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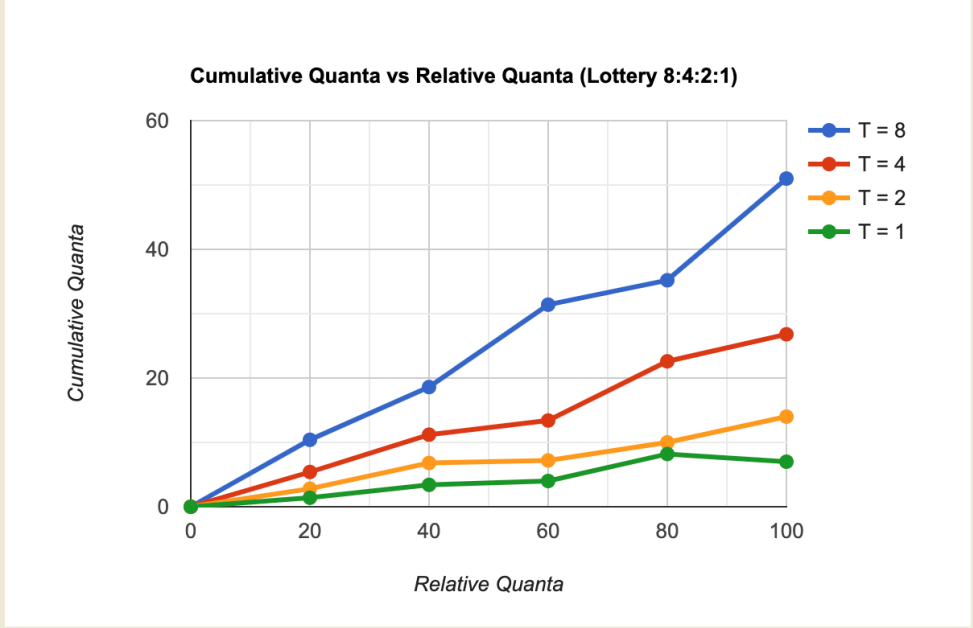
Lab 2 - Modifying XV6 Scheduler

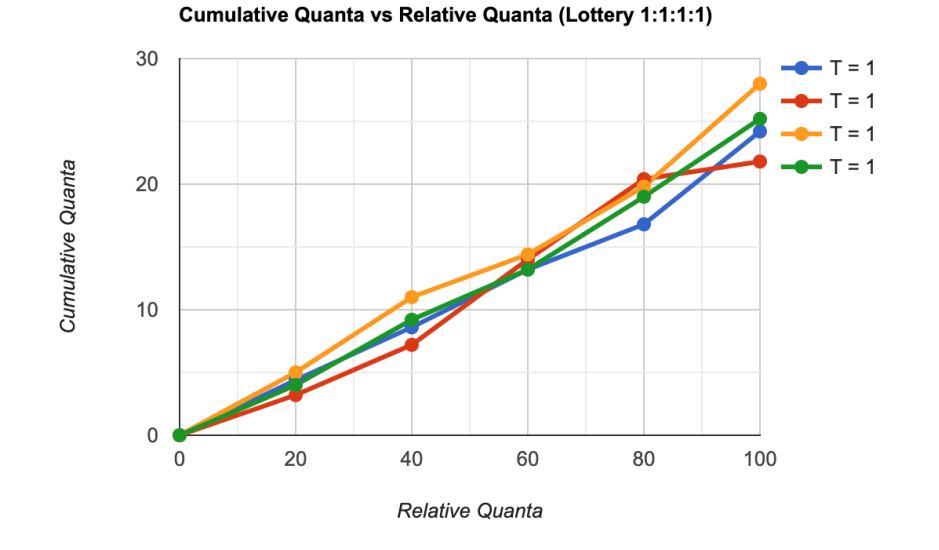
Video Demo Link: https://youtu.be/e7qYz3HHkPY

