5118020-03 Operating Systems

Proportional Share Scheduler

OSTEP Chapter 9

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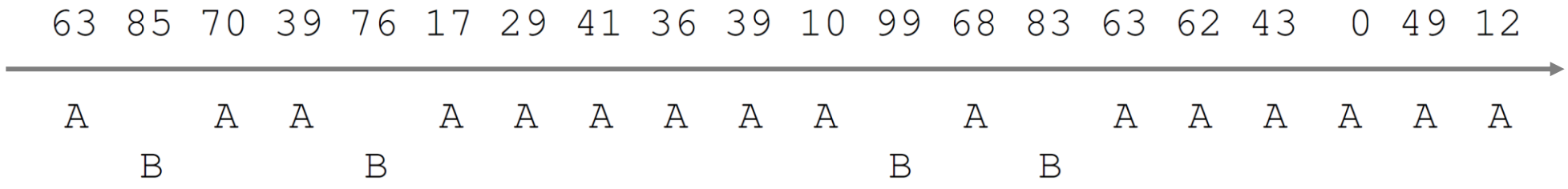
Lottery Scheduler

- Proportional-share scheduler guarantees that each process receives a certain portion of the CPU time on a regular basis
- Lottery scheduling: hold a lottery to determine a process for the next turn
  - a process holds **tickets.** The number of tickets a process hold represents the resource-share that a process should receive
  - for each scheduling decision:
    - counts the total number of tickets held by the runnable processes
    - picks a winning ticket from the whole tickets
    - dispatches the owner process of the winning ticket
  - Ex. Process A with 75 tickets (0 to 74) & Process B with 25 tickets (75 to 99)



Lottery Scheduler - Good Points

- The algorithm is simple and does not incur much runtime overhead

- By managing the total number of tickets, the system can control scheduling priorities of different processes easily and reliably
  - mechanisms
    - ticket currency
    - ticket transfer
    - ticket inflation
- It achieves good fairness
  - unless processes run for a short period of time

Stride Scheduling

- A deterministic fair-share scheduler
- A process is given with a **stride** value which is inverse in proportion to the number of tickets
  - the shorter a stride, the more time slices (steps) the process have in a time unit
- A **pass** value is assigned to each process, which is incremented by the stride every time the process receives a time slice
- At a scheduling decision, the scheduler selects a ready process with the smallest pass value

```
curr = remove_min(queue);    // pick client with min pass
schedule(curr);              // run for quantum
curr->pass += curr->stride; // update pass using stride
insert(queue, curr);         // return curr to queue
```

Example

Pass(A) (stride=100)	Pass(B) (stride=200)	Pass(C) (stride=40)	Who Runs?
0	0	0	A
100	0	0	B
100	200	0	C
100	200	40	C
100	200	80	C
100	200	120	A
200	200	120	C
200	200	160	C
200	200	200	...

