Process Scheduling & Synchronization intro

CS 241

February 29, 2012

Announcements

Mid-semester feedback survey (linked off web page)

MP4 due Friday (not Tuesday)

Midterm

- Next Tuesday, 7-9 p.m.
- Study guide released this Wednesday
- Next Monday's lecture: review session

Today

Interactive scheduling

- Round robin
- Priority scheduling
- How long is a quantum?

Synchronization intro

Process scheduling

Deciding which process/thread should occupy each resource (CPU, disk, etc.) at each moment

Scheduling is everywhere...

- disk reads
- process/thread resource allocation
- servicing clients in a web server
- compute jobs in clusters / data centers
- jobs using physical machines in factories

Scheduling algorithms

Batch systems

- Usually non-preemptive: running process keeps CPU until it voluntarily gives it up
  - Process exits
  - Switches to blocked state
- First come first serve (FCFS)
- Shortest job first (SJF) (also preemptive version)

Interactive systems

- Running process is forced to give up CPU after time quantum expires
  - Via interrupts or signals (we'll see these later)
- Round robin
- Priority

These are some of the important ones to know, not a comprehensive list!

Thus far: Batch scheduling

FCFS, SJF, SRPT useful when fast response not necessary

- weather simulation
- processing click logs to match advertisements with users
- ...

What if we need to respond to events quickly?

- human interacting with computer
- packets arriving every few milliseconds
- ...

Interactive Scheduling

Usually preemptive

- Time is sliced into quanta, i.e., time intervals
- Scheduling decisions are made at the beginning of each quantum

Performance metrics

- Average response time
- Fairness (or proportional resource allocation)

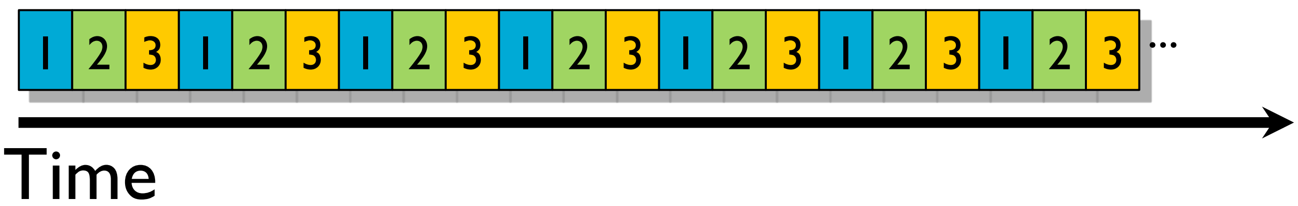
Representative algorithms

- Round-robin
- Priority scheduling

Round-robin

One of the oldest, simplest, most commonly used scheduling algorithms

Select process/thread from ready queue in a round-robin fashion (i.e., take turns)



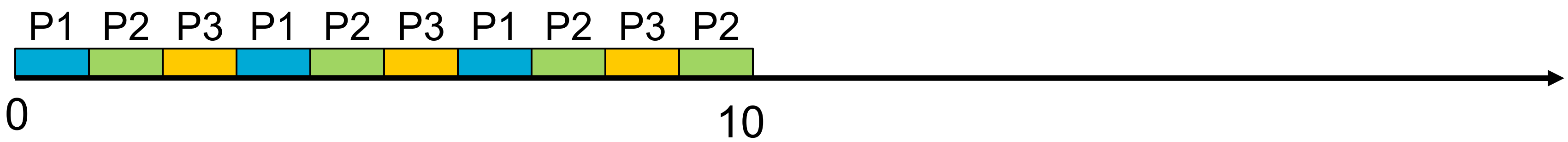
Problems

- Might want some jobs to have greater share
- Context switch overhead

Round-robin: Example

Process	Duration	Order	Arrival Time
P1	3	1	0
P2	4	2	0
P3	3	3	0

Suppose time quantum is 1 unit and P1, P2 & P3 never block



P1 waiting time:
P2 waiting time:
P3 waiting time:

The average waiting time (AWT):

