Homework Assignment #3
Race Condition & Mutex

Outline

- **Race Condition**
- **Mutex Locks**
- **Application Programming Interface**
  - Exercise 3.20 API
  - Exercise 4.28 API
  - Pthread Mutex
- **Homework Assignment #3**
- **Reference**

Race Condition

- A situation that several threads access the same data concurrently and the outcome depends on the uncontrollable sequence.

Thread 1	Thread 2	bitmap/300/	Pid_th1	Pid_th2
if(bitmap/300/ == 0)		0	NULL	NULL
	if(bitmap/300/ == 0)	0	NULL	NULL
bitmap/300/ = 1		1	300	NULL
	bitmap/300/ = 1	1	300	300

Race Condition

Race Condition

```
tid is 140172315629312
pid is 0, will sleep 7 seconds
tid is 140172324022016
pid is 1, will sleep 2 seconds
tid is 140172307236608
pid is 0, will sleep 7 seconds
tid is 140172374378240
tid is 140172357592832
pid is 4, will sleep 8 seconds
pid is 6, will sleep 6 seconds
tid is 140172365985536
pid is 2, will sleep 10 seconds
tid is 140172349200128
pid is 3, will sleep 5 seconds
tid is 140172298843904
pid is 0, will sleep 1 seconds
tid is 140172340807424
pid is 5, will sleep 8 seconds
tid is 140172332414720
pid is 7, will sleep 6 seconds
```

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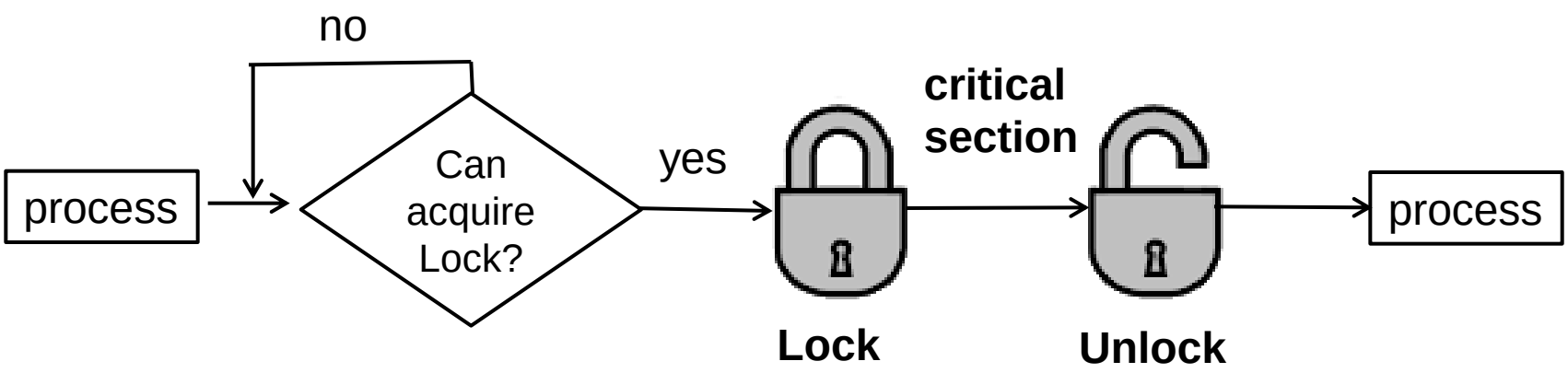
Mutex Locks

- We use the mutex lock to protect critical sections and thus prevent race conditions.
- A process must acquire the lock before entering a critical section; it releases the lock when it exits the critical section.
- A mutex lock has a boolean variable whose value indicates if the lock is available or not.



