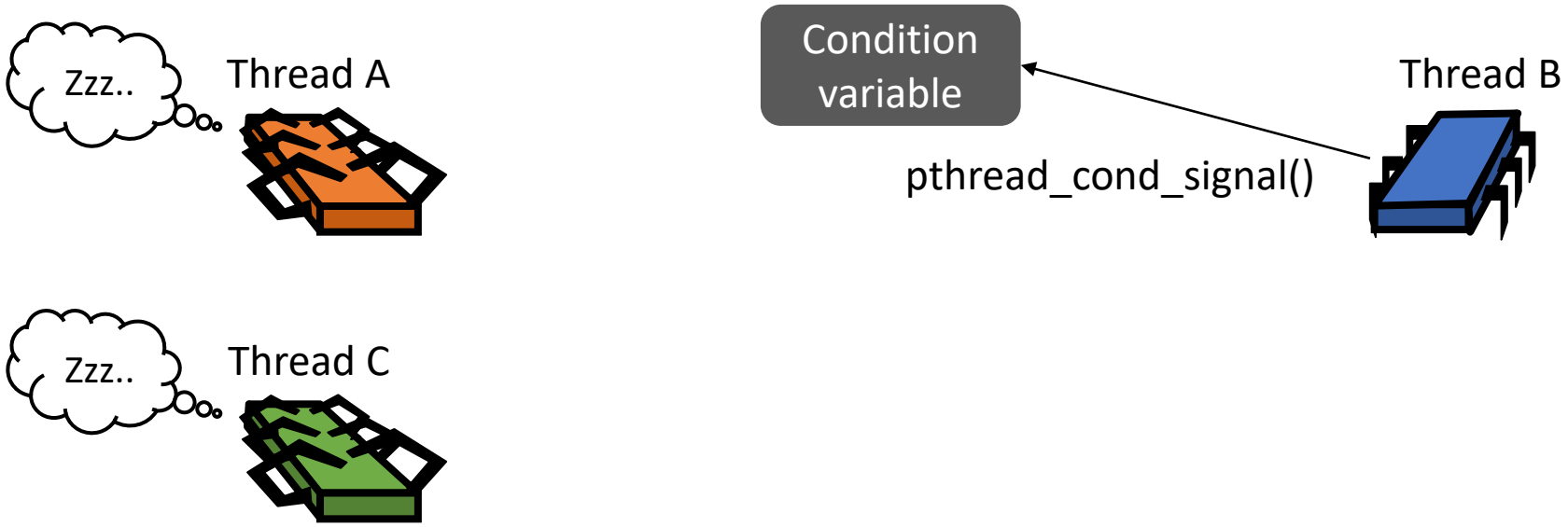
pthread_cond_signal



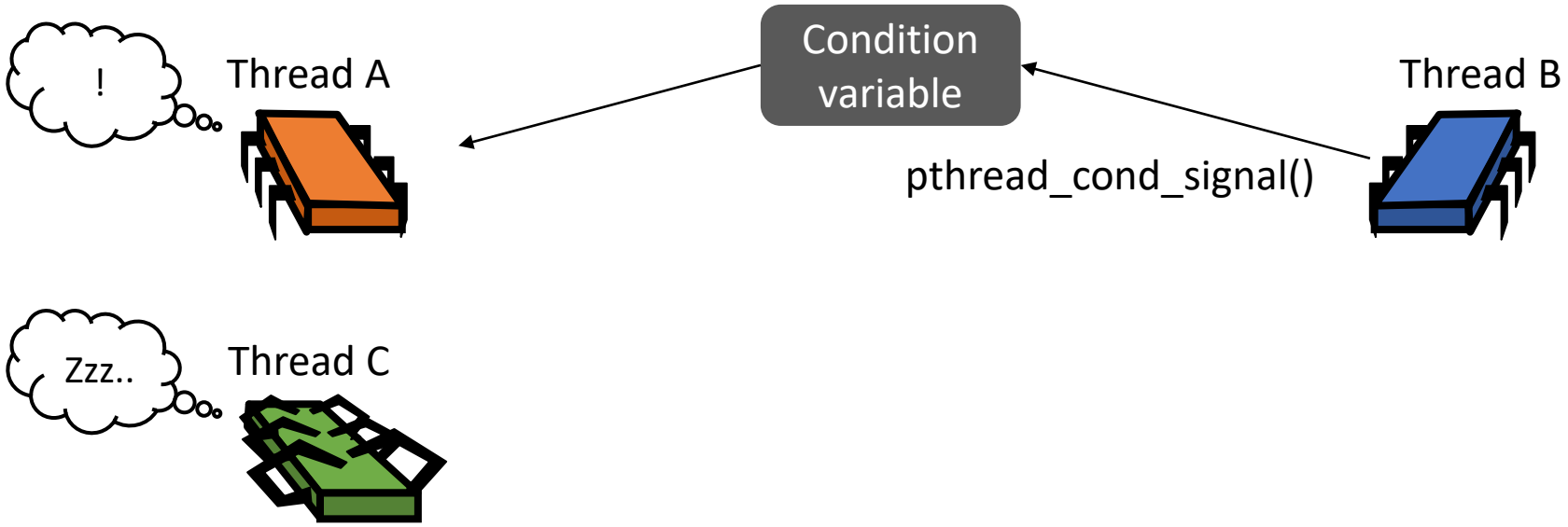
pthread_cond_signal



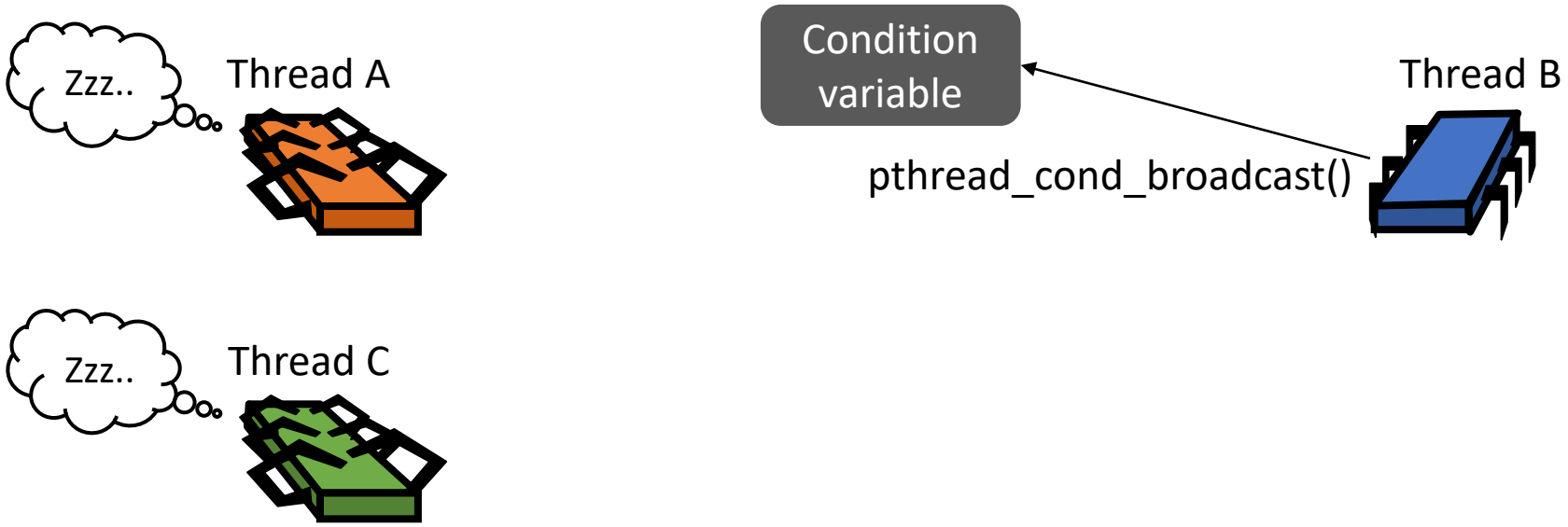
pthread_cond_signal



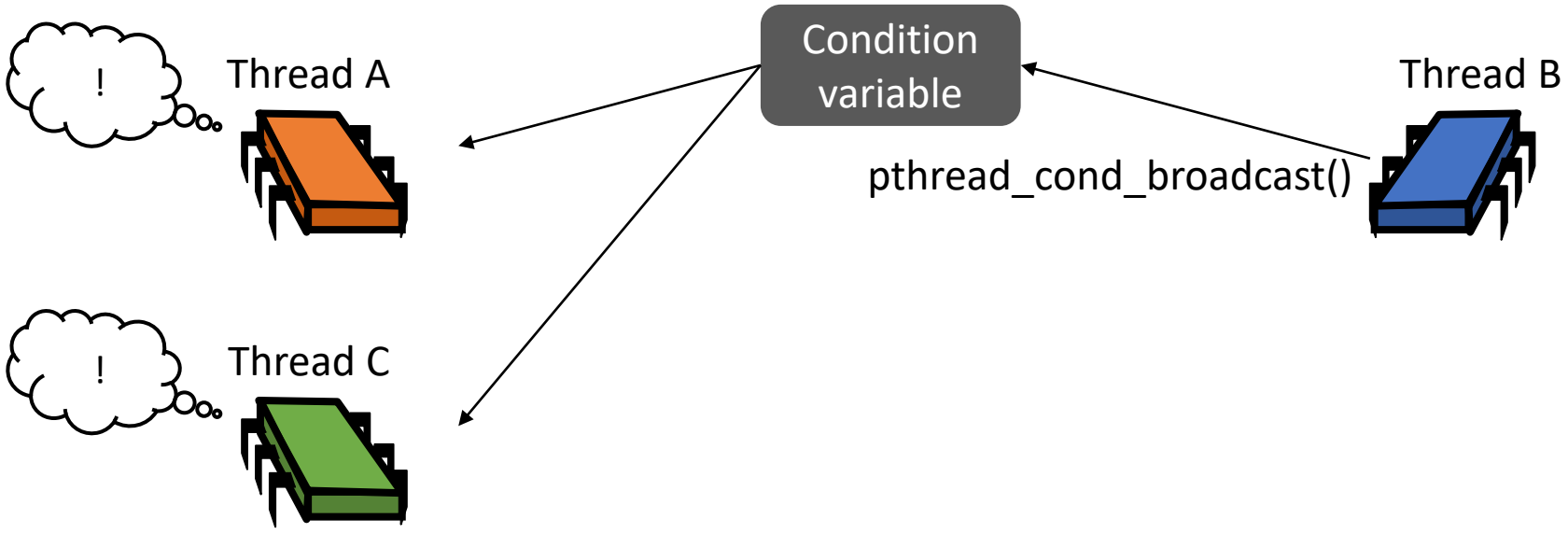
pthread_cond_signal



pthread_cond_broadcast



pthread_cond_broadcast

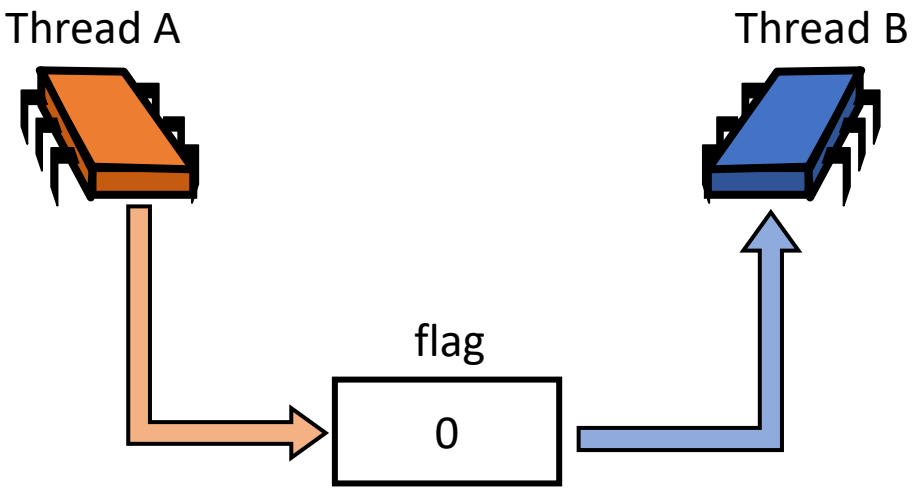


Lost wake-up problem

- Calling **pthread_cond_signal()/pthread_cond_broadcast()** without holding the corresponding *mutex* of the condition variable can lead to **lost wake-up** problem

Lost wake-up problem

```
10 pthread_cond_t cond;
11 int flag;
12
13 void func_threadA(void) {
14   flag = 1;
15   pthread_cond_signal(&cond);
16 }
17
18 void func_threadB(void) {
19   while (flag == 0) {
20     pthread_cond_wait(&cond);
21   }
22 }
```



