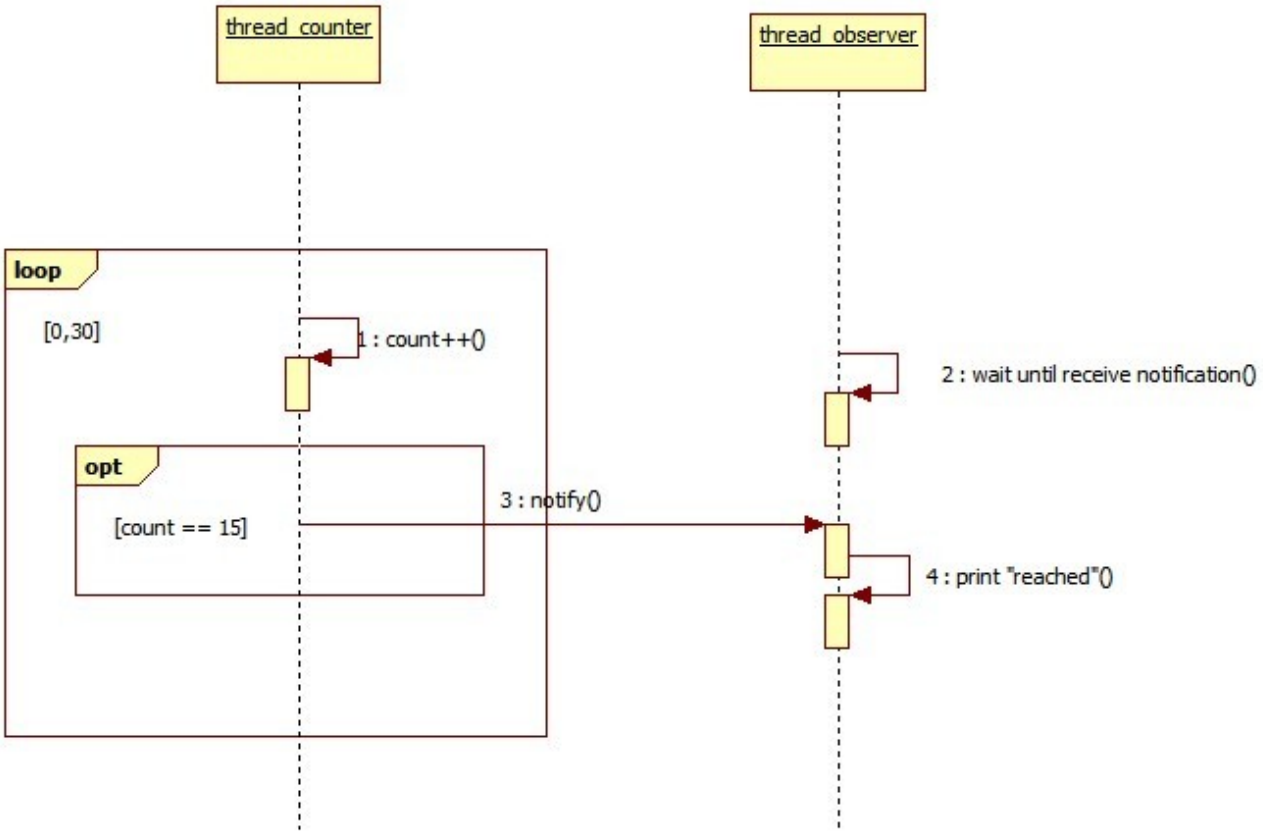
PTHREAD CONDITION VARIABLE

What is condition variable

Condition variable is a synchronization primitive that can be used to:
- Allow a thread to wait for a condition.
- Allow a thread to notify other threads when condition happens.

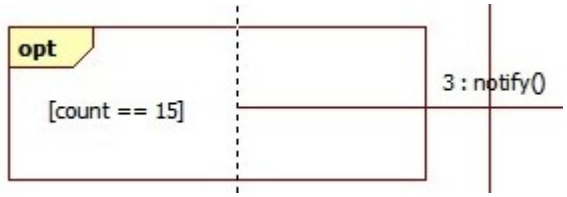
Lets start with Counter & Observer sample

- thread_counter increase count variable from 0 to 30.
- thread_observer wait until received notification from thread_counter to print "reached".

