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1) Add a system call to change priority of a process.
Approach: Added implementation for setPriority(int priority). To make the required changes, I changed some files. Following are the files changed and a brief summary of the changes done in each:
a) syscall.h
Defined a system call and associated it with a number:
#define SYS_setPriority 24

b) syscall.c
Added the function prototype for setPriority() – **extern int sys_ setPriority(void);**
Added a pointer to the system call in the array of function pointers:

```
static int(*syscalls[]) (void) = {
    .
    .
    .
    [SYS_ setPriority]    sys_ setPriority,
}
```

c) usys.S
In order for a user program to call the system call, an interface was added:
SYS_CALL(setPriority)

d) sysproc.c
Added the handler for setPriority system call to update priority for process:

```
int sys_ setPriority(void) {
   int priority;
   if(argint(0, &priority) < 0) return -1;
   return setPriority(priority);
}
```

e) defs.h
Added forward declaration of system call setPriority() in "proc.c" section:
int setPriority(int);

f) user.h
Added user level definition of setPriority() under system calls:
int setPriority(int);

g) proc.h
Added a field 'priority' in the proc struct which stores the state of a process:

```
struct proc {
   .
   .
   int priority;
}
```

h) proc.c
This contains the actual implementation of the setPriority(). Current process is obtained using myproc(). Then, that process' priority is updated with the argument passed.

```
int setPriority(int p) {
   struct proc *curr = myproc();
   curr->priority = p;
   return 0;
}
```

2) Change scheduler from simple round robin to a priority scheduler. Implement aging of priority to avoid starvation.
Approach: The default priority of a process should be 10. The range of priority is between 0 to 31 both inclusive. When scheduling from the ready list, always the highest priority thread/process should be scheduled first. If a process waits, its priority increases. If a process runs, its priority decreases. For this, I changed two functions in **proc.c** file:
a) Set the default priority of process:

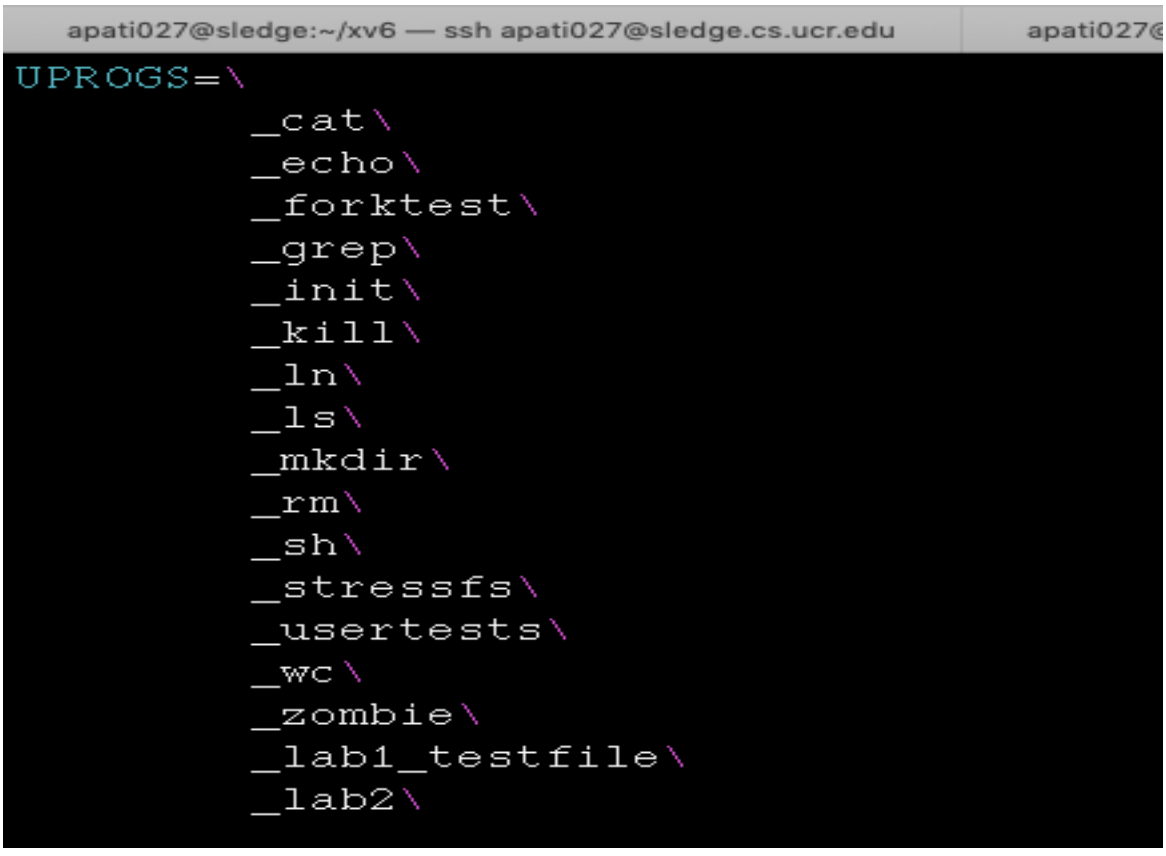
```
allocproc() {
   .
   .
   p->priority = 10;
   return p;
}
```