All Modified Files

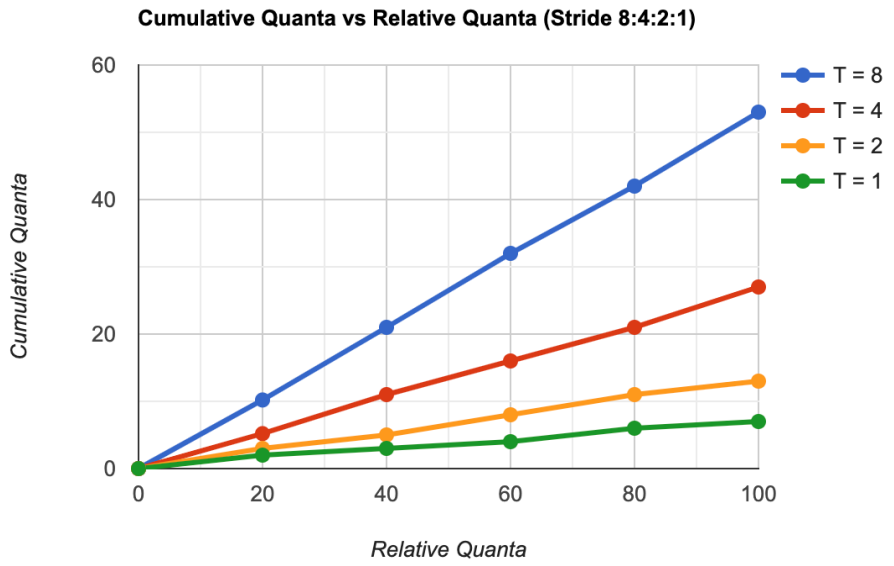
- ~/kernel/ files
    - Defs.h
    - Proc.c
    - Proc.h
    - Syscall.c
    - Syscall.h
    - Sysproc.c
- ~/user/ files:
    - User.h
    - Usys.pl
    - lab2.c was created as a test files for the schedulers
- Makefile

Change Explanations and screenshots

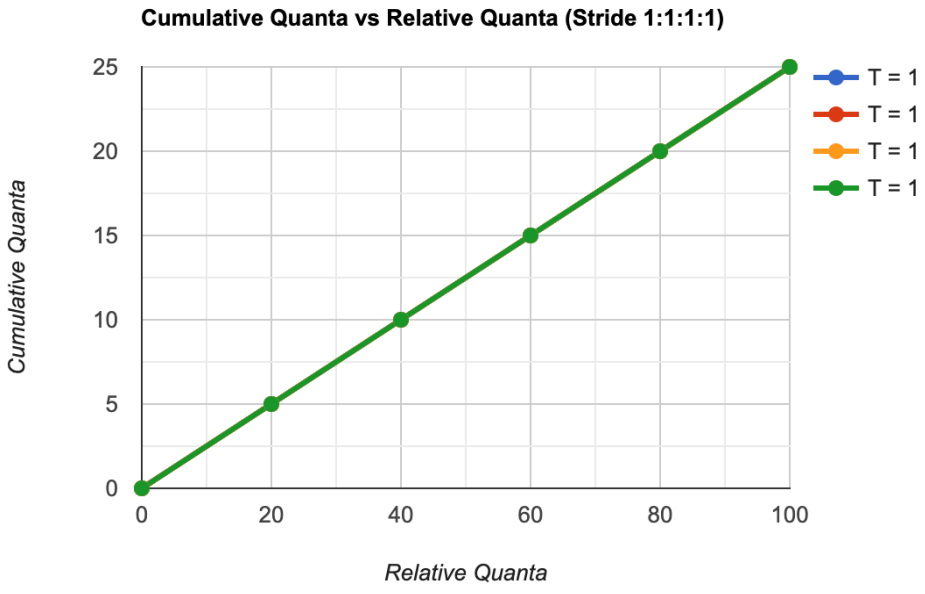
- Figures for Part 3
  - Lottery 8:4:2:1 Allocation
  - 

