

Light-weight Process

Operating Systems: Three Easy Pieces

Programming Project with xv6

Final due date: May 24, 2022

1 OVERVIEW

1. Light-weight process

A process is a computer program running on a computer. It is an independent execution object that is a target of a scheduler. Processes have independent resources for execution, such as address spaces and file descriptors. A light-weight process (LWP) is a little bit different. A LWP is a process that shares resources such as address space with other LWP(s), and allows multitasking to be done at the user level. The purpose of this project is to improve the multitasking capabilities of xv6 by implementing an abstraction of LWP.

2. POSIX thread

POSIX threads (abbreviated as Pthread) are light-weight processes initially implemented in UNIX, and the management of pthreads is done through the standard pthread APIs provided for writing software allowing parallel execution. Pthread is a commonly used library on all UNIX-like operating systems. When we write code for a parallel application on Linux, we generally use pthread. This pthread is an implementation of the LWP mentioned above, so the behavior of the pthread will be a good reference for implementing your version of LWP in the xv6. In addition, the tests for evaluation follow the behavior of the pthread unless stated otherwise.

2 IMPLEMENTATION SPECIFICATIONS

1. Simplified Pthread

The goal of this project is to create a LWP in the xv6. Similar to pthread, but a much simplified version, each LWP shares its address space except for the stack. That is, **it must have a separate stack for independent execution**. Also, in the case of pthread, it is possible to set the stack size, detach status, scheduling policy, etc. through attributes. However, in this project, the requirements are simplified to create a joinable LWP with the same properties as a normal process.

2. MLFQ and Stride Scheduling

Context switching between LWPs that are within the same group can be implemented in a more efficient way than a context switch between normal processes. You should think carefully about the difference between them. During the implementation, you have to reimplement the scheduler that you've made for project1 so that it works correctly with your LWP implementation.

We define a LWP group as a set of LWPs all executing inside the same process, and LWPs within the same LWP group should adopt the same scheduling policy. LWP group applies Round Robin scheduling internally, and context switching within the LWP group occurs every *1tick* in a given time quantum. The procedure of context switching between LWPs within the same group should be implemented differently from that of a normal process. When a context switching occurs between LWPs within the same group, **an LWP should switch its context with another LWP directly**; context switching between an LWP and the scheduler never occurs. The details are as follows.

- MLFQ (Multi-level feedback queue) scheduling
 - All LWPs within the same LWP group should share *their time quantum and time allotment*. If an LWP is selected to run by the scheduler, It should use its time quantum within the LWP group.
 - Each level of the queue adopts Round Robin policy with different time quantum.
 - * The highest priority queue: 5 ticks
 - * Middle priority queue: 10 ticks
 - * The lowest priority queue: 20 ticks
 - Each queue has different time allotment.
 - * The highest priority queue: 20 ticks
 - * Middle priority queue: 40 ticks
 - To prevent starvation, priority boosting needs to be performed periodically.
 - * Priority boosting is the only way to move the process upward.

- * Frequency of priority boosting: 200 ticks
- Stride scheduling
 - The default time quantum is 5 ticks.
 - All LWPs within the same LWP group should share *their time quantum*. If a LWP is selected to be run by the scheduler, It should use its time quantum within the LWP group.
 - When a LWP calls `set_cpu_share()`, all LWPs in this group have to be managed by the stride scheduler.
 - The total sum of CPU shares requested from processes in the stride queue can not exceed 80% of the CPU time. Exception handling needs to be properly implemented to handle oversubscribed requests.

3. The First Milestone : Design Basic LWP Operations

-Due Date: **ASAP**

Carefully read the project2 specifications. Review lectures related to your project and write down your understanding on your wiki.

a) Process / Thread

- Briefly explain about Process and Thread.
- Briefly explain about context switching in both sides.

b) POSIX thread : Briefly explain about the pthread library.

- `int pthread_create(pthread_t *thread, const pthread_attr_t *attr, void *(*start_routine)(void *), void *arg);`
- `int pthread_join(pthread_t thread, void **ret_val);`
- `void pthread_exit(void *ret_val);`

c) Design Basic LWP Operations for xv6

- Write down your understanding of milestone 2 and milestone 3.
- Write a rough design for Milestone 2 and milestone 3.

4. The Second Milestone : Basic LWP Operations - Create, Join and Exit

-Due Date: **May 10**

IMPORTANT: Never proceed to this milestone until the first milestone is passed.

The operations below should be provided to users through system calls.