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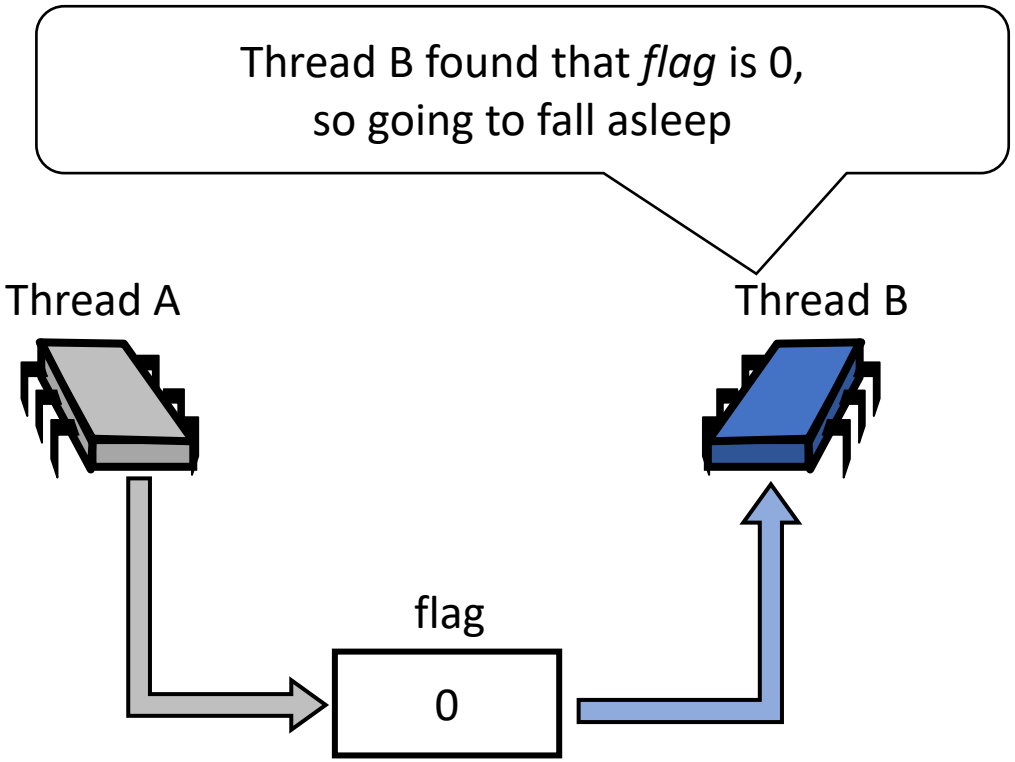

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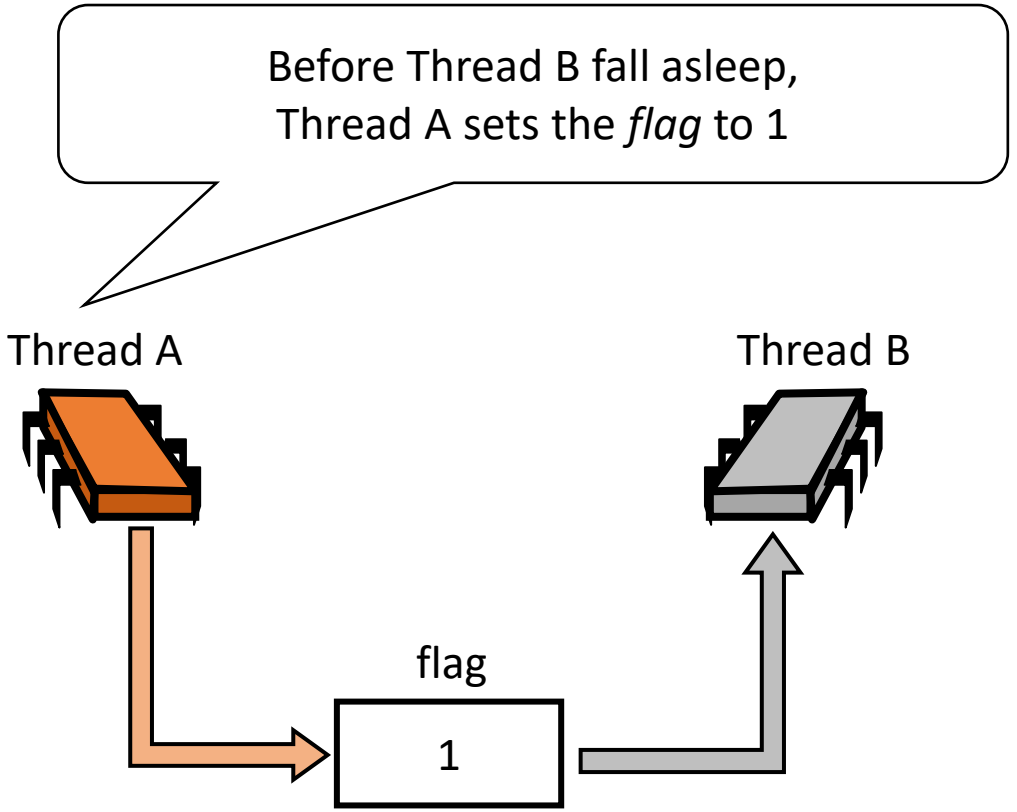

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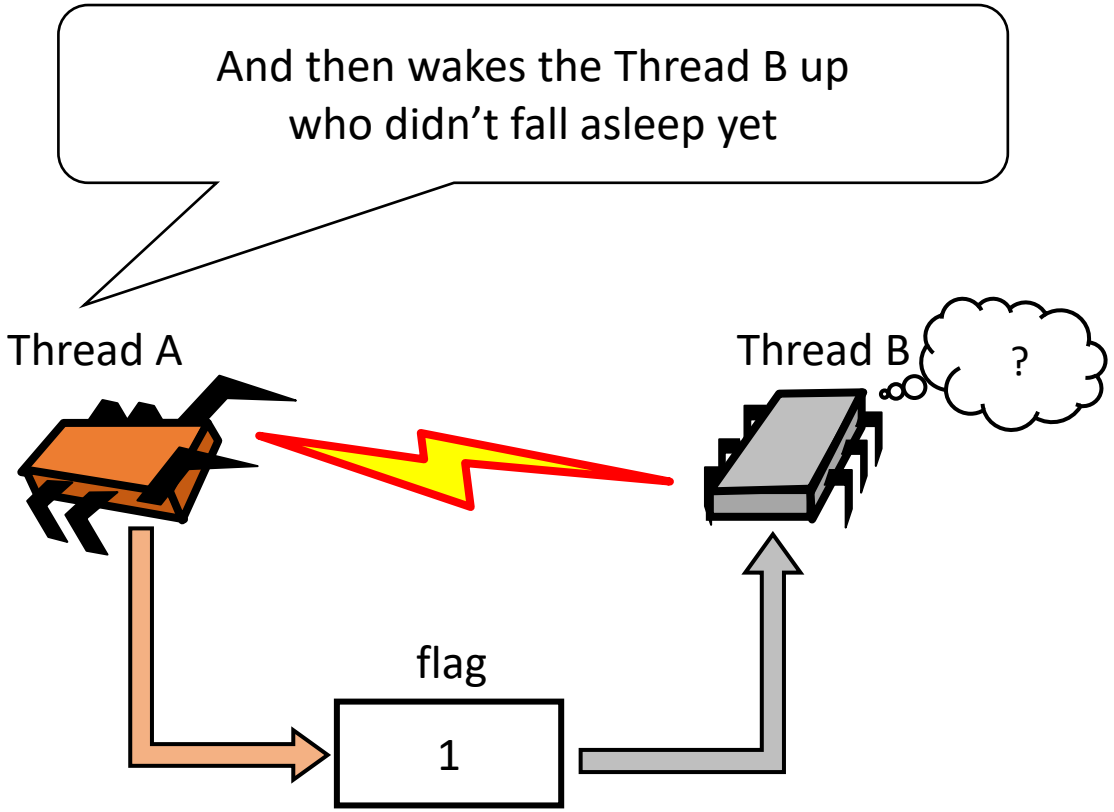

