운영체제의 기초: CPU Scheduling

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Agenda

I. Basic Concepts
II. Scheduling Policies
III. Fair Share Scheduling of Linux
IV. Summary

I. Basic Concepts

Until now…

- You have heard about processes
  - Process implementation
  - Process dispatching

Resource Scheduling in General (1)

- From now on, you'll hear a lot about *resources*
  - *Resources* are things used or operated upon by processes
  - Example: CPU time, disk space, network channel time

- Resources fall into two classes
  → *Distinction is a little arbitrary, like (non-)breakable, though*
  - Preemptible
    - Can take resource away, use it for something else, then give it back later
    - Examples: Processor or disk
  - Non-preemptible
    - Once given, it can't be reused until process gives it back
    - Examples: File space, terminal

Resource Scheduling in General (2)

- OS makes two related kinds of decisions about resources
  - Who gets it next?
  - How long can they keep it?

- Resource #1 to examine:
  - The processor

Entities Involved in Scheduling

- Multiprogramming
  - OS allows more than one process to be loaded into memory
  - Such *processes* share *CPU* thru *time*-multiplexing

Simpsons
(Processes)

Chair
(CPU)

Pizza
(CPU time)

CPU Burst (1)

- In multiprogramming, OS alternates code execution and I/O operations to maximize CPU utilization
  - CPU-I/O burst cycle
    - Process execution consists of a cycle of *CPU execution* and *I/O wait*
    - CPU burst distribution varies significantly

- "*CPU burst*" is the entity participating in CPU scheduling in most modern operating systems

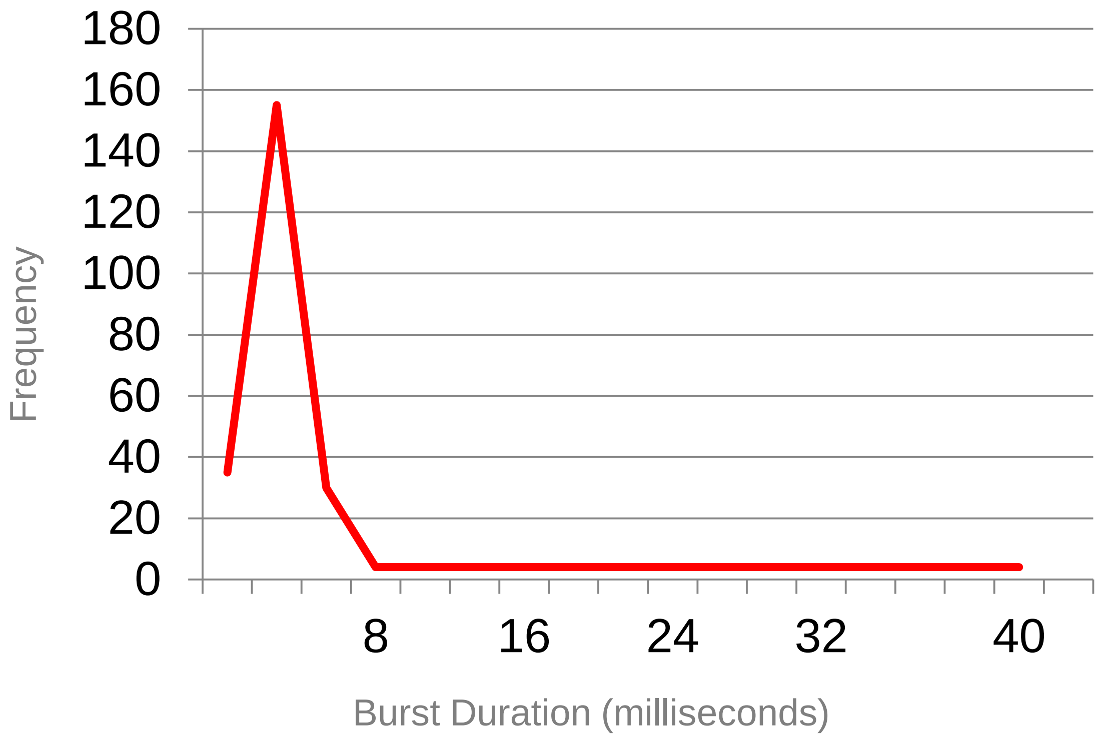
CPU Burst (2)