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Exercise 3.20 API

- We have used three APIs in homework#1.
  - ***int allocate map(void)*** ：

    Initializes a data structure for representing pids;

    returns −1 if unsuccessful, 1 if successful

  - ***int allocate pid(void)*** ：

    Allocates and returns a pid; returns −1 if unable to allocate a pid (all pids are in use)

  - ***void release pid(int pid)*** ：

    Releases a pid

Exercise 4.28 API

- We have used three Pthreads APIs in homework#2.
  - ***#include <pthread.h>***
  - ***int pthread_create(pthread_t *thread, const pthread_attr_t *attr,void *(*start_routine) (void *), void *arg);***

    Create a thread
  - ***int pthread_join(pthread_t thread, void **value_ptr);***

    Wait for a thread

    Causes the caller to wait for the specified thread to exit
  - ***int pthread_exit(void *value_ptr);***

    Exit a thread without exiting process

Pthread Mutex Locks

- There is a whole set of library calls associated with mutex locks, most of whose names start with **`pthread_mutex`**
- To use these library calls, we must include the file **`pthread.h`**, and link with the pthread library using **`–pthread`**

```
oslab@oslab-VirtualBox: ~/Desktop
oslab@oslab-VirtualBox:~/Desktop$ cd ~/Desktop
oslab@oslab-VirtualBox:~/Desktop$ gcc -o a a.c -pthread
oslab@oslab-VirtualBox:~/Desktop$
oslab@oslab-VirtualBox:~/Desktop$
```

```
*a.c (~/Desktop) - gedit
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筆記 ×  *a.c ×
#include <pthread.h>
pthread_mutex_t mutex;
```

Pthread Mutex Locks

- We will use the following four functions
  - ***int pthread_mutex_init()***
    - Initialize a mutex.
  - ***int pthread_mutex_lock()***
    - Lock the critical section.
  - ***int pthread_mutex_unlock()***
    - Unlock the critical section.
  - ***int pthread_mutex_destroy()***
    - Release the resource and destroy a mutex.

Pthread Mutex Locks

- **pthread_mutex_init**
  - Initializes the mutex lock.

```
#include<pthread.h>
int pthread_mutex_init(pthread_mutex_t *mutex,
 const pthread_mutexattr_t *attr);
```

```
EX: pthread_mutex_init(& mutex  , NULL);
```

mutex: Pointer to the mutex to be initialized.

attr: Use the attributes to initialize the mutex. NULL for the default values.

On success, returns 0. On error, one of the following values is returned : EAGAIN, EINVAL , EFAULT , ENOMEM

Pthread Mutex Locks

- **pthread_mutex_lock**
  - Lock the critical section.

```
int pthread_mutex_lock( pthread_mutex_t* mutex );
```

```
EX: pthread_mutex_lock(& mutex );
```

mutex: A pointer to the pthread_mutex_t object that you want to lock.
The ***pthread_mutex_lock()*** locks the mutex object referenced by ***mutex***.

If the mutex is already locked, then the calling thread blocks until it has acquired the mutex.

On success, returns 0**.** On error, one of the following values is returned **:**
EAGAIN, EINVAL , EFAULT , ENOMEM

Pthread Mutex Locks

- **pthread_mutex_unlock**
  - Unlock the critical section.

```
int pthread_mutex_unlock( pthread_mutex_t* mutex );
```

```
EX: pthread_mutex_unlock(& mutex );
```

mutex: A pointer to the pthread_mutex_t object that you want to unlock. The ***pthread_mutex_unlock()*** unlocks the ***mutex***.

If ***mutex*** has been locked more than once, it must be unlocked the same number of times before the next thread is given ownership of the mutex.

On success, returns 0**.** On error, one of the following values is returned **:** EAGAIN, EINVAL , EFAULT , ENOMEM

Pthread Mutex Locks

- **pthread_mutex_destroy**
  - Destroys a previously declared mutex.

```
int pthread_mutex_destroy(pthread_mutex_t *mutex);
```

```
EX: pthread_mutex_destroy (& mutex );
```

mutex: Pointer to the mutex to be destroyed.

The mutex mustn't be used after it has been destroyed.