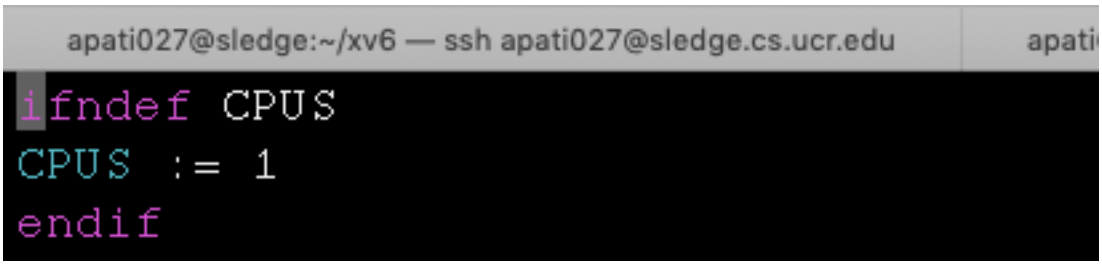
b) Changed the scheduler from Round Robin to priority scheduler with "aging":

```
scheduler() {
   .
   .
   for(;;) {
      sti();

      acquire(&ptable.lock);
      struct proc *nextProc = ptable.proc;
      int highestPriority = nextProc->priority;

      for(p = ptable.proc; p < &ptable.proc[NPROC]; p++) {
          if(p->state != RUNNABLE || p == nextProc) continue;
```

```
        if(p->priority < highestPriority) {
          highestPriority = p->priority;
          nextProc->priority -= 1;
          nextProc = p;
        } else {
          if(p->priority > 0) p->priority -= 1;
        }
      }
      if(nextProc->priority < 31) nextProc->priority += 1;
      c->proc = nextProc;
      switchuvm(nextProc);
      .
      .
      switchkvm();
      c->proc = 0;
      release(&ptable.lock);
    }
}
```

3) Modified Makefile for including lab2 under UPROGS and changed the number of CPUS to 1.