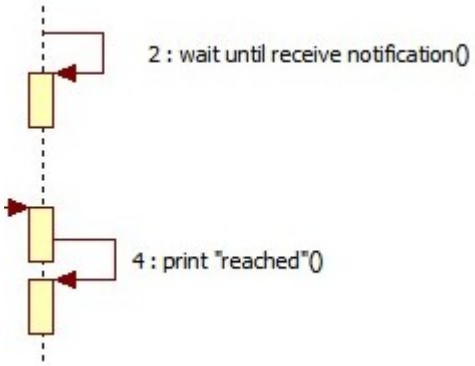



```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int count = 0;
```

```
pthread_cond_t cond = PTHREAD_COND_INITIALIZER;

void* inc_count(void* arg) {
    for(int i = 0; i < 30; i++){
        sleep(1);

        count ++;
        printf("thread counter: %d\n", count);

        if (count == 15) {
            pthread_cond_signal(&cond);
        }
    }
}
```




```
void* watch_count(void* arg) {
    pthread_cond_wait(&cond, &mtx);

    printf("\nthread observer: reached\n\n");
}
```




```
int main(){
    pthread_t thread_counter, thread_observer;

    pthread_create(&thread_counter, NULL, inc_count, NULL);
    pthread_create(&thread_observer, NULL, watch_count, NULL);

    pthread_join(thread_counter, NULL);
    pthread_join(thread_observer, NULL);

    return 0;
}
```

Result

```
thread counter: 12
thread counter: 13
thread counter: 14
thread counter: 15

thread observer: reached

thread counter: 16
thread counter: 17
thread counter: 18
thread counter: 19
```

How does above program work?

Variable cond work as a signal.

pthread_cond_t cond

thread_observer call **pthread_cond_wait()** to suspend and wait until it receive signal on **cond**. While waiting, thread_observer does not consume CPU resources.

pthread_cond_wait(&cond, &mtx)

thread_counter call p**thread_cond_signal()** on **cond** to notify **thread_observer**.

pthread_cond_signal(&cond)

Initialize and Destroy

How to Initialize?

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

pthread_cond_init function initialize the condition variable cond with attributes defined by attr.
If attr is NULL, condition variable will initialized with default attribute.

PTHREAD_COND_INITIALIZE

is used to initialize a condition variable only when it is declared.

in order to initialize it during runtime, we must use pthread_cond_init

How to Destroy?

```
int pthread_cond_destroy(pthread_cond_t *cond)
```

pthread_cond_destroy function deinitialize condition variable and release underlying memory.

Destroy the condition variable

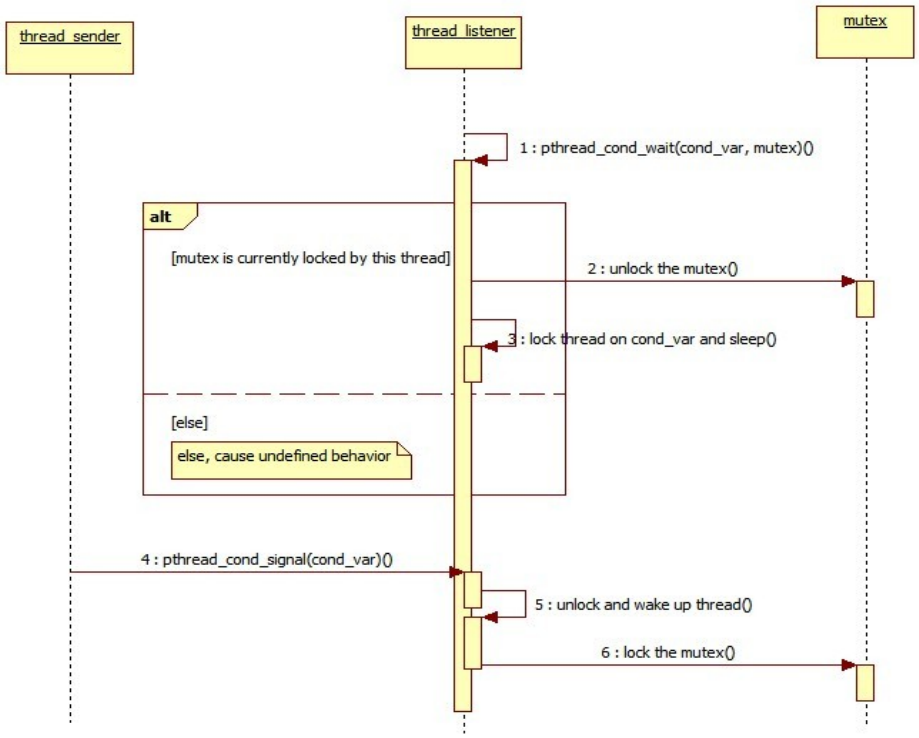
which is currently blocked by a thread

lead to undefined behavior

Wait & Signal

We can use pthread_cond_wait() to command thread to wait for a condition variable and pthread_cond_signal() to notify that the condition happened.

Each condition variable is used together with a mutex.