On success, returns 0. On error, one of the following values is returned : EAGAIN , EINVAL , EFAULT , ENOMEM

Pthread Mutex Locks_Example

```
#include <stdio.h>
#include <stdlib.h>
#include <pthread.h>
#define MAXPID 100000
pthread_mutex_t mutex;    // Declare the name of pthread_mutex_t .
int glob=0;
//This is thread function
void *threadFunc() {
    int i=0;
    printf("--------------------------------\n");
    printf("This is thread function\n");
    printf("thread ID: %lu\n", pthread_self());
    printf("Mutex Lock the critical section.\n");
    //critical section start
    pthread_mutex_lock( &mutex );            //Lock the critical section.

    while(i<MAXPID){
                i++;
                glob++;
    }
    pthread_mutex_unlock ( &mutex);          //Unlock the critical section.
    //critical section end
    printf("Mutex unlock the critical section.\n");

    printf("sum : %d\n", i);
    printf("--------------------------------\n");
    pthread_exit(NULL);
}
```

```
void *threadFunc2() {
    int i=0;
    printf("--------------------------------\n");
    printf("This is thread2 function\n");
    printf("thread ID: %lu\n", pthread_self());
    printf("Mutex Lock the critical section.\n");
    //critical section start
    pthread_mutex_lock( &mutex );
                //Lock the critical section.
    while(i<MAXPID){
                i++;
                glob++;
    }
    pthread_mutex_unlock ( &mutex);
                //Unlock the critical section.
    //critical section end
    printf("Mutex unlock the critical section.\n");

    printf("sum : %d\n", i);
    printf("--------------------------------\n");
    pthread_exit(NULL);
}
```

Pthread Mutex Locks_Example(cont.)

```
int main(int argc, char** argv)
{
        pthread_t thread,thread2;
        pthread_mutex_init(& mutex  , NULL );        //Initializes the mutex.
        int rc, t=100;
        void *reBuf;
        rc = pthread_create(&thread, NULL, threadFunc, NULL);
        rc = pthread_create(&thread2, NULL, threadFunc2, NULL);
        if(rc)
        {
                printf("ERROR; return code from pthread_create() is %d\n", rc);
                exit(-1);
        }
        pthread_join(thread, &reBuf);
        pthread_join(thread2, &reBuf);

        //Release the resource  and destroy a mutex.
        pthread_mutex_destroy (& mutex );
        printf("%d\n",glob);
    return 0;
}
```

Pthread Mutex Locks_Example(cont.)

```
-----------------------------------
This is thread function
thread ID: 140558076548864
Mutex Lock the critical section.
-----------------------------------
This is thread2 function
thread ID: 140558068156160
Mutex Lock the critical section.
Mutex unlock the critical section.
sum : 100000
-----------------------------------
Mutex unlock the critical section.
sum : 100000
-----------------------------------
200000
```