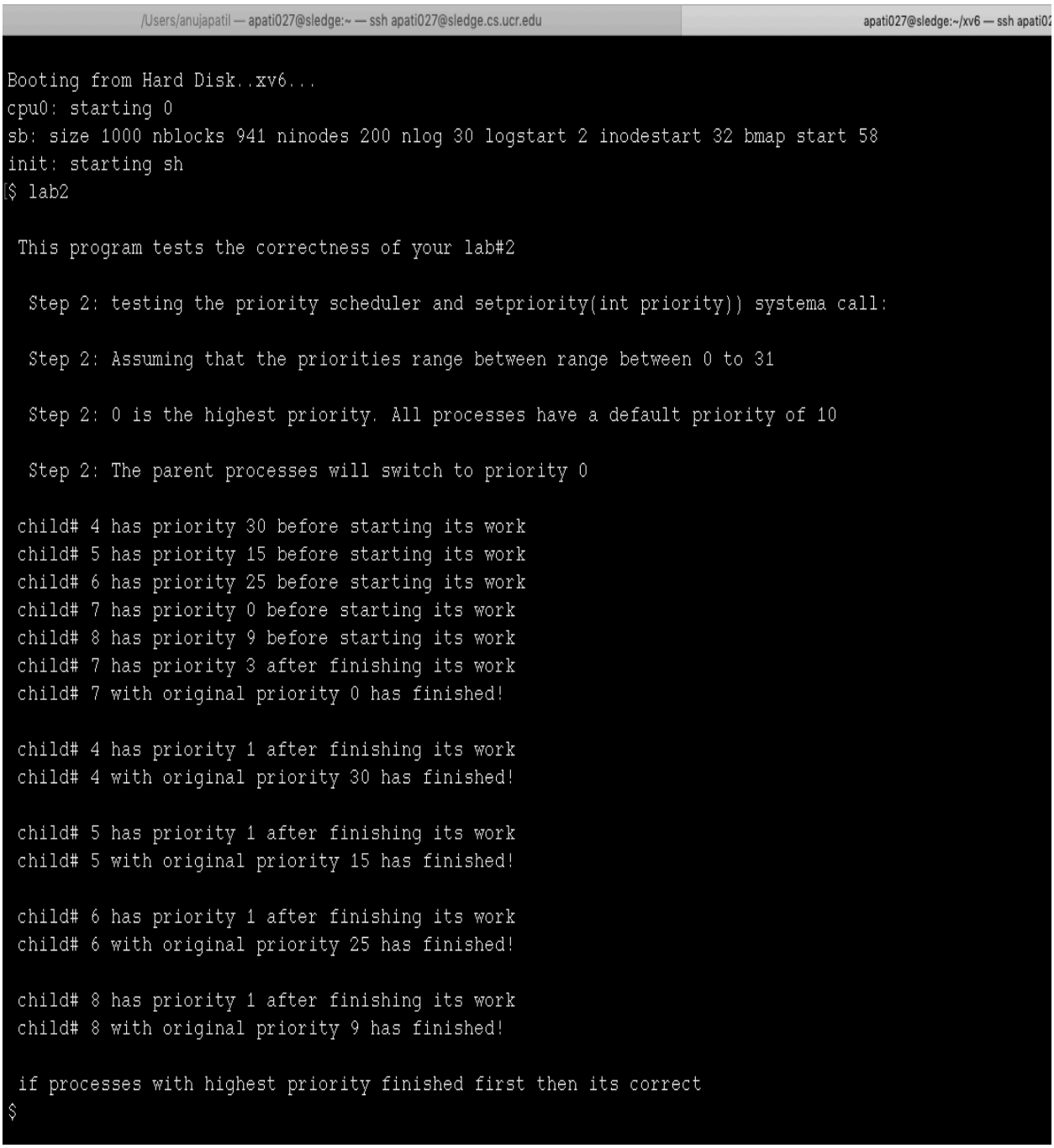


4) Modified test file (lab2.c) for testing aging of priority with priority scheduler.
Approach: Created an array of priorities “priorityArr”. Put print statements before and after the nested for loops for child processes with initially set and updated priorities. To print updated priorities, I created another system call “**getPriority()**” and changed in the same files which are needed to create a system call.

5) To make and run the lab2.c: (We are inside xv6 folder)
> make clean
> make qemu-nox