- Alternating CPU and I/O bursts

⋮	
load store **add store** **read** from file	*CPU Burst*
wait for I/O	*I/O Burst*
wait for CPU	Preemption
store increment **index** **write** to file	*CPU Burst*
wait for I/O	*I/O Burst*
wait for CPU	Preemption
load store **add store** **read** from file	*CPU Burst*
wait for I/O	*I/O Burst*
⋮	

CPU Burst (3)

- Histogram of CPU burst times



CPU Scheduler (1)

- Selects one among the processes in memory that are ready to execute and allocates the CPU to the selected one
- CPU scheduling decisions may take place when a process:
  1. Switches from running to waiting state
  2. Switches from running to ready state
  3. Switches from waiting to ready
  4. Terminates

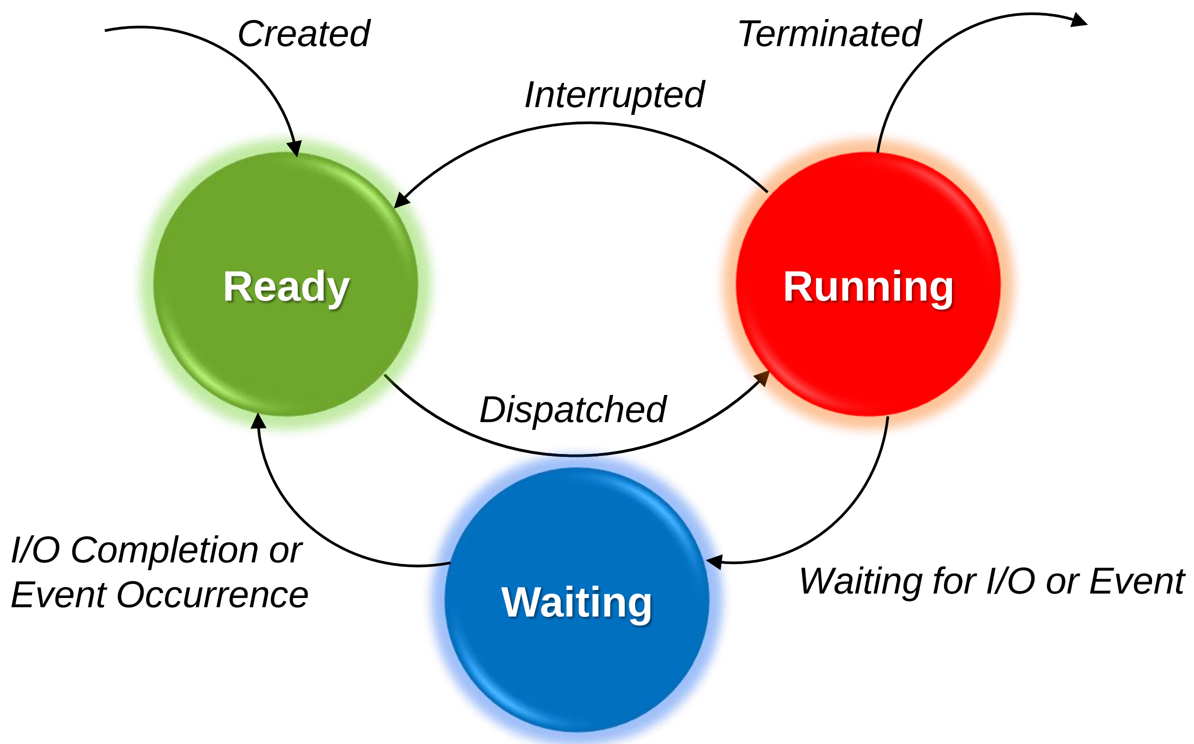
  - Scheduling under the 1st and 4th is nonpreemptive
  - All other scheduling is preemptive

CPU Scheduler (2)

- Processes may be in any of three scheduling states
  - Running
    - Has the CPU
  - Ready
    - Wants the CPU
  - Waiting (Blocked)
    - Waiting for some event (disk I/O, message, semaphore, etc.)