  - Lottery 1:1:1:1 Allocation
  - 

- Stride 8:4:2:1 Allocation



- Stride 1:1:1:1 Allocation



- The above four figures represent Part 3 of this lab demonstrating the number of ticks each process gets allocated based on their respective number of tickets. Simulations were run with both an 8:4:2:1 ticket allocation and a 1:1:1:1 allocation on step sizes of 20, 40, 60, 80, and 100 ticks. Each ticket allocation was tested 5 times at each step size and the average allocated tickets at each step size were plotted in the above charts. We can see that in the Lottery 8:4:2:1 allocation, the tick allocations rise somewhat linearly although they still fluctuate from the ideal allocation significantly, especially at smaller step sizes. Similarly, in the Lottery 1:1:1:1 allocation, the tick allocations fluctuate greatly at smaller step sizes but converge much closer to the ideal at larger step sizes. The Stride 8:4:2:1 allocation is nearly perfectly matching the ideal at each step size with a near linear increase for each process. This shows the deterministic strength of stride scheduling over lottery scheduling. This determinism is demonstrated again in the Stride 1:1:1:1 allocation where when allocated equal tickets, all 4 processes receive the same number of ticks at every step size.
- Defs.h
  - ```
    113   int             sched_statistics(void);      // sched_statistics
    114   int             sched_tickets(int);          // sched_tickets
    ```
  - Declaring syscall function headers in defs.h
- Proc.c
  - ```
    18  unsigned short rand()
    19  {
    20    bit = ((lfsr >> 0) ^ (lfsr >> 2) ^ (lfsr >> 3) ^ (lfsr >> 5)) & 1;
    21    return lfsr = (lfsr >> 1) | (bit << 15);
    22  }
    ```
  - Random number generator for lottery scheduling

-
```
168     // Initialize the tickets, stride, pass, and ticks
169     p->tickets = 10000;
170     p->stride = 10000 / p->tickets;
171     p->pass = p->stride;
172     p->ticks = 0;
```
- Initializing new proc variables for lottery/stride scheduler

-
```
498   struct proc *winner = 0;
499   int totalTickets = 0;
500   // Calculate the total number of tickets in the system
501   for (p = proc; p < &proc[NPROC]; ++p) {
502     acquire(&p->lock);
503     if (p->state == RUNNABLE) {
504       totalTickets += p->tickets;
505     }
506     release(&p->lock);
507   }
508
509   // Generate a random number between 0 and the total number of tickets
510   if (totalTickets > 0) {
511     int winningTicket = rand() % totalTickets;
512     int iteratedTickets = 0;
513
514     // Iterate through the processes to find the process
515     // with the winning ticket
516     for (p = proc; p < &proc[NPROC]; ++p) {
517       acquire(&p->lock);
518       if (p->state == RUNNABLE) {
519         iteratedTickets += p->tickets;
520         if (iteratedTickets > winningTicket) {
521           winner = p;
522           release(&p->lock);
523           break;
524         }
525       }
526       release(&p->lock);
527     }
528   }
529
530   // If a process was chosen, run it
531   if (winner != 0 && winner->state == RUNNABLE) {
532     p = winner;
533     acquire(&p->lock);
534     p->ticks++;
535
536     p->state = RUNNING;
537     c->proc = p;
538     swtch(&c->context, &p->context);
539     c->proc = 0;
540     release(&p->lock);
541   }
```
- Lottery Scheduler

```
568     struct proc *minimumPassProc = 0;
569     int minimumPass = 0x7FFFFFFF;
570
571     // Iterate through the processes to find the process
572     // with the smallest pass value
573     for (p = proc; p < &proc[NPROC]; ++p) {
574       acquire(&p->lock);
575       if (p->state == RUNNABLE && p->pass < minimumPass) {
576           minimumPassProc = p;
577           minimumPass = p->pass;
578       }
579       release(&p->lock);
580     }
581
582     // If a process was chosen, run it
583     if (minimumPassProc != 0 && minimumPassProc->state == RUNNABLE) {
584       p = minimumPassProc;
585       acquire(&p->lock);
586       p->ticks++;
587       p->pass += p->stride;
588       p->state = RUNNING;
589       c->proc = p;
590       swtch(&c->context, &p->context);
591       c->proc = 0;
592       release(&p->lock);
593     }
594
595   #else
596     /*
```