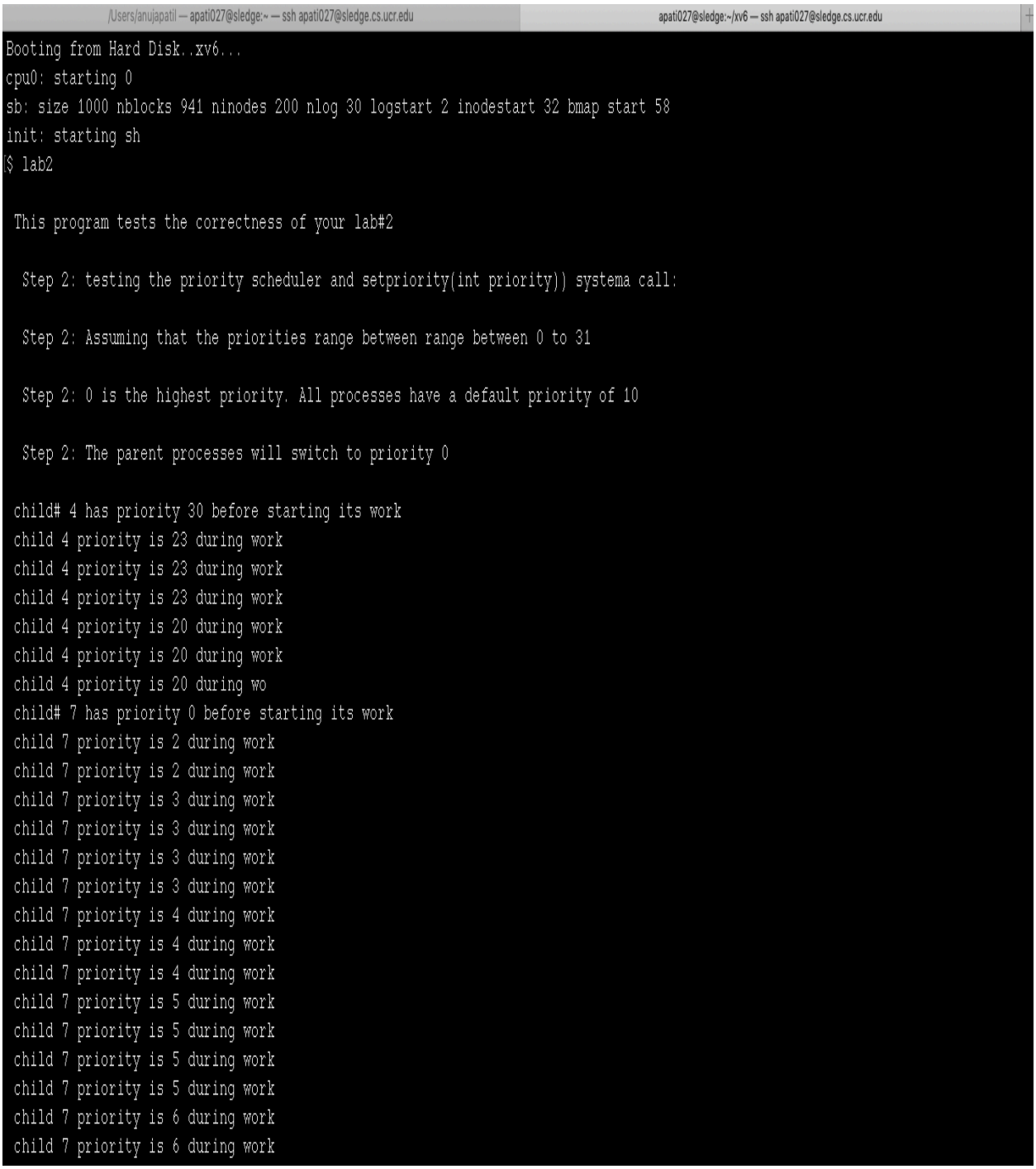
This will open qemu console. Then run:
$ lab2

Following are the outputs for 5 processes (created array “priorityArr” in **lab2.c** which contains priorities – 30, 15, 25, 0, and 9):