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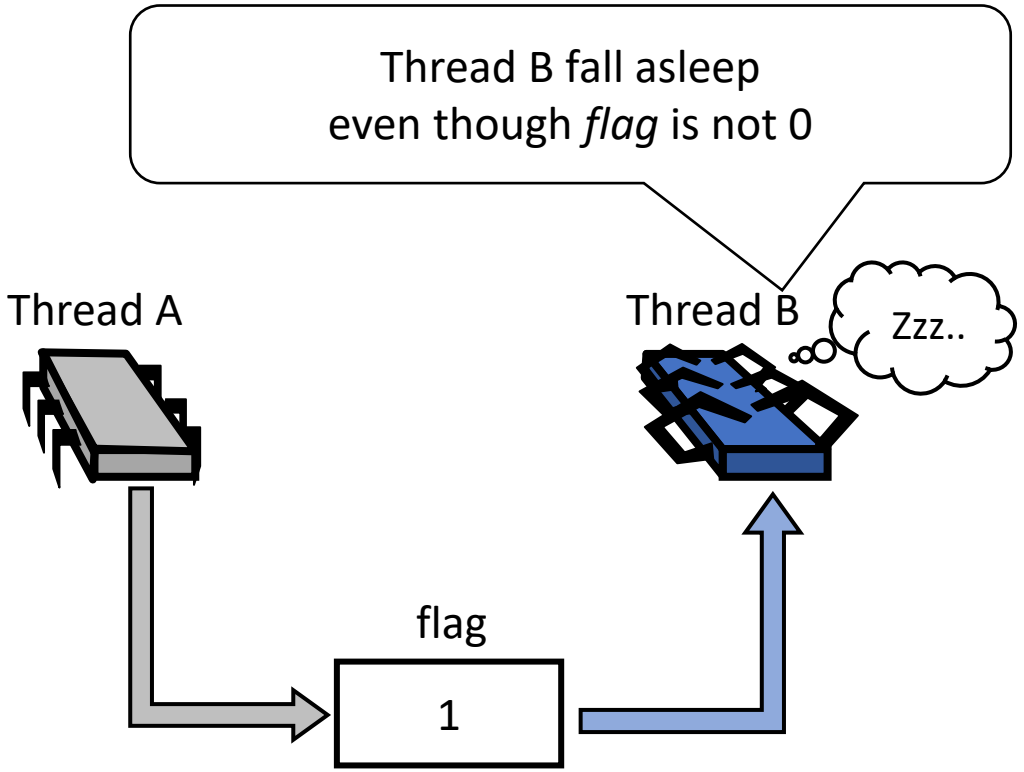