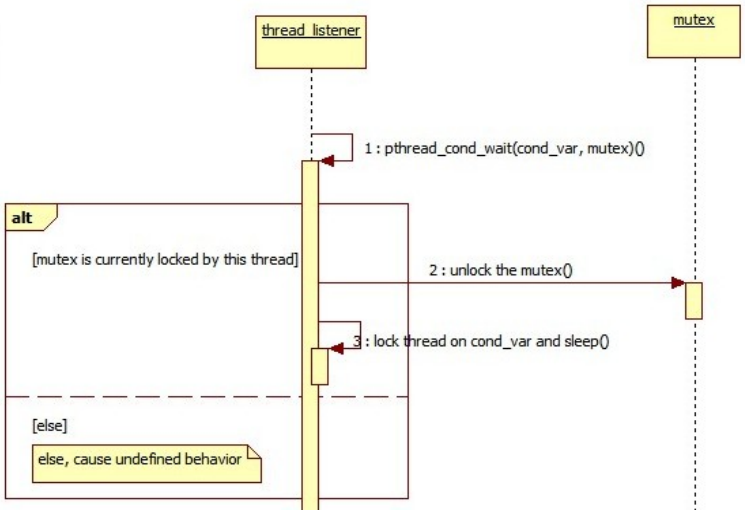


What does pthread_cond_wait do?

```
pthread_cond_wait(pthread_cond_t* cond_var, pthread_mutex_t* mutex)
```

If mutex is currently locked by the calling thread, the function performs following steps:
- Release the mutex
- Block the thread on condition variable. Until another thread signals on the condition variable. While blocking, the thread does not consume CPU resources.

If the mutex is not locked by the calling thread, it will cause undefined behavior.



What does pthread_cond_signal do?

```
pthread_cond_signal(pthread_cond_t* cond_var)
```

- Unblock at least on of threads that are blocked on the condition variable cond_var.
- The unblocked thread will release the mutex that is in conjunction with the condition variable.

Conjunct condition variable and mutex

What wrong with previous Counter & Observer sample?

```
void* inc_count(void* arg) {
    for(int i = 0; i < 30; i++){
        sleep(1);

        count ++;
        printf("thread counter: %d\n", count);

        if (count == 15) {
            pthread_cond_signal(&cond);
        }
    }
}

void* watch_count(void* arg) {
    pthread_cond_wait(&cond, &mtx);

    printf("\nthread observer: reached\n\n");
}
```

count variable can be read/write by multiple threads at the same time

but it is not protected by any exclusive mechanism

This may cause data race.

pthread_cond_wait is called on a unlocked mutex.

This may cause undefined behavior.

Lets fix the issue

```
void* inc_count(void* arg) {
    for(int i = 0; i < 30; i++){
        sleep(1);

        pthread_mutex_lock(&mtx);

        count ++;
        printf("thread counter: %d\n", count);

        if (count == 15) {
            pthread_cond_signal(&cond);
        }

        pthread_mutex_unlock(&mtx);
    }
}


void* watch_count(void* arg) {

    pthread_mutex_lock(&mtx);

    pthread_cond_wait(&cond, &mtx);

    pthread_mutex_unlock(&mtx);


    printf("\nthread observer: reached\n\n");
}
```

Protect count variable from data race

Lock mutex before pthread_cond_wait()

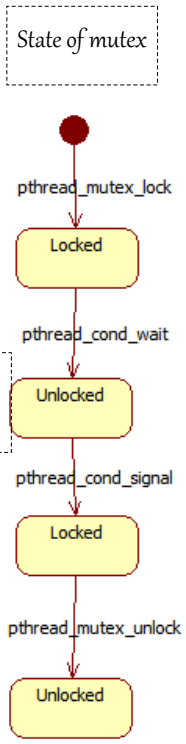
Because pthread_cond_wait() will unlock the mutex.

If mutex is not currently locked, undefined behavior may happen

After thread receive signal and wake up

it relock the mutex

Unlock the mutex, to avoid deadlock



All code

```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int count = 0;

pthread_mutex_t mtx = PTHREAD_MUTEX_INITIALIZER;
pthread_cond_t cond = PTHREAD_COND_INITIALIZER;

void* inc_count(void* arg) {
    for(int i = 0; i < 30; i++){
        sleep(1);

        pthread_mutex_lock(&mtx);
```

```
        count ++;
        printf("thread counter: %d\n", count);

        if (count == 15) {
            pthread_cond_signal(&cond);
        }

        pthread_mutex_unlock(&mtx);
    }
}

void* watch_count(void* arg) {
    pthread_mutex_lock(&mtx);
    pthread_cond_wait(&cond, &mtx);
    pthread_mutex_unlock(&mtx);

    printf("\nthread observer: reached\n\n");
}

int main(){
    pthread_t thread_counter, thread_observer;

    pthread_create(&thread_counter, NULL, inc_count, NULL);
    pthread_create(&thread_observer, NULL, watch_count, NULL);

    pthread_join(thread_counter, NULL);
    pthread_join(thread_observer, NULL);

    return 0;
}
```