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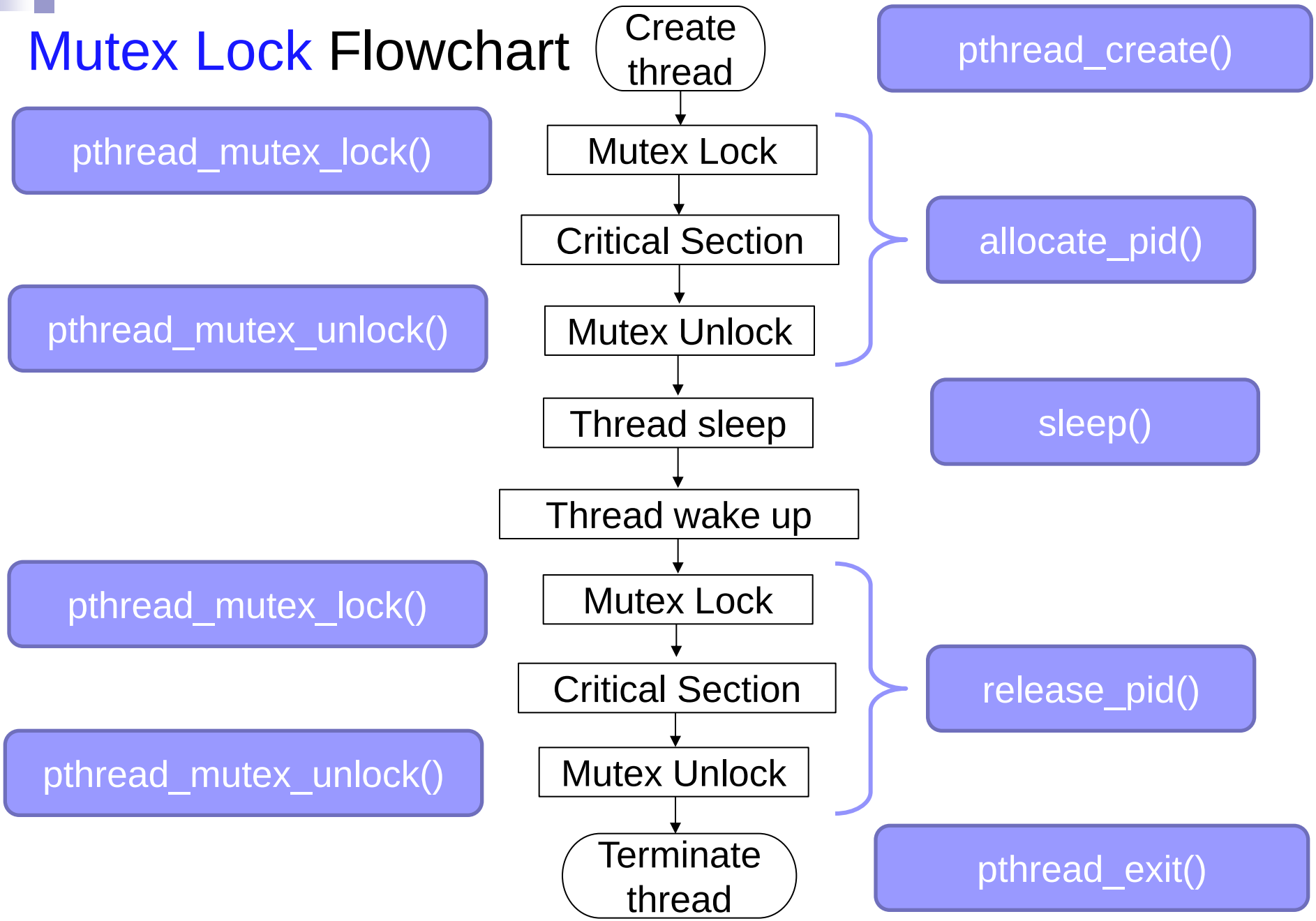
Homework Assignments #3

- Use Pthreads API to create 100 threads.

- For each thread
  - Step1. Use **Mutex Lock** to protect PID manager, which can allocate PID for each thread. (PID range : 0~99)
  - Step 2. Use **Mutex Unlock** after allocating PID.
  - Step 3. Let thread sleep for 1~3 seconds.
  - Step 4. When the thread wake up, using **Mutex Lock** to protect PID manager, which can release its PID.
  - Step 5. Use **Mutex Unlock** after releasing PID.
  - Step 6. Terminate the thread and Destroy the mutex.