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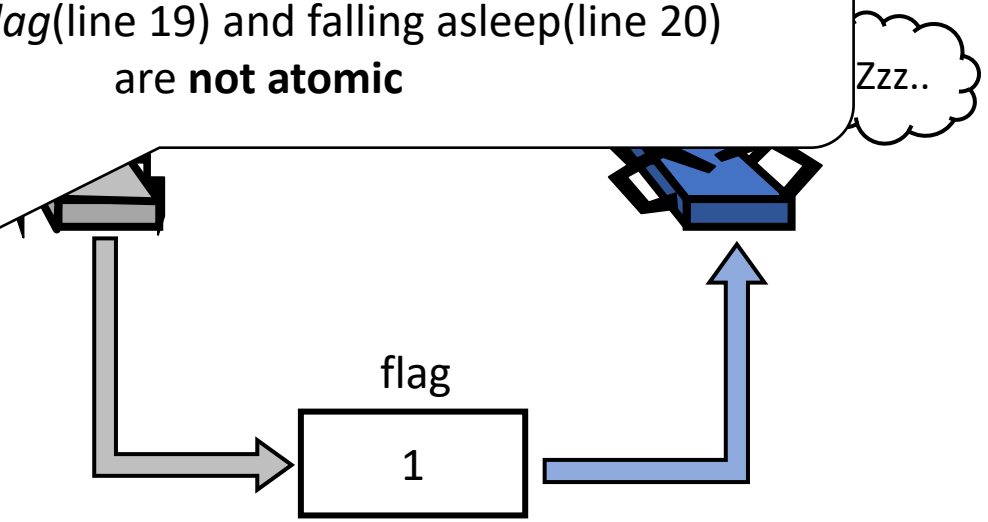
```

Lost wake-up occurs because
checking *flag*(line 19) and falling asleep(line 20)
are **not atomic**



Lost wake-up problem

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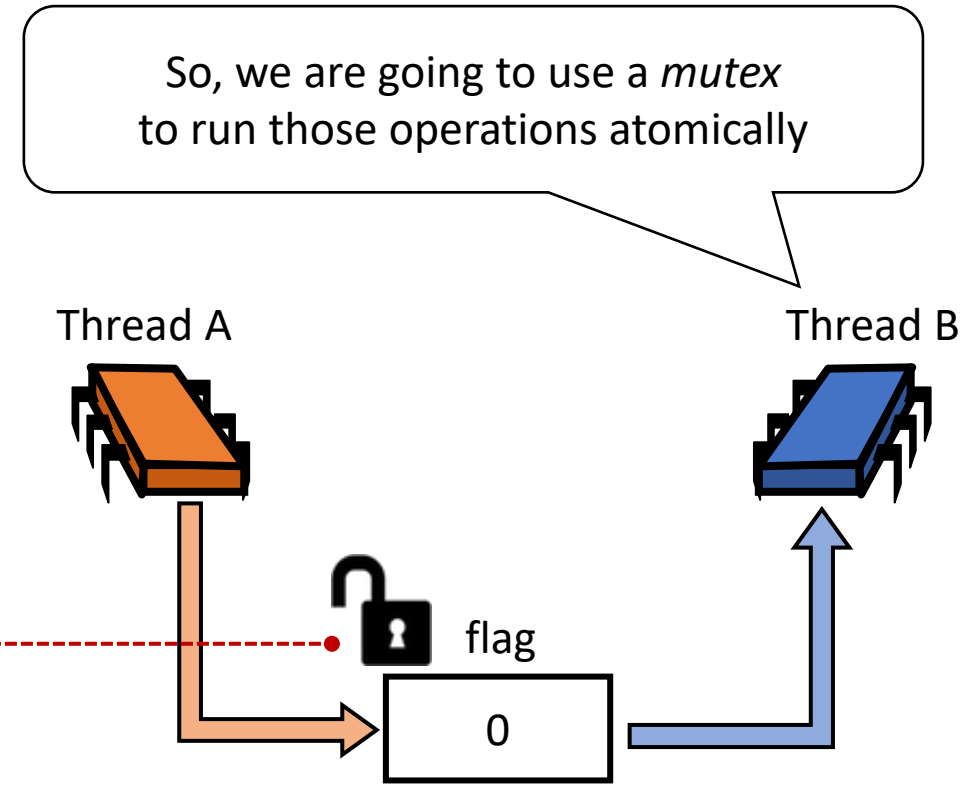