Round-robin: Example

Process	Duration	Order	Arrival Time
P1	3	1	0
P2	4	2	0
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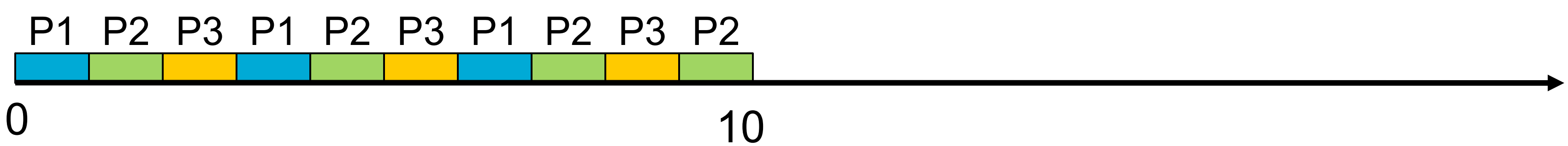
Suppose time quantum is 1 unit and P1, P2 & P3 never block



P1 waiting time: 4
P2 waiting time: 6
P3 waiting time: 6

The average waiting time (AWT):
(4+6+6)/3 = 5.33

Round-robin: Summary

Advantages

- Jobs get fair share of CPU
- Shortest jobs finish relatively quickly

Disadvantages

- Larger than optimal average waiting time
  - Example: 10 jobs each requiring 10 time slices
  - RR: All complete after about 100 time slices
  - FCFS performs about 2x better!
- Performance depends on length of time quantum

Priority Scheduling

Rationale: higher priority jobs are more mission-critical

- Example: DVD movie player vs. send email

Each job is assigned a priority

Select highest priority runnable job

- FCFS or Round Robin to break ties

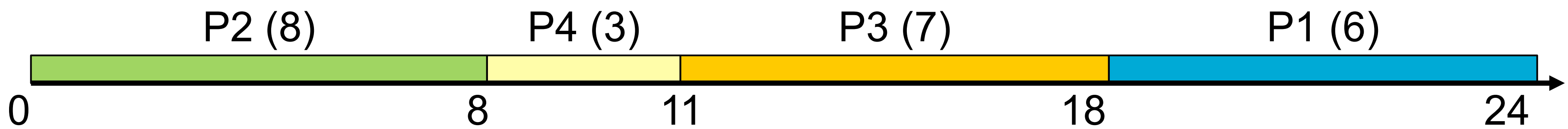
Problems

- May not give the best AWT
- Starvation of lower priority processes

Priority Scheduling: Example

(Lower priority number is preferable)

Process	Duration	Priority	Arrival Time
P1	6	4	0
P2	8	1	0
P3	7	3	0
P4	3	2	0



P1 waiting time:
P2 waiting time:
P3 waiting time:
P4 waiting time:

The average waiting time (AWT):

Priority Scheduling: Example

(Lower priority number is preferable)

Process	Duration	Priority	Arrival Time
P1	6	4	0
P2	8	1	0
P3	7	3	0
P4	3	2	0

P1 waiting time: 18
P2 waiting time: 0
P3 waiting time: 11
P4 waiting time: 8

The average waiting time (AWT):
(0+8+11+18)/4 = 9.25
(worse than SJF's 7)

Setting priorities: nice

nice [OPTION] [COMMAND [ARG]...]

- Run COMMAND with an adjusted niceness
- With no COMMAND, print the current niceness.
- Nicenesses range from -20 (most favorable scheduling) to 19 (least favorable).

Options

- -n, --adjustment=N
  - add integer N to the niceness (default 10)
- --help
  - display this help and exit
- --version
  - output version information and exit

Setting priorities in C

```
#include <sys/time.h>
#include <sys/resource.h>
int getpriority(int which, int who);
int setpriority(int which, int who, int prio);
```

Access scheduling priority of process, process group, or user

Returns:

- setpriority() returns 0 if there is no error, or -1 if there is
- getpriority() can return the value -1, so it is necessary to clear errno prior to the call, then check it afterwards to determine if a -1 is an error or a legitimate value

Parameters:

- which
  - PRIO_PROCESS, PRIO_PGRP, or PRIO_USER
- who

  A process identifier for PRIO_PROCESS, a process group identifier for PRIO_PGRP, or a user ID for PRIO_USER

Choosing the time quantum

How should we choose the time quantum?