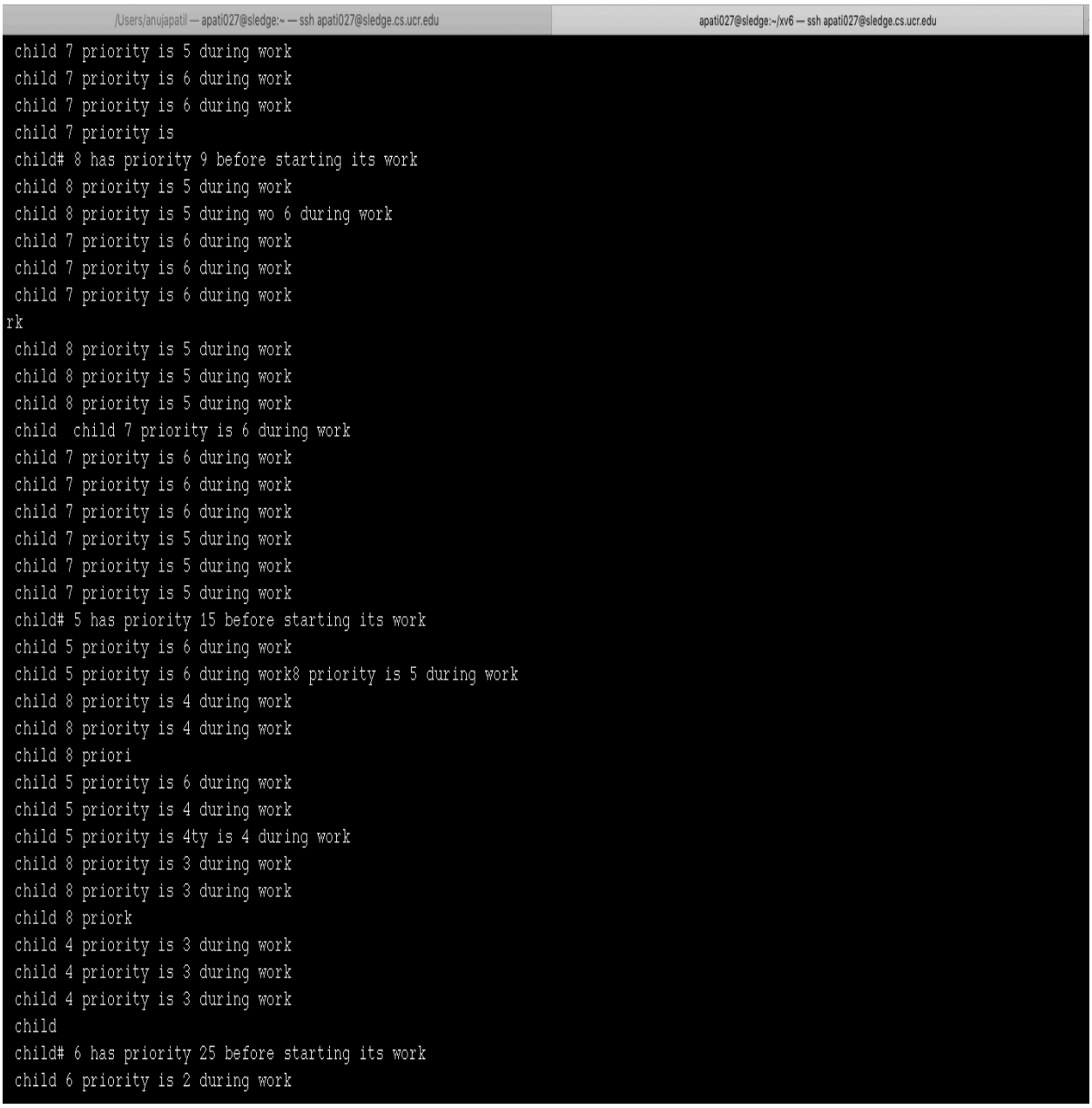


Child processes 4, 5, 6, 7, and 8 are created with priorities 30, 15, 25, 0 and 9. We can see that child 7 has executed first and hence its priority increased to 3 (assuming the middle values have run quickly) and then it has finished execution. We can see that rest processes' priorities are increased to 1 and it stopped going lower than that as I have that condition put in the code that does not set priority lesser than 0. Since now their priorities are same, any order execution has happened.

I have another screenshot of outputs with same priorityArr as above. Just to slow down the process, I have also put print statements between the nested loops to indicate “in the middle of work”. I have reduced the number of iterations too so that program can run quickly.



We can see here that child 7’s priority is increasing as it was having the highest priority and it was executing where as child 4’ priority is decreasing.



At some point, child 8 with priority 9 was not the highest and hence its priority increased to 5. Similarly child 5 having priority 15, was not run initially, so its priority increased to 6.

/Users/anujapatil — apati027@sledge:~ — ssh apati027@sledge.cs.ucr.edu | apati027@sledge:~/xv6 — ssh apati027@sledge.cs.ucr.edu

```
child 4 priority is 3 during work
child
child# 6 has priority 25 before starting its work
child 6 priority is 2 during work
child 6 priority is 2 4 priority is 3 during work
child 4 priority is 2 during work
child 4 priority is 2 during work
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child 4 priority is 2 during work
```
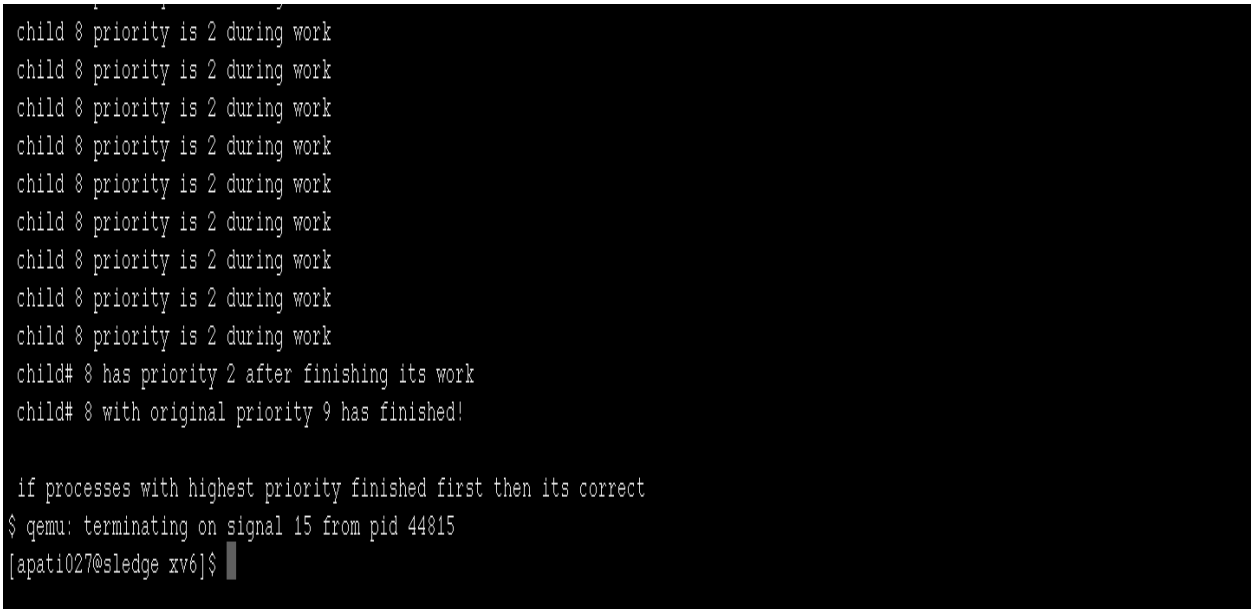