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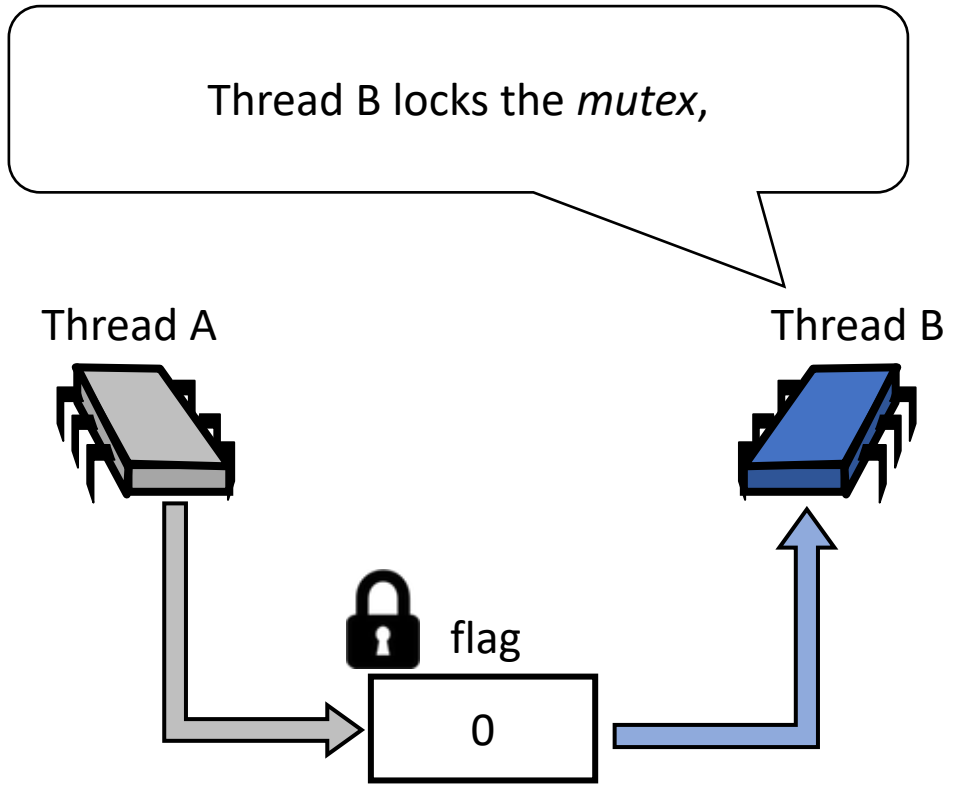

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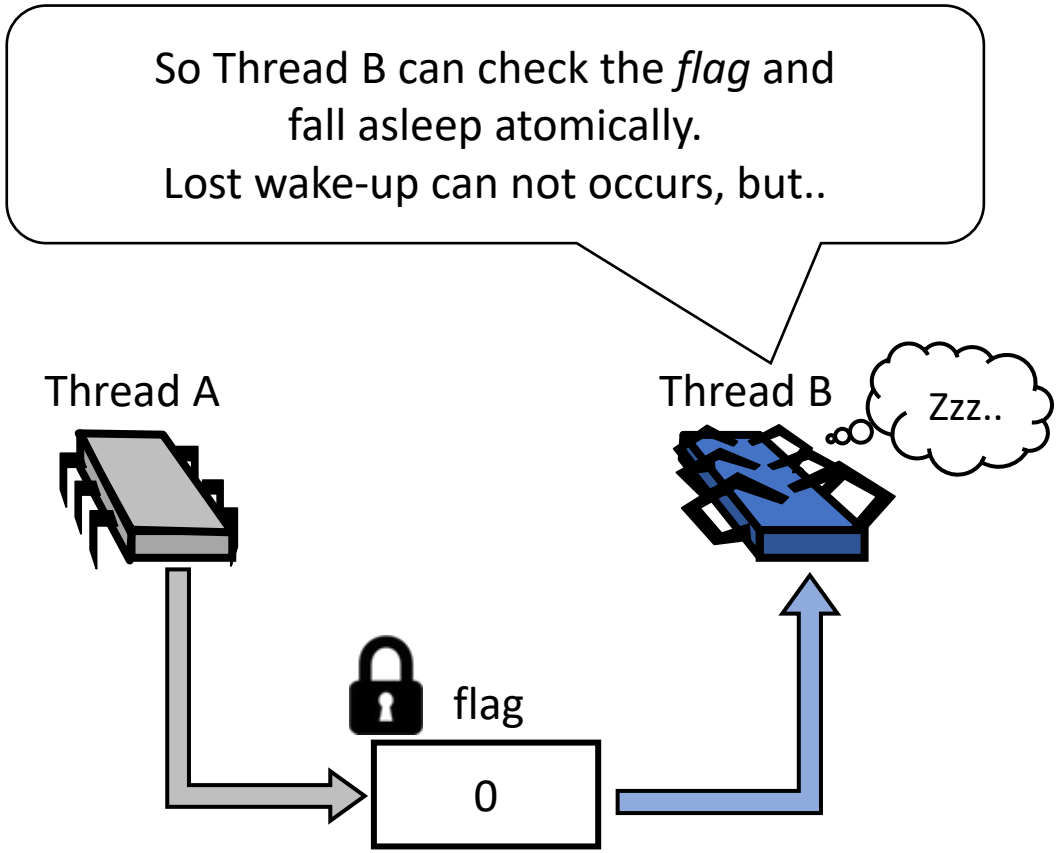

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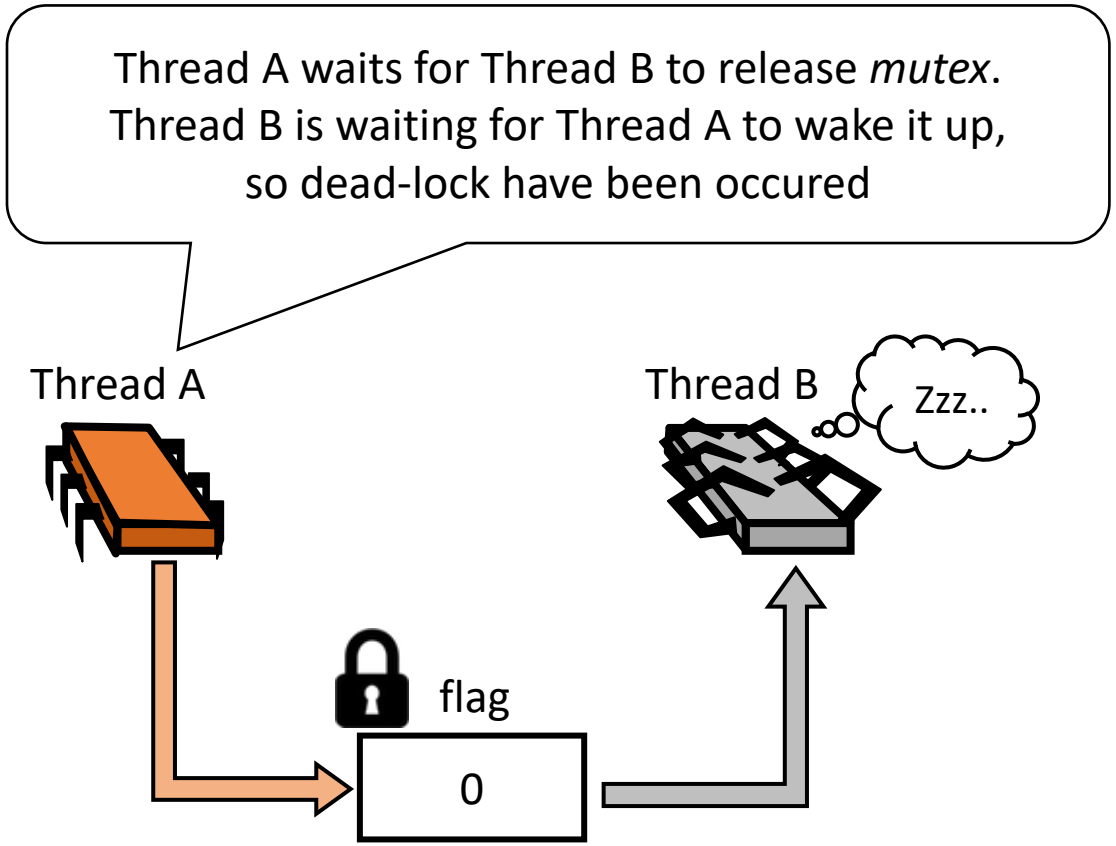

REMIND - pthread_cond_wait