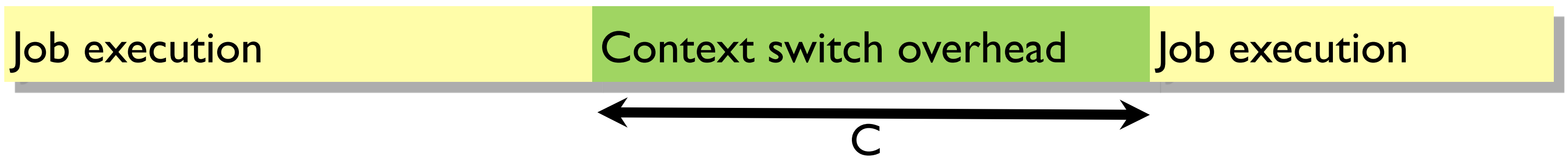
Time quantum too large

- FIFO behavior
- Poor response time

Time quantum too small

- Too many context switches (overhead)
- Inefficient CPU utilization

Choosing the time quantum



Objective 1: Fast response time

Best case: quantum = 0,
response time = C

Objective 2: Efficiency

Best case: quantum = infinity,
Job completion time = J

General strategy: set quantum somewhere in the middle

Choosing the time quantum

Choice depends on

- Priorities, architecture, etc.

Typical quantum: 10-100 ms

- Large enough that overhead is small percentage
- Small enough to give illusion of concurrency
- e.g., linux.ews.illinois.edu: 99.98 ms quantum using round-robin

Questions

- Does 100 ms matter? (how long is this in practical terms?)
- Does this mean all processes wait 100 ms to run?

Experiment: the quantum in practice

```
typedef struct printer_arg_t {
    int thread_index;
} printer_arg_t;

#define BUF_SIZE     100

void * printer_thread( void *ptr )
{
    /* Create the message we will print out */
    printer_arg_t* arg = (printer_arg_t*) ptr;
    char message[BUF_SIZE];
    int i;
    for (i = 0; i < BUF_SIZE; i++)
        message[i] = ' ';
    sprintf(message + 10 * arg->thread_index, "thread %d\n",
            arg->thread_index);

    /* Print it forever */
    while (1)
        printf("%s", message);
}
```

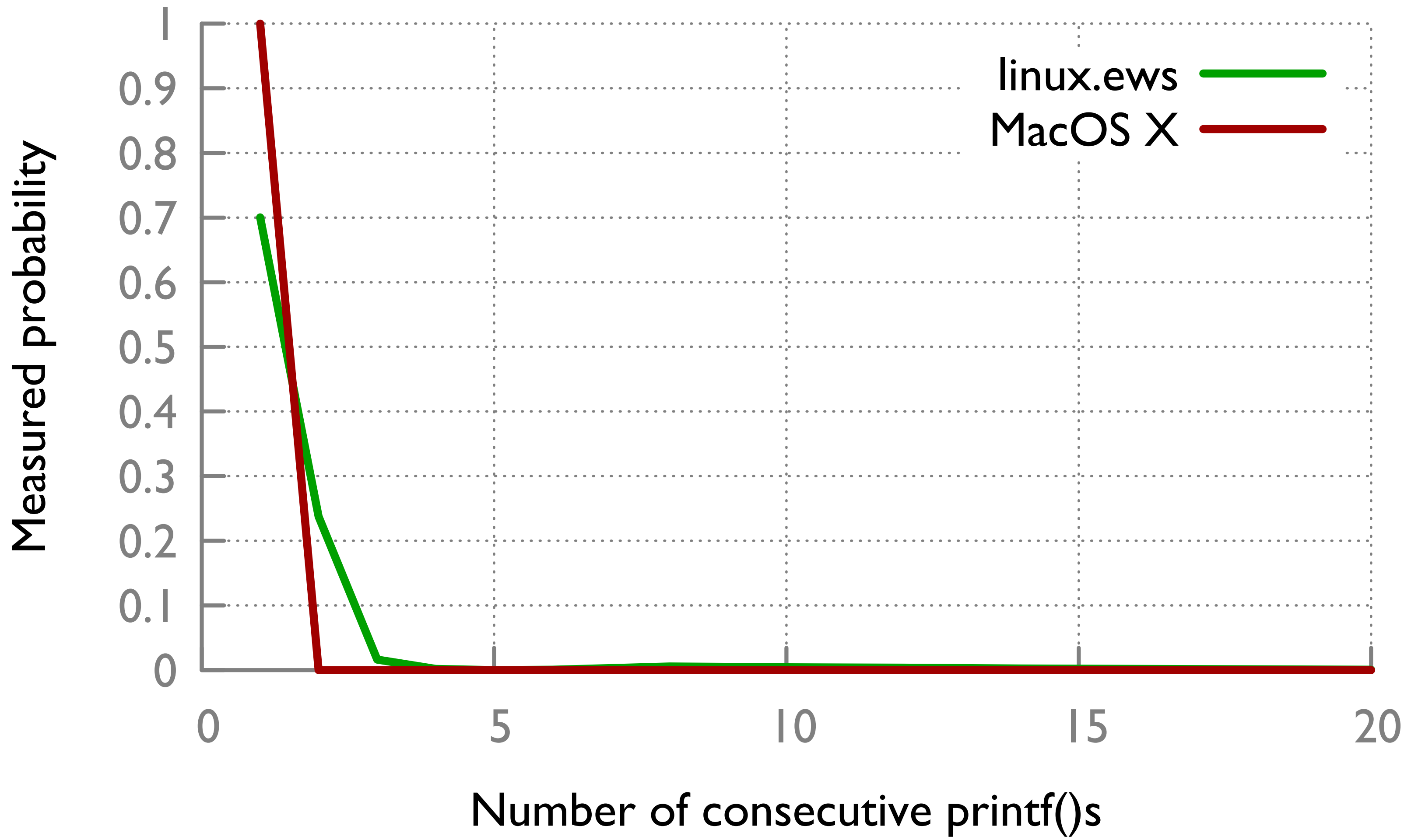
Experiment: results on linux.ews

```
          thread 1                 thread 0
          thread 1                           thread 1
          thread 1                 thread 0
          thread 1                 thread 0
          thread 1                 thread 0
          thread 1                 thread 0
          thread 1                 thread 0
thread 0                           thread 0
thread 0                           thread 0
thread 0                           ...
thread 0
thread 0
thread 0
thread 0
thread 0
thread 0
thread 0
thread 0
thread 0
thread 0
```