Mutex Lock Flowchart



Result

```
pid is 0, will sleep 8 seconds
tid is 139957604431424
pid is 1, will sleep 7 seconds
tid is 139957596038720
pid is 2, will sleep 3 seconds
tid is 139957570860608
pid is 3, will sleep 10 seconds
tid is 139957562467904
pid is 4, will sleep 2 seconds
tid is 139957545682496
pid is 5, will sleep 6 seconds
tid is 139957537289792
pid is 6, will sleep 7 seconds
tid is 139957612824128
pid is 7, will sleep 4 seconds
tid is 139957587646016
pid is 8, will sleep 10 seconds
tid is 139957579253312
pid is 9, will sleep 6 seconds
tid is 139957554075200
pid is 10, will sleep 8 seconds
tid is 139957528897088
pid is 11, will sleep 6 seconds
tid is 139957520504384
pid is 12, will sleep 5 seconds
tid is 139957512111680
pid is 13, will sleep 3 seconds
tid is 139957495326272
pid is 14, will sleep 4 seconds
tid is 139957503718976
pid is 15, will sleep 6 seconds
tid is 139957486933568
pid is 16, will sleep 2 seconds
tid is 139957478540864
pid is 17, will sleep 3 seconds
tid is 139957461755456
pid is 18, will sleep 5 seconds
tid is 139957470148160
pid is 19, will sleep 7 seconds
tid is 139957453362752
pid is 20, will sleep 6 seconds
tid is 139957419791936
pid is 24, will sleep 8 seconds
tid is 139957428184640
pid is 23, will sleep 3 seconds
tid is 139957436577344
pid is 21, will sleep 5 seconds
tid is 139957444970048
pid is 22, will sleep 5 seconds
tid is 139957411399232
```

```
pid is 25, will sleep 2 seconds
tid is 139957403006528
pid is 26, will sleep 6 seconds
tid is 139957394613824
pid is 27, will sleep 6 seconds
tid is 139957386221120
pid is 28, will sleep 10 seconds
tid is 139957377828416
pid is 29, will sleep 3 seconds
tid is 139957369435712
pid is 30, will sleep 5 seconds
tid is 139957361043008
pid is 31, will sleep 8 seconds
tid is 139957352650304
pid is 32, will sleep 2 seconds
tid is 139957344257600
pid is 33, will sleep 9 seconds
tid is 139957335864896
pid is 34, will sleep 9 seconds
tid is 139957319079488
pid is 35, will sleep 5 seconds
tid is 139957327472192
pid is 36, will sleep 7 seconds
tid is 139957310686784
pid is 37, will sleep 6 seconds
tid is 139957302294080
pid is 38, will sleep 8 seconds
tid is 139957293901376
pid is 39, will sleep 8 seconds
tid is 139957285508672
pid is 40, will sleep 1 seconds
tid is 139957277115968
pid is 41, will sleep 7 seconds
tid is 139957268723264
pid is 42, will sleep 3 seconds
tid is 139957226759744
pid is 43, will sleep 7 seconds
tid is 139957251937856
pid is 44, will sleep 10 seconds
tid is 139957260330560
pid is 45, will sleep 7 seconds
tid is 139957235152448
pid is 46, will sleep 3 seconds
tid is 139957243545152
pid is 47, will sleep 1 seconds
tid is 139957218367040
pid is 48, will sleep 1 seconds
tid is 139957209974336
pid is 49, will sleep 7 seconds
tid is 139957201581632
```

```
pid is 50, will sleep 7 seconds
tid is 139957151225408
pid is 56, will sleep 9 seconds
tid is 139957142832704
pid is 57, will sleep 4 seconds
tid is 139956949800512
tid is 139957117654592
pid is 63, will sleep 1 seconds
tid is 139957092476480
pid is 64, will sleep 3 seconds
pid is 80, will sleep 9 seconds
tid is 139957016942144
pid is 72, will sleep 3 seconds
tid is 139957042120256
pid is 69, will sleep 8 seconds
tid is 139957075691072
pid is 62, will sleep 6 seconds
tid is 139957100869184
tid is 139957109261888
pid is 60, will sleep 2 seconds
pid is 65, will sleep 3 seconds
tid is 139957067298368
tid is 139957159618112
tid is 139957033727552
pid is 70, will sleep 1 seconds
pid is 55, will sleep 4 seconds
tid is 139957168010816
pid is 54, will sleep 3 seconds
tid is 139957176403520
pid is 53, will sleep 10 seconds
tid is 139957025334848
tid is 139957193188928
pid is 51, will sleep 8 seconds
tid is 139957008549440
pid is 73, will sleep 5 seconds
tid is 139957084083776
pid is 61, will sleep 7 seconds
tid is 139956991764032
pid is 74, will sleep 8 seconds
tid is 139957184796224
pid is 52, will sleep 7 seconds
tid is 139957134440000
pid is 58, will sleep 4 seconds
tid is 139956983371328
pid is 76, will sleep 1 seconds
tid is 139956974978624
pid is 77, will sleep 4 seconds
tid is 139956874266176
pid is 71, will sleep 9 seconds
tid is 139956807124544
```

```
pid is 66, will sleep 2 seconds
tid is 139956933015104
pid is 82, will sleep 8 seconds
tid is 139956916229696
pid is 84, will sleep 7 seconds
tid is 139956907836992
pid is 85, will sleep 1 seconds
tid is 139956891051584
tid is 139956790339136
pid is 99, will sleep 5 seconds
tid is 139956857480768
pid is 91, will sleep 9 seconds
tid is 139957126047296
pid is 59, will sleep 9 seconds
tid is 139957058905664
pid is 67, will sleep 6 seconds
tid is 139956849088064
pid is 92, will sleep 4 seconds
tid is 139956865873472
pid is 90, will sleep 9 seconds
tid is 139956966585920
pid is 78, will sleep 8 seconds
tid is 139957000156736
pid is 75, will sleep 1 seconds
pid is 89, will sleep 5 seconds
tid is 139956958193216
pid is 79, will sleep 4 seconds
pid is 96, will sleep 9 seconds
tid is 139956815517248
pid is 97, will sleep 1 seconds
tid is 139956798731840
pid is 98, will sleep 5 seconds
tid is 139956941407808
pid is 81, will sleep 6 seconds
tid is 139956924622400
pid is 83, will sleep 2 seconds
tid is 139956899444288
pid is 86, will sleep 10 seconds
tid is 139956823909952
pid is 95, will sleep 10 seconds
pid is 87, will sleep 4 seconds
tid is 139956882658880
pid is 88, will sleep 3 seconds
tid is 139957050512960
pid is 68, will sleep 7 seconds
tid is 139956840695360
pid is 93, will sleep 10 seconds
tid is 139956832302656
pid is 94, will sleep 9 seconds
```