```
int pthread_cond_wait(pthread_cond_t *cond,
                      pthread_mutex_t* mutex);
```

- **Atomically release the *mutex* and block** the calling thread on the *cond*.
- **Always return with the *mutex* acquired**

```
@param[in]  cond        Condition variable on which calling thread will block
@param[in]  mutex       Mutex to be released
@return                 0 if complete successfully
```

Lost wake-up problem

```
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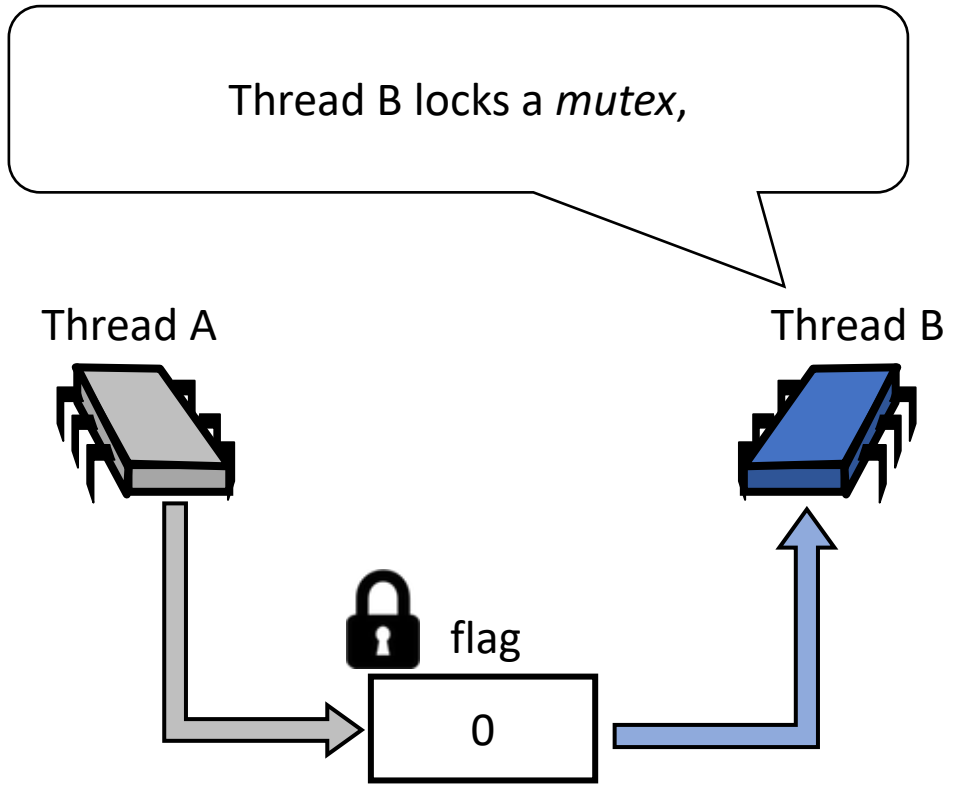

