

# Homework 3

## Academic Honesty

Aside from the narrow exception for collaboration on homework, all work submitted in this course must be your own. Cheating and plagiarism will not be tolerated. If you have any questions about a specific case, please ask me. We will be checking for this!

NYU Poly's Policy on Academic Misconduct:

<http://engineering.nyu.edu/academics/code-of-conduct/academic-misconduct>

## Homework Notes :

### General Notes:

- Read the assignment carefully, including what files to include.
- Don't assume limitations unless they are explicitly stated.
- Treat provided examples as just that, not exhaustive list of cases that should work.
- When in doubt regarding what needs to be done, ask. Another option is test it in the real UNIX operating system. Does it behave the same way?
- **TEST** your solutions, make sure they work. It's obvious when you didn't test the code.

Due Date: Oct 29<sup>th</sup> 11:55 pm.

Turn It In: See instructions below

## Preliminaries

In this assignment we will go back to using xv6

Start by getting a modified version of the xv6 source code from github.

```
$ git clone https://github.com/gussand/xv6-public.git
Cloning into 'xv6-public'...
remote: Counting objects: 4484, done.
remote: Compressing objects: 100% (36/36), done.
remote: Total 4484 (delta 11), reused 0 (delta 0), pack-reused 4448
Receiving objects: 100% (4484/4484), 11.69 MiB | 3.79 MiB/s, done.
Resolving deltas: 100% (1779/1779), done.
Checking connectivity... done.
```

```
Switch to the homework branch:
```

```
$ cd xv6-public
$ git checkout hw4
Branch hw4 set up to track remote branch hw4 from origin.
Switched to a new branch 'hw4'
```

The modified version has some new features:

1. It contains a random number generator. You can use it by including ``rand.h`` in a source file and then calling the function

```
long random_at_most(long max)
```

To get a random number between ``0`` and ``max``, *\*inclusive\**.

2. It contains a new system call,  
``int gettime(struct rtcdate *date)``,

which retrieves the current date and time from the CMOS RTC and stores it in an ``rtcdate`` structure (you can see how ``struct rtcdate`` is defined by looking at ``date.h``).

3. It contains a program designed to test the lottery scheduler you will develop, in the source file ``lotterytest.c``.

### Important Note

For simplicity in testing, you should run the tests for this assignment in QEMU with just one CPU. You can do this by invoking the Makefile as:

```
make qemu CPUS=1
```

### Lottery Scheduling

For this assignment, you will implement and test *\*lottery scheduling\**, a randomized algorithm (discussed in class and in the reading) that allows processes to receive a proportional share of the CPU without explicitly tracking how long each process has been run.

Specifically, you should modify xv6 so that:

1. Each ``struct proc`` has an additional field, ``tickets``, that tracks how many tickets it has.
2. New processes are assigned 10 lottery tickets when they are created.
3. When the scheduler runs, it picks a random number between 0 and the

total number of tickets. It then uses the algorithm described in class to loop over runnable processes and pick the one with the winning ticket.

4. User processes have a new system call, `settickets`, that allows a process to specify how many lottery tickets it wants. Normally this would be a bad idea, since it would let a process hog the CPU by specifying an arbitrary number of tickets -- but xv6 has no security anyway, so this is not that big a deal.

In addition to Tannenbaum's description of lottery scheduling in *Modern Operating Systems*, you may find it helpful to read over [Operating Systems: Three Easy Pieces, Chapter 9: Scheduling: Proportional Share](<http://pages.cs.wisc.edu/~remzi/OSTEP/cpu-sched-lottery.pdf>).

Of course, once you have implemented this, you will want to test that the scheduler works. Aside from basic tests that the system is still functioning, you should verify that allocating more tickets to a process does increase its share of the CPU allotted by the scheduler.

Included in the source distribution is a new program, `lotterytest`, which forks two children, sets their priorities, and runs a CPU-intensive task in each, timing the results. The test assigns 80 tickets to one and 20 to the other, so the first should be scheduled 4 times as often as the second (an 80% / 20% split).

To build `lotterytest`, just add it to the `UPROGS` list in the `Makefile` (taking care to use a tab character for indentation rather than 4 spaces). Note that it will not compile until you have added the `settickets` system call. The relevant portion of the `Makefile` is shown below:

```
.PRECIOUS: %.o

UPROGS=\
    _cat\
    _echo\
    _forktest\
    _grep\
    _init\
    _kill\
    _ln\
    _ls\
    _mkdir\
    _rm\
    _sh\
    _stressfs\
    _usertests\
    _wc\
```

```

_zombie\
_hackbench\

fs.img: mkfs README $(UPROGS)
./mkfs fs.img README $(UPROGS)