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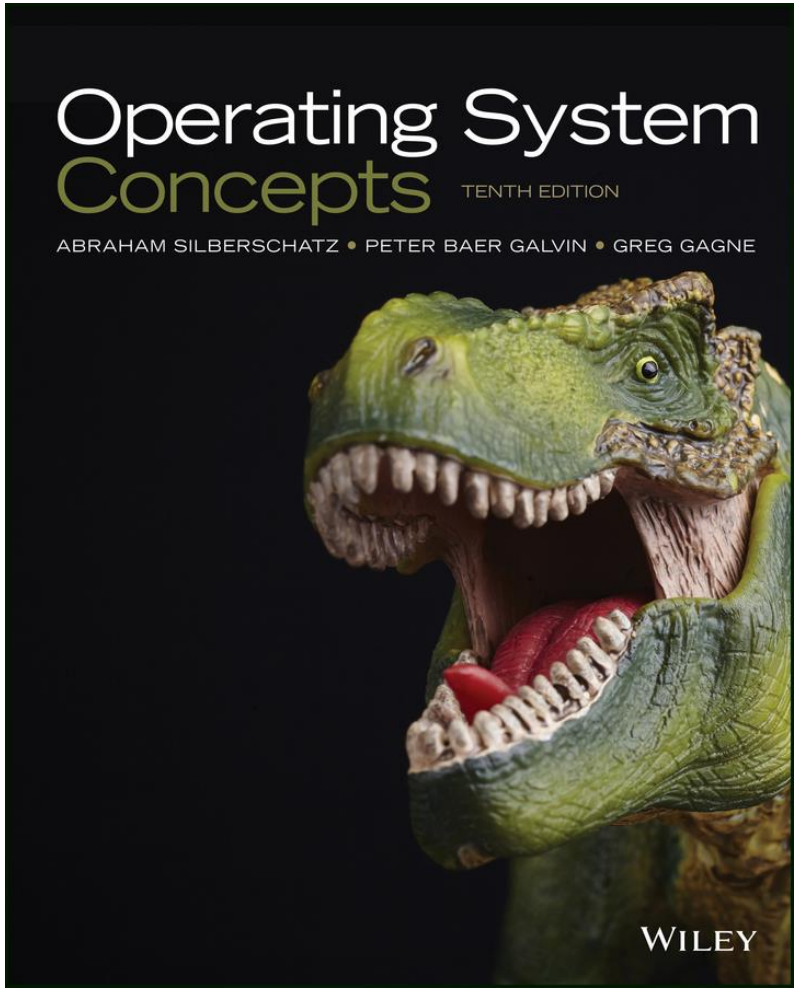
Reference

- Operating System Concepts, 10th Edition



Turn in

- Deadline

  2022/12/29 PM.11:59:59
- Upload to iLearning
- File name
  - HW3_ID.zip (e.g. HW3_4106056000.zip)
    - Source code
      - .c file
    - Word

- If you don’t hand in your homework on time, your score will be deducted 10 points every day.

TA

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- Lab: OSNET(1001)