- Stride Scheduler

```
int
sched_statistics(void)
{
  // Declare variables
  struct proc *p;

  // Print the process info
  for (p = proc; p < &proc[NPROC]; ++p) {
    acquire(&p->lock);

    if (p->state != UNUSED) {
      printf("%d|(%s): tickets: %d, ticks: %d\n", p->pid, p->name,
             p->tickets, p->ticks);
    }
    release(&p->lock);
  }

  return 0;
}
```

- Sched_statistics() syscall implementation

```
int
sched_tickets(int tickets)
{
  // Declare variables
  struct proc *p = myproc();

  // Check if the input is valid
  if (tickets < 0 || tickets > 10000) {
    return -1;
  }

  // Set the number of tickets
  acquire(&p->lock);
  p->tickets = tickets;
  p->stride = 10000 / tickets;
  p->pass = p->stride;
  release(&p->lock);

  return 0;
}
```

- Sched_tickets() syscall implementation

- Proc.h

```
95    int tickets;                // Number of tickets for process
96    int stride;                 // Stride of process
97    int pass;                   // Pass of process
98    int ticks;                  // Number of ticks process has run
99
```

- Defining new proc variables for lottery/stride scheduling

- Syscall.c

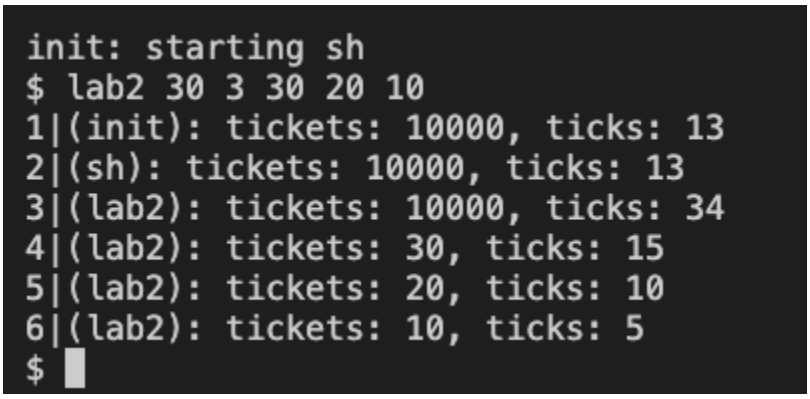
```
110   extern uint64 sys_sched_statistics(void); // sched_statistics: declaration
111   extern uint64 sys_sched_tickets(void); // sched_tickets: declaration
```

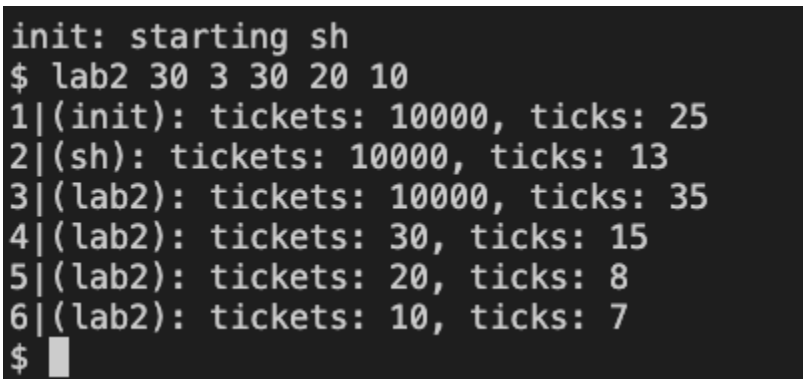
```
140   [SYS_sched_statistics] =sys_sched_statistics, // sched_statistics: syscall entry
141   [SYS_sched_tickets] =sys_sched_tickets, // sched_tickets: syscall entry
142   };
```