CPU Scheduler (3)

- Process scheduling = Process state transition



Dispatcher

- Dispatcher module gives control of the CPU to the process selected by the short-term scheduler; this involves
  - Switching context
  - Switching to user mode
  - Jumping to the proper location in the user program to restart that program

- Dispatch latency
  - Time it takes for the dispatcher to stop one process and start another running

II. Scheduling Policies

Scheduling Objectives

- Maximize resource utilization
  - Keep the CPU and I/O devices as busy as possible
- Minimize overhead
- Minimize context switches
- Distribute CPU cycles equitably

Optimization Metrics

- Throughput
  - # of processes that complete their execution per time unit
- Turnaround time
  - Amount of time to execute a particular process
- Waiting time
  - Amount of time a process has been waiting in the ready queue
- Response time
  - Amount of time it takes from when a request was submitted until the first response is produced, not output (for time sharing environment)

Scheduling Policies

- Policies used by the CPU scheduler
- Scheduling disciplines
  - FIFO (FCFS), RR, SJF, MLFQ (EQ), etc.

1. First In First Out (1)

- Key ideas
  - Let the first one run until finish
  - Also called First Come Fist Served (FCFS)
  - In the simplest case, this means uniprogramming
  - Usually, “finished” means “blocked”
    - One process can use CPU while another waits on a semaphore
    - Go to the back of run queue when ready
  - Problem
    - One process can monopolize CPU
  - Solution
    - Limit maximum amount of time that a process can run without a context switch
    - This time is called a “time slice”

1. First In First Out (2)

Process	Burst Time
P_1	24
P_2	3
P_3	3

- Suppose processes arrive in the order: P_1 , P_2 , P_3
  - Gantt Chart for the schedule is:

  - Waiting time for P_1 = 0; P_2 = 24; P_3 = 27
  - Average waiting time: (0 + 24 + 27) / 3 = 17

1. First In First Out (3)

- Suppose processes arrive in the order: P_2 , P_3 , P_1
  - Gantt Chart for the schedule is:

  - Waiting time for $P_1 = 6; P_2 = 0; P_3 = 3$
  - Average waiting time: (6 + 0 + 3) / 3 = 3

  - Much better than previous case
  - *Convoy effect*: short process behind long process

2. Shortest Job First (1)

- Key operations
  - Associate with each process the length of its next CPU burst
  - Use these lengths to schedule the process with the shortest time
- SJF is optimal
  - Gives the minimum average waiting time for a given set of processes

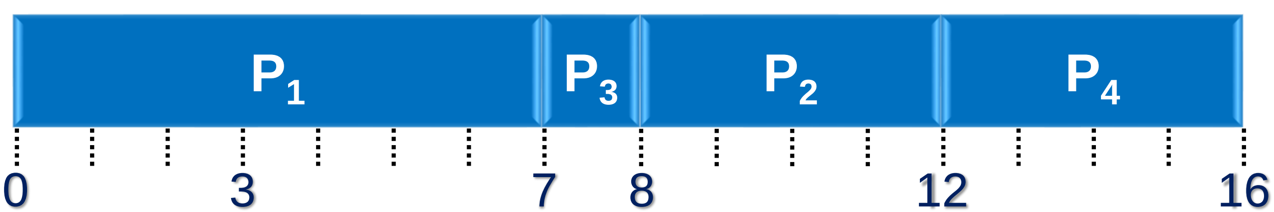
2. Shortest Job First (2)

- Two variations
  - Nonpreemptive
    - Once CPU is given to a process, it cannot be preempted until it completes its CPU burst
  - Preemptive
    - If a new process arrives with CPU burst length less than remaining time of current executing process, preempt it
    - This scheme is know as the Shortest Remaining Time First (SRTF) or Shortest Time to Completion First (STCF)

2. Shortest Job First (3)

Process	Arrival Time	Burst Time
P_1	0	7
P_2	2	4
P_3	4	1
P_4	5	4

- SJF (nonpreemptive)