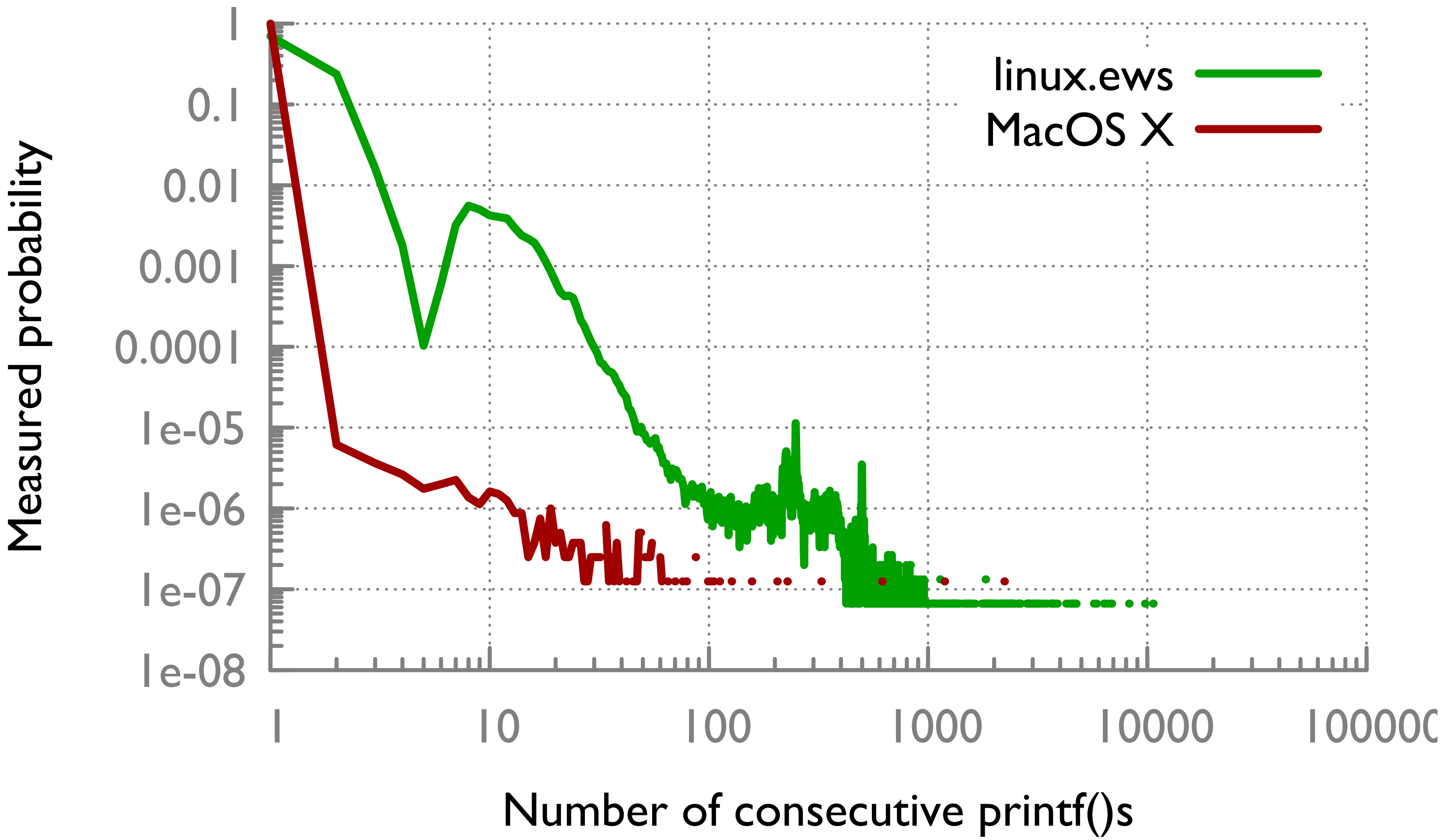
Experiment: results on Mac OS X

```
thread 0
           thread 1
thread 0
           thread 1
thread 0
           thread 1
thread 0
           thread 1
thread 0
           thread 1
thread 0
           thread 1
thread 0
           thread 1
thread 0
           thread 1
thread 0
...
```