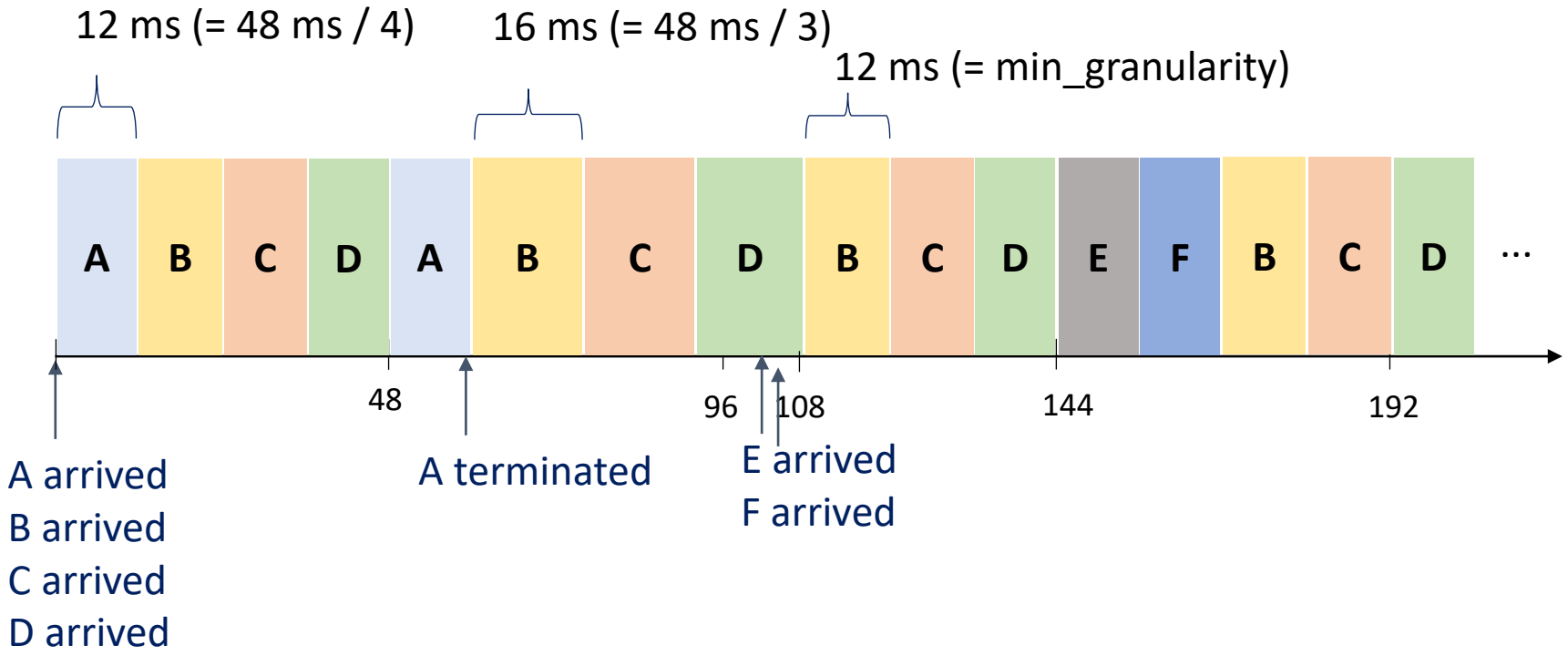
The Linux Completely Fair Scheduler (CFS)

- The cost of running scheduler is a significant factor of system performance
  - Around 5% of overall CPU time of Google datacenter is consumed by computation for scheduling

- CFS aims to reduce the number of context-switches while achieving fairness
  - reduce the number of context-switches
    - divide a period of CPU time (`sched_latency`) evenly among all ready processes while keeping a time-slice from getting too fine-grained (`min_gradularity`)
    - enable users to give time-slice weighting to control process priority
  - share CPU time fairly
    - use a periodic timer interrupt to check the expiration of a current time slice
    - count virtual runtime to trace the accumulated CPU time of each process
    - select the runnable process of the minimum virtual runtime

Example

- sched_latency: 48 ms
- min_granularity: 12 ms
- timer interrupt: every 4 ms



Process Weighting

- The nice level in Unix represents the priority of a process
  - the lower a nice value, the higher the priority is (the greater the share is).
- The time slice of a process is proportional to its weight

$$\text{time\_slice}_k = \frac{\text{weight}_k}{\sum_{i=0}^{n-1} \text{weight}_i} \cdot \text{sched\_latency}$$

```
static const int prio_to_weight[40] = {
 /* -20 */ 88761, 71755, 56483, 46273, 36291,
 /* -15 */ 29154, 23254, 18705, 14949, 11916,
 /* -10 */  9548,  7620,  6100,  4904,  3906,
 /*  -5 */  3121,  2501,  1991,  1586,  1277,
 /*   0 */  1024,   820,   655,   526,   423,
 /*   5 */   335,   272,   215,   172,   137,
 /*  10 */   110,    87,    70,    56,    45,
 /*  15 */    36,    29,    23,    18,    15,
```

- accumulated CPU runtime is measured with respect to process weighting scheme
  - otherwise, a high priority process can starve

$$\text{vruntime}_i = \text{vruntime}_i + \frac{\text{weight}_0}{\text{weight}_i} \cdot \text{runtime}_i$$

Process Management

- A ready queue is formed as a red-black tree having vruntime as a key
  - balanced binary tree
  - log(n) for search, insertion, removal
- When a process is awakened from a sleep, the scheduler sets its vruntime as the minimum vruntime in the ready queue, not zero to avoid possible monopoly