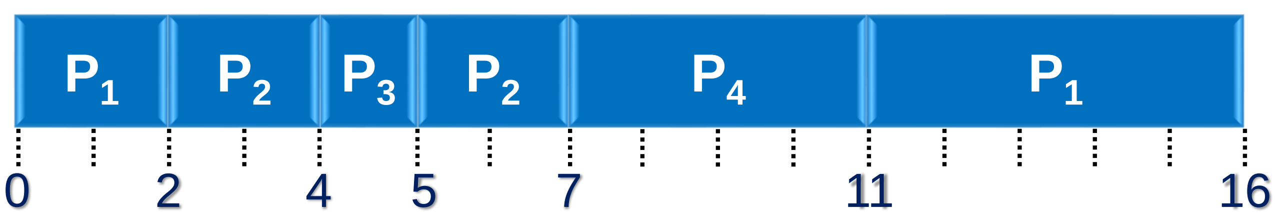


- Average waiting time = (0 + 6 + 3 + 7) / 4 = 4

2. Shortest Job First (4)

Process	Arrival Time	Burst Time
P_1	0	7
P_2	2	4
P_3	4	1
P_4	5	4

- SJF (preemptive)



- Average waiting time = (9 + 1 + 0 + 2) / 4 = 3

2. Shortest Job First (5)

- Challenge: Predicting the next CPU burst size
  - One can only estimate the length
    - Done by using the length of previous CPU bursts via exponential smoothing using exponential moving average
  - Exponential smoothing
    - First suggested by Robert Goodell Brown in 1956
  - Exponential moving average
    - Define $\tau_{n+1} = \alpha t_n + (1 - \alpha)\tau_n$ where
      - τ_{n+1} = predicted value for the next CPU burst
      - t_n = actual length of n^{th} CPU burst
      - α, $0 \leq \alpha \leq 1$: called "*smoothing factor*"

2. Shortest Job First (6)

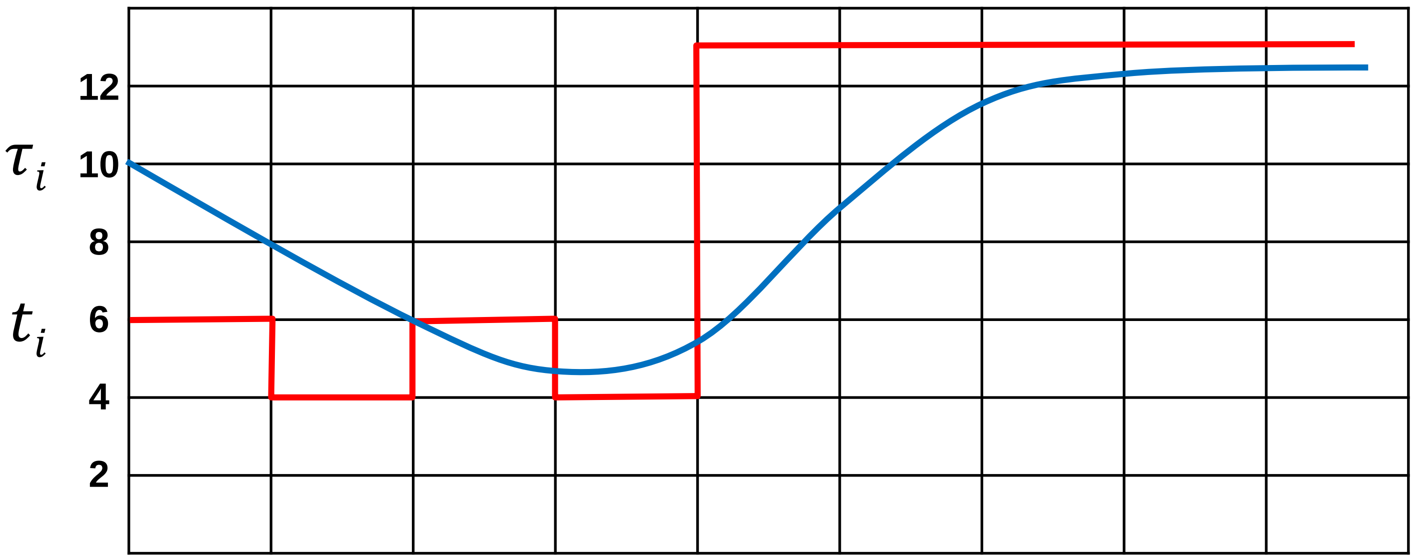
- Exponential moving average (cont'd)
  - $\alpha = 0$
    - $\tau_{n+1} = \tau_n$
    - Recent history does not count
  - $\alpha = 1$
    - $\tau_{n+1} = t_n$
    - Only the actual last CPU burst counts
  - If we expand the formula, we get

$$\tau_{n+1} = \alpha\, t_n + (1 - \alpha)\, \alpha\, t_{n-1} + \dots + (1 - \alpha)^j\, \alpha\, t_{n-j} + \dots + (1 - \alpha)^n\, t_0$$