Experiment: results



Experiment: results



Take-away point: unpredictability

Scheduling varies across operating systems

Scheduling is non-determinstic even for one OS

- Default (non-real-time) scheduling does not guarantee any fixed length
- Potentially huge variability in work accomplished in one quantum
    - Factor of >10,000 difference in number of consecutive printfs in our experiment!

Quantum may be fairly long (visible to human)

Scheduling: Issues to remember

Why doesn't scheduling have one easy solution?

What are the pros and cons of each scheduling policy?

How does this matter when you're writing multiprocess/ multithreaded code?

- Can't make assumptions about when your process will be running relative to others!
- May need specialized scheduling for specialized applications

Synchronization

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Playing together is not easy

Easy to share data among threads

But, not always so easy to do it **correctly**...

Easy case: one obvious "owner"

- e.g., main() creates arguments, hands off to child thread
- child now owns it, no one else will never read or write it

What if threads need to work together? e.g., in web server:

- multiple threads concurrently access cache of files in memory, occasionally adding or removing
- multiple threads concurrently update count of total # clients

Do threads conflict in practice?

```
#include <stdio.h>
#include <stdlib.h>
#include <pthread.h>
#include <assert.h>


int cnt = 0;

void * worker( void *ptr )
{
    int i;
    for (i = 0; i < 50000; i++)
        cnt++;
}
```

Do threads conflict in practice?

```
#define NUM_THREADS 2

int main(void)
{
    pthread_t threads[NUM_THREADS];
    int i, result;

    for (i = 0; i < NUM_THREADS; i++) {
        result = pthread_create(&threads[i], NULL, worker, NULL);
        assert(result == 0);
    }

    for (i = 0; i < NUM_THREADS; i++) {
        result = pthread_join(threads[i], NULL);
        assert(result == 0);
    }

    /* Print result */
    printf("Final value: %d\n", cnt);
}
```

Do threads conflict in practice?

If everything worked...

```
$ ./20-counter
Final value: 100000
```

Q: What are the minimum and maximum final value?

Q: What value do you expect in practice?

Next time

- How do we guarantee correct interaction between threads? Synchronization!
- Guess the final value (win a fabulous prize!)