Child 4’s priority is continuously at 2 because I have the lower limit condition on priority.

Skipping some screenshots and attaching the last few lines:



Following are some screenshots of modified code:

scheduler() in proc.c:

```
void
scheduler(void)
{
  struct proc *p;
  struct cpu *c = mycpu();
  c->proc = 0;

  for(;;){
    // Enable interrupts on this processor.
    sti();

    // Loop over process table finding the highest priority ready process.
    // Implementing aging of priority: If process waits, its priority is
    // increased. If process runs, its priority is decreased.
    acquire(&ptable.lock);
    struct proc *nextProc = ptable.proc;
    int highestPriority = nextProc->priority;

    //acquire(&ptable.lock);
    for(p = ptable.proc; p < &ptable.proc[NPROC]; p++) {
      if(p->state != RUNNABLE || p == nextProc) continue;

      if(p->priority < highestPriority) {
        highestPriority = p->priority;
        // Increase priority of nextProc as it will now be waiting.
        nextProc->priority = nextProc->priority - 1;
        nextProc = p;
      } else {
        // this process is going to wait, so increase its priority if it
        // is greater than 0. Keep it unchanged for priority 0 (min priority).
        if(p->priority > 0) p->priority--;
      }
    }

    // Run the nextProc process which has the highest priority. Since this
    // process runs, decrease its priority if it is less than 31 (max
    // priority). First check if nextProc is not null, otherwise just continue.
    if(nextProc->priority < 31) {
```

```
apati027@sledge:~/xv6 — ssh apati027@sledge.cs.ucr.edu        ~ — apati027@sledge:~/xv6 — ssh apati027@sledge.cs.ucr.ed
    // Run the nextProc process which has the highest priority. Since this
    // process runs, decrease its priority if it is less than 31 (max
    // priority). First check if nextProc is not null, otherwise just continue.
    if(nextProc->priority < 31) {
      nextProc->priority = nextProc->priority + 1;
    }
    // Switch to the chosen process (nextProc). It is the process's job
    // to release ptable.lock and then reacquire it before jumping
    // back to us.
    c->proc = nextProc;
    switchuvm(nextProc);
    nextProc->state = RUNNING;

    swtch(&(c->scheduler), nextProc->context);
    switchkvm();

    // Process is done running for now.
    // It should have changed its nextProc->state before coming back.
    c->proc = 0;
    release(&ptable.lock);
```

set and get priority methods in proc.c:

```
int
setPriority(int priority)
{
  struct proc *curproc = myproc();
  curproc->priority = priority;
  return 0;
}

int
getPriority()
{
  struct proc *curproc = myproc();
  return curproc->priority;
}
```

Summary for lab2:

The lab2 was about learning to implement a priority scheduler. For this, we needed to create a system call for setting and getting priority of process, then modify the logic of scheduler. Also implemented aging of priority – when process waits, its priority should increase, and when it runs, its priority should decrease. This is done to avoid starvation.