  - Since both α and $(1 - \alpha)$ are less than or equal to 1, each successive term has less weight than its predecessor

2. Shortest Job First (7)

- Exponential moving average (cont'd)



CPU burst (t_i)		6	4	6	4	13	13	13 …
"guess" (τ_i)	10	8	6	6	5	9	11	12 …

3. Round Robin (1)

- Key ideas
  - Run a process for *one time slice*
  - Then move it to the back of the runqueue
  - Each process gets equal share of the CPU
  - Most systems use some variant of this
- Often implemented with priorities
  - Run highest-priority processes first
  - Round robin among processes of equal priority
  - Re-insert process into the runqueue
    behind all processes of greater or equal priority

3. Round Robin (2)

- Key question
  - What happens if the time slice isn't chosen carefully?
    - Too long:
      - A process can monopolize the CPU
    - Too short:
      - Too much context switch overhead

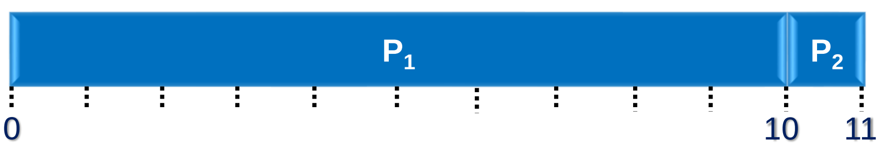
- Time slice selection
  - Originally, Unix had 1 second time slices
    - Too long
  - Current systems have time slices of around 1~10 ms

3. Round Robin (3)

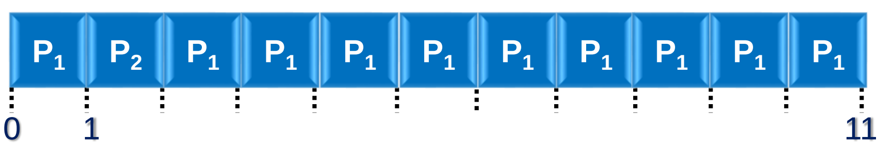
- Comparing RR with FIFO

Process	Burst Time
P_1	10
P_2	1

  - Gantt chart with FIFO
    - Waiting time for P_1 = 0; P_2 = 10 (average waiting time = 5)



  - Gantt chart with RR
    - Waiting time for P_1 = 1; P_2 = 1 (average waiting time = 1)

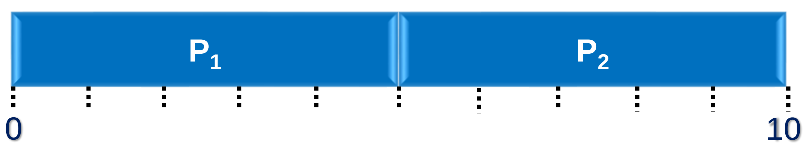


3. Round Robin (4)

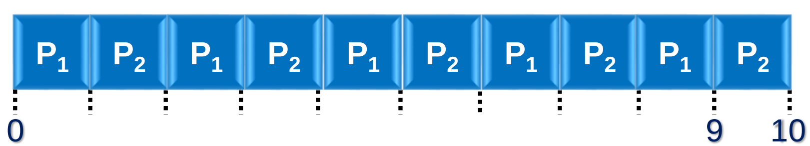
- Comparing RR with FIFO

Process	Burst Time
P_1	5
P_2	5

  - Gantt chart with FIFO
    - Waiting time for P_1 = 0; P_2 = 5 (average waiting time = 2.5)



  - Gantt chart with RR
    - Waiting time for P_1 = 4; P_2 = 5 (average waiting time = 4.5)



3. Round Robin (5)