- Adding the new syscalls to the syscall entry table

- Syscall.h
  - ```
    #define SYS_sched_statistics 25 // sched_statistics
    #define SYS_sched_tickets 26 // sched_tickets
    ```
    - Defining new syscall numbers for the new syscalls
- Sysproc.c
  - ```
    // sched_statistics syscall definition
    uint64
    sys_sched_statistics(void)
    {
      return sched_statistics();
    }

    // sched_tickets syscall definition
    uint64
    sys_sched_tickets(void)
    {
      int n;
      argint(0, &n);
      return sched_tickets(n);
    }
    ```
    - Helper functions defined in syscall.c to execute the actual syscall
- User.h
  - ```
    int sched_statistics(void); // sched_statistics
    int sched_tickets(int); // sched_tickets
    ```
    - Declaring new syscalls in the user space
- Usys.pl
  - ```
    entry("sched_statistics"); # sched_statistics syscall for user
    entry("sched_tickets"); # sched_tickets syscall for user
    ```
    - Defining wrapper functions for new syscalls. These functions bridge the gap between user and kernel space

- Makefile
  -
```
138     $U/_lab1_test\
139     $U/_lab2\
```
  - Modified Makefile for lab2 test file
  -
```
73    LAB2 = RR
74    CFLAGS += -D$(LAB2)
```
  - Modified Makefile to handle Lottery and Stride scheduling (Round robin by default)
- Test file (lab2.c)
  -
```c

#define MAX_PROC 10
int main(int argc, char *argv[])
{
    int sleep_ticks, n_proc, ret, proc_pid[MAX_PROC];
    if (argc < 4) {
        printf("Usage: %s [SLEEP] [N_PROC] [TICKET1] [TICKET2]...\n", argv[0]);
        exit(-1);
    }
    sleep_ticks = atoi(argv[1]);
    n_proc = atoi(argv[2]);
    if (n_proc > MAX_PROC) {
        printf("Cannot test with more than %d processes\n", MAX_PROC);
        exit(-1);
    }
    for (int i = 0; i < n_proc; i++) {
        int n_tickets = atoi(argv[3+i]);
        ret = fork();
        if (ret == 0) { // child process
            sched_tickets(n_tickets);
            while(1);
        }
        else { // parent
            proc_pid[i] = ret;
            continue;
        }
    }
    sleep(sleep_ticks);
    sched_statistics();

    for (int i = 0; i < n_proc; i++) kill(proc_pid[i]);

    exit(0);
}

```

- Stride Test Output
  - 

- Lottery Test Output
  - 

Description of XV6 Source Code

By default, xv6 uses a round robin process scheduler in which processes are iterated over sequentially and scheduled for equal amounts of time. We implemented two new schedulers, lottery and stride schedulers, that provide a probabilistic and deterministic, respectively, way to prioritize and schedule some processes over others. Our test program iterates over each process passed in the command line and schedules them with the passed ticket allocation using the sched_tickets() syscall.The sched_tickets() syscall sets the passed value of tickets to the current process and computes stride and pass values as well. It then goes to the scheduler where, for lottery, a winning ticket value is selected and the first process to hold a ticket above that value gets scheduled and their ticks counted, while for stride, the process with the lowest pass value gets scheduled next and their ticks counted. This repeats for all processes. After iterating through all the processes and counting their ticks, the test file calls sched_statistics() to output the allocated tickets and actual number of allocated ticks for each process. To switch between each scheduler, one must run ‘make clean; make LAB2=LOTTERY (or) make LAB2=STRIDE; make qemu’.

Summary of Contributions

- Anthony Mendez implemented the two syscalls, sched_tickets() and sched_statistics(). He also implemented the stride scheduler and assisted in debugging.
- Jordan Kuschner implemented the lottery scheduler, generated the charts for part 3, assisted in debugging, and wrote the report.