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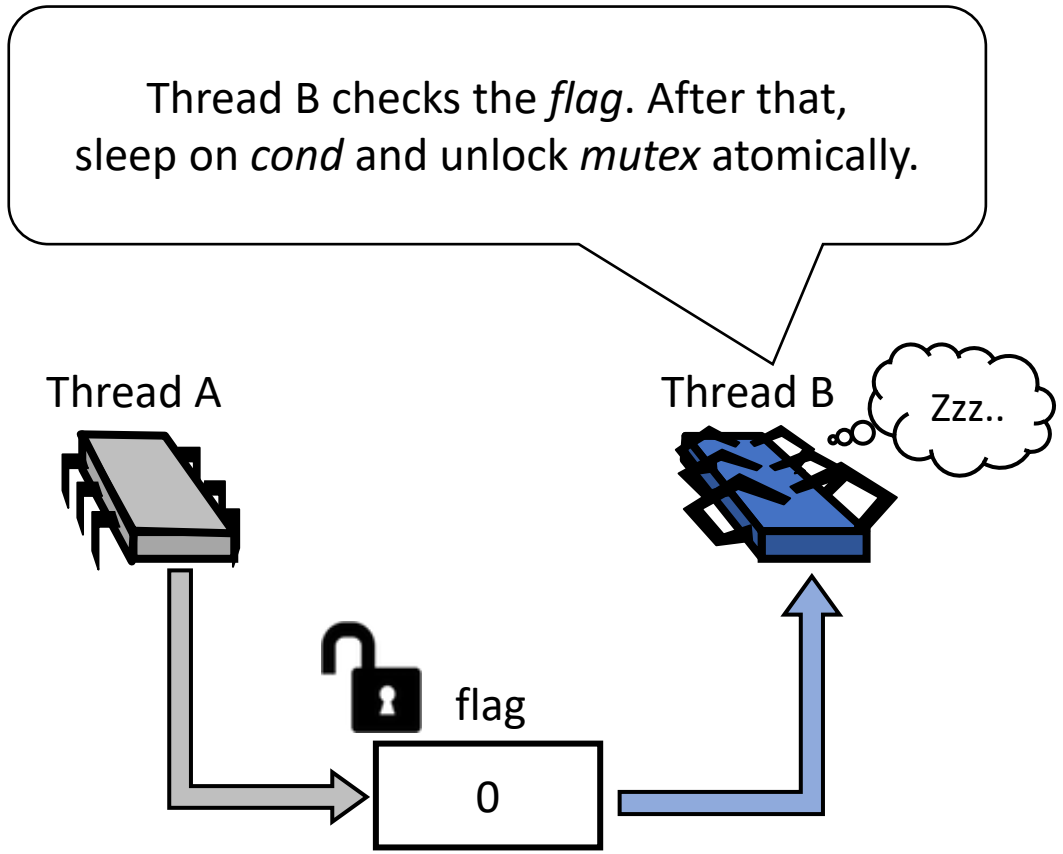

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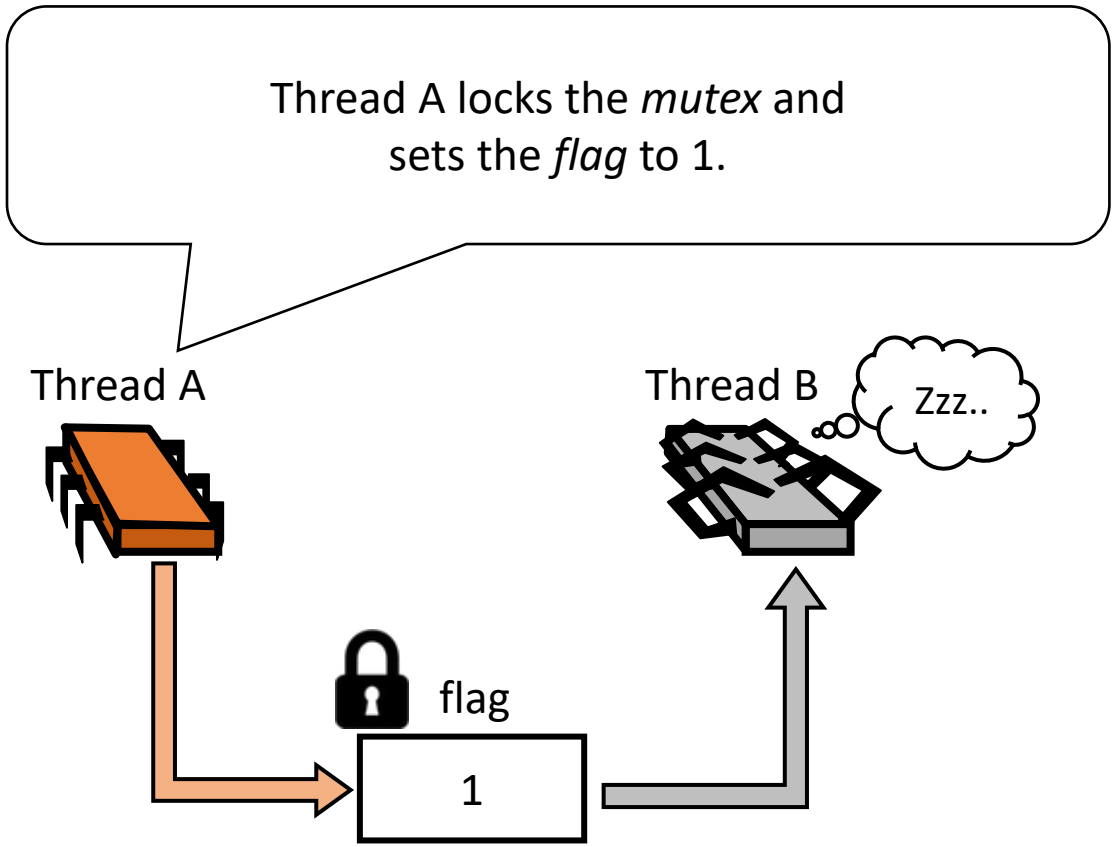

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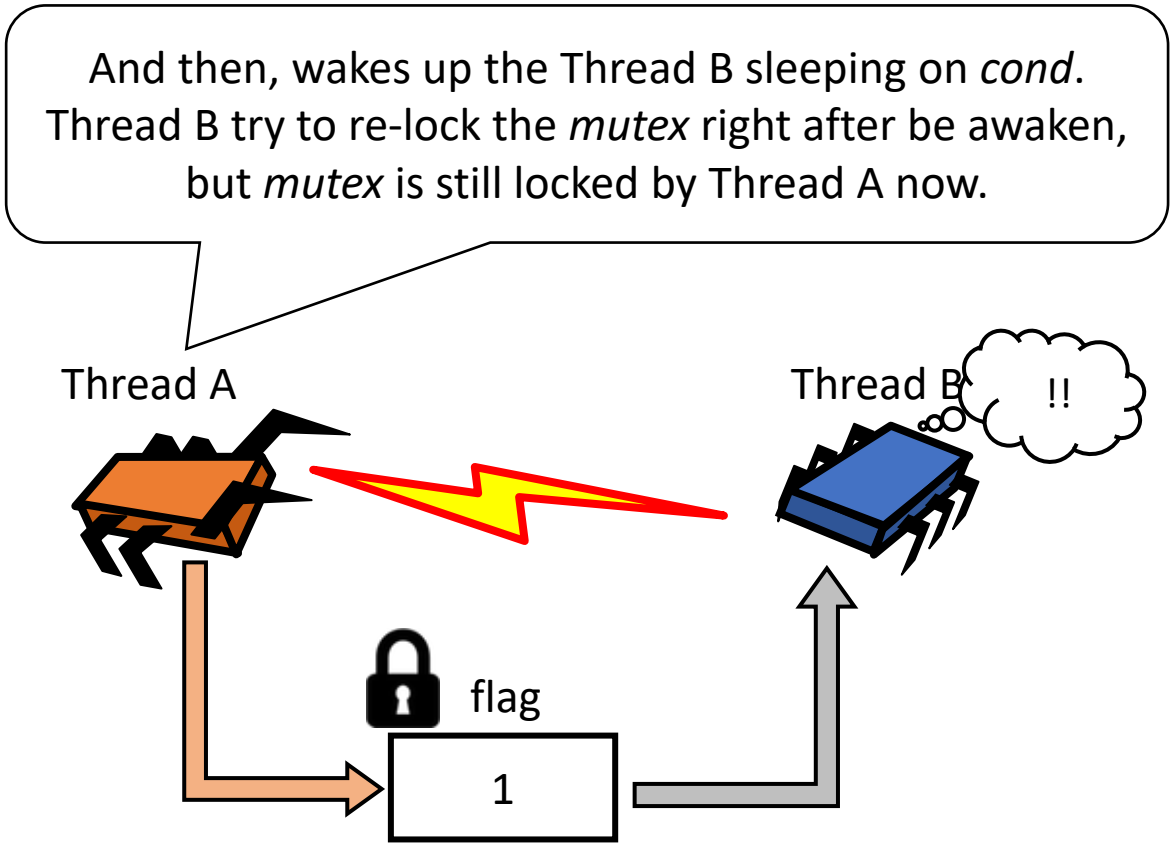