- a) **Create** : You must provide a method to create threads within the process. From that point on, the execution routine assigned to each thread starts.

```
int thread_create(thread_t * thread, void * (*start_routine)(void *), void *arg);
```

- `thread` - return the thread id.
 - `start_routine` - the pointer to the function to be threaded. The function has a single argument: pointer to void.
 - `arg` : the pointer to an argument for the function to be threaded. To pass multiple arguments, send a pointer to a structure.
 - `ret_val` : On success, `thread_create` returns 0. On error, it returns a non-zero value.
- b) **Exit** : You must provide a method to terminate the thread in it. As the main function do, you call the `thread_exit` function at the end of a thread routine. Through this function, you must be able to return a result of a thread. In xv6, when the program's main function returns, the routine for safely exit is not included in the user stack. That is, in xv6, `exit()` must be explicitly called when the process is terminated. This is the same for threads. If you want to perform the test yourself, take this into account and explicitly call the `thread_exit` function at the point where the thread exits.

```
void thread_exit(void *retval);
```

- `retval` : Return value of the thread.
- c) **Join** : You must provide a method to wait for the thread specified by the argument to terminate. If that thread has already terminated, then this returns immediately. In the join function, you have to clean up the resources allocated to the thread such as a page table, allocated memories and stacks. You can get the return value of a thread through this function.

```
int thread_join(thread_t thread, void **retval);
```

- `thread` : the thread id allocated on `thread_create`.
- `retval` : the pointer for a return value.
- `ret_val` : On success, this function returns 0. On error, it returns a non-zero value.

5. The Third Milestone : Interaction with other services in xv6

-Due Date: May 24

IMPORTANT: Never proceed to this milestone until the first milestone is passed.

- a) Interaction with system calls in xv6

A newly created LWP must interact properly with the services already provided by the operating system. Therefore, it is necessary to consider the operation behaviors when calling other system calls in the multithreaded environment provided by the LWP that you'll make. In particular, we will mainly evaluate operations related to a process and it should follow the operation behaviors of `pthread` unless stated otherwise. The system calls to consider include `exit`, `fork`, `exec`, `sbrk`, `kill`, `pipe`, `sleep`, etc. The specific behavior is described in the test case section stated below.

- b) Interaction with the schedulers that you implemented in Project 1: MLFQ and Stride.

A newly created LWP should be able to interact appropriately with the schedulers you made in Project 1. We proposed one way above, and you have to follow these specifications.

3 EVALUATION

1. Document

You must write a detailed document of your work on the gitlab wiki. It is evaluated based on that document. If you miss a description for something, it may not be evaluated. Please do careful work that describes your work. The document may include design, implementation, solved problems(evaluating list below) and considerations for evaluation.

2. How to evaluate and self-test

The evaluation of this project is based on the requirements of the implementation specifications described above and can be verified through the test-cases provided. The points are given as follows.

Evaluation items	Points
Documents	20
Basic LWP operations	55
Interaction with system calls	35
Interaction with the schedulers that you made in Project 1	20
Other corner cases	10
Total Points	140

3. Test Cases

The test program will be updated in the next specification. Below is the detail descriptions on how to operate for each test cases. These descriptions are based on pthread and if there is no description for a specific situation, follow the behaviors of pthread.

- a) **Basic Operations** : The behaviors of the LWPs spawned by the system calls should share their address space, have their own context and stack, and be able to generate a race condition if they share a resource. You also need to be able to manage the LWPs through the create, join, and exit system calls presented in this project.
- b) **Exit** : When a LWP calls the exit system call, all LWPs are terminated and all resources used for each LWP must be cleaned up, and the kernel should be able

to reuse it at a later point of time. Also, no LWP should survive for a long time after the exit system call is executed.

- c) **Fork** : Even if multiple LWPs call the fork system call at the same time, a new process must be created according to the fork's behavior, and the address space of the LWP must be copied normally. You should also be able to wait for the child process normally by the wait system call. Note the parent-child relationship between processes after the fork.
- d) **Exec** : If you call the exec system call, the resources of all LWPs are cleaned up so that the image of another program can be loaded and executed normally in one LWP. At this time, the process executed by the exec must be guaranteed to be executed as a general process thereafter.
- e) **Sbrk** : When multiple LWPs simultaneously call the sbrk system call to extend the memory area, memory areas must not be allocated to overlap with each other, nor should they be allocated a space of a different size from the requested size. The expanded memory area must be shared among LWPs.
- f) **Kill** : If more than one LWP is killed, all LWPs must be terminated and the resources for each LWPs in that process must be cleaned up. After a kill for a LWP is called, no LWP in that group should survive for a long time.
- g) **Pipe** : All LWPs must share a pipe, and reading or writing data should be synchronized and not be duplicated.
- h) **Sleep** : When a specific LWP executes a sleep system call, only the requested LWP should be sleeping for the requested time. If a LWP is terminated, the sleeping LWP should also be terminated.
- i) **Other corner cases** : We will also conduct tests for other corner cases as well as the tests mentioned above. As there are many corner cases like creating a thread in a thread, please mimic the behavior of the pthread as much as possible. The more defensive on such corner cases, the higher the score.
- j) **Interaction with the schedulers that you made in Project 1** : All threads belonging to the same process are scheduled by the same scheduler. Threads in Stride and MLFQ scheduler share the time slice of their origin process.

Noted items :

1. An LWP is a process just sharing a same address space. We recommend using the proc structure to implement the LWP.
2. Sharing address space means sharing the same page table among LWPs spawned by a process.
3. You can get many hints from fork, exec, exit and wait functions in xv6.
4. Pay attention to using the lock for ptable.

5. We recommend you to make various test cases using Pthread on a linux machine and get an intuition for your implementation.
6. **Plagiarism issue will not be forgiven under any circumstances as mentioned before. Be careful not to upload any of your code on a public community since both the contributor and the plagiarist will be treated the same.**