```

Given two processes started at the same time, that do the same amount of work, we expect that they will finish at the same time if they have the same number of tickets. We can predict how long they should take when the CPU is divided between them at various ratios. Suppose that we have two tasks  $T_1$  and  $T_2$ , each of which takes 5 seconds to run. Regardless of the share of the CPU each has, they will take 10 seconds total for both to finish. Running them with an equal share of the CPU will cause them both to finish at the same time. We can calculate the expected runtime of  $T_1$  when given a certain fraction of the CPU as:

```

R( $T_1$ , 1.0) = 5 seconds
R( $T_1$ , 0.5) = 10 seconds
R( $T_1$ , x) = 1/x * R( $T_1$ , 1.0)

```

So from this we can compute that if  $T_1$  is given an 80% share of the CPU, it should finish in 6.25 seconds;  $T_2$  will still finish in 10 seconds (remember, the scheduler is just redistributing the work to be done, so running the two tasks still takes 10 seconds no matter what

By running `lotterytest` a few times, you should be able to verify that the process with 80 tickets finishes sooner than the process with only 20. For example, here's the output I get:

```

$ make qemu CPUS=1
qemu-system-i386 -nographic -hdb fs.img xv6.img -smp 1 -m 512

WARNING: Image format was not specified for 'fs.img' and probing
guessed raw.
    Automatically detecting the format is dangerous for raw
images, write operations on block 0 will be restricted.
    Specify the 'raw' format explicitly to remove the
restrictions.
WARNING: Image format was not specified for 'xv6.img' and probing
guessed raw.
    Automatically detecting the format is dangerous for raw
images, write operations on block 0 will be restricted.
    Specify the 'raw' format explicitly to remove the
restrictions.
xv6...

```

```

cpu0: starting
sb: size 1000 nblocks 941 ninodes 200 nlog 30 logstart 2 inodestart
32 bmap start 58
init: starting sh
$ lotterytest
starting test at 17 hours 22 minutes 22 seconds
spin with 80 tickets ended at 17 hours 22 minutes 28 seconds
spin with 20 tickets ended at 17 hours 22 minutes 32 seconds

```

You can see that the process with 80 tickets finished after 6 seconds, while the process with 20 tickets finished after 10 seconds. You can also play with the numbers in `lotterytest` to see the effect of varying the number of tickets.

### **\*\*Hints\*\*:**

1. One possible way to track the total number of tickets is by carefully finding each place where the process state changes, and adding or subtracting tickets from a global as appropriate. However, this is actually rather tricky to get right. An alternative is to simply compute the number of tickets each time we enter the scheduler loop, before choosing the winning ticket.
2. Right now, the scheduler loop picks up where it left off after scheduling a process -- so if it finds a runnable process at index `i`, the next time the scheduler runs it will keep going through the list at index `i+1`. In order to make the lottery algorithm work, you will need to restructure the scheduler loop so that it starts back at the beginning of the list every time we return to the scheduler.
3. No changes are needed to the process list itself; you can continue to use the `ptable.proc` array (i.e., you don't have to implement a process queue).
4. You can consult the slides to find out how to add a new system call when adding `settickets`.
5. As with the previous homework, the use of gdb to debug your code is highly encouraged.
6. If you want to see the list of running processes at any time, you can type `Control-p` at the xv6 console and it will print out a list of running processes. You may also want to modify this function (`procdump` in `proc.c`) to print out the number of tickets each process has so that you can debug your `settickets` call.

### Submitting

You will use git to create a patch that contains your changes. First, tell git who you are:

```

$ git config --global user.email "you@example.com"
$ git config --global user.name "Your Name"

```

Then, commit your changes:

```

$ git commit --all --message="Implement lottery scheduling"
[hw4 94b0cf7] Implement lottery scheduling

```

```
7 files changed, 60 insertions(+), 7 deletions(-)
```

(Note: if you added any new files, you will also have to use

```
`git add <filename>` before you run `git commit`.)
```

Finally, create a patch file. The command takes an argument that specifies what code we're comparing against to make the patch; in this case I have created a git *\*tag\** that refers to the unmodified Homework 4 called ``hw4.unmodified``, so you should run:

```
$ git format-patch hw4.unmodified
0001-Implement-lottery-scheduling.patch
```

The command creates a file, ``0001-Implement-lottery-scheduling.patch``, containing the changes you've made. Submit this file on NYU Classes, along with the usual ``partner.txt`` listing your partner (if any).

### **\*\*Submission Note\*\***

Don't try to edit the patch file after creating it. Doing so will most likely corrupt the patch file and make it impossible to apply. Instead, change the original file, commit your changes, and run ``git format-patch`` again:

```
$ git commit --all --message="Description of your change here"
[hw4 7cc4977] Description of your change here
1 file changed, 1 insertion(+), 1 deletion(-)
$ git format-patch hw4.unmodified
0001-Implement-lottery-scheduling.patch
0002-Description-of-your-change-here.patch
```

Then submit *\*both\** patch files.