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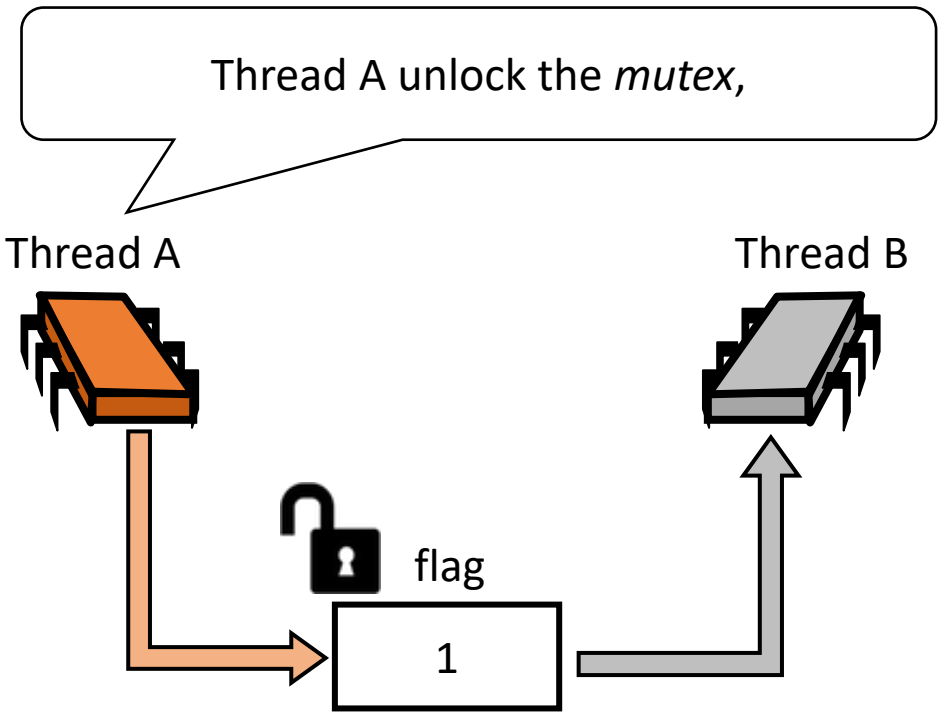

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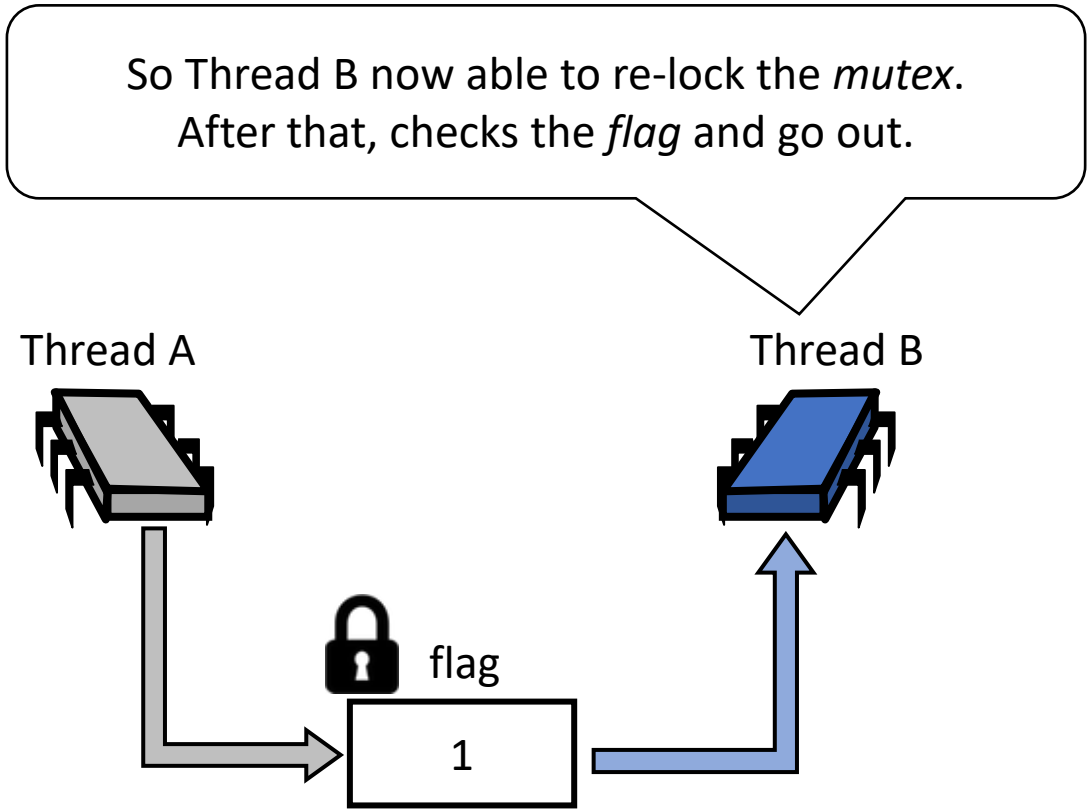

Practice

- Prepare the *prime_mt.cpp (fixed version of prime_mt_bug.cpp), workload.txt* from the Piazza resource page

- Improve the code to *prime_cond.cpp*
  - Create worker threads at once
  - Wake up the threads when job is comes in
  - Put the threads to sleep after a job done
  - Compare the performance with *prime_mt* using *workload.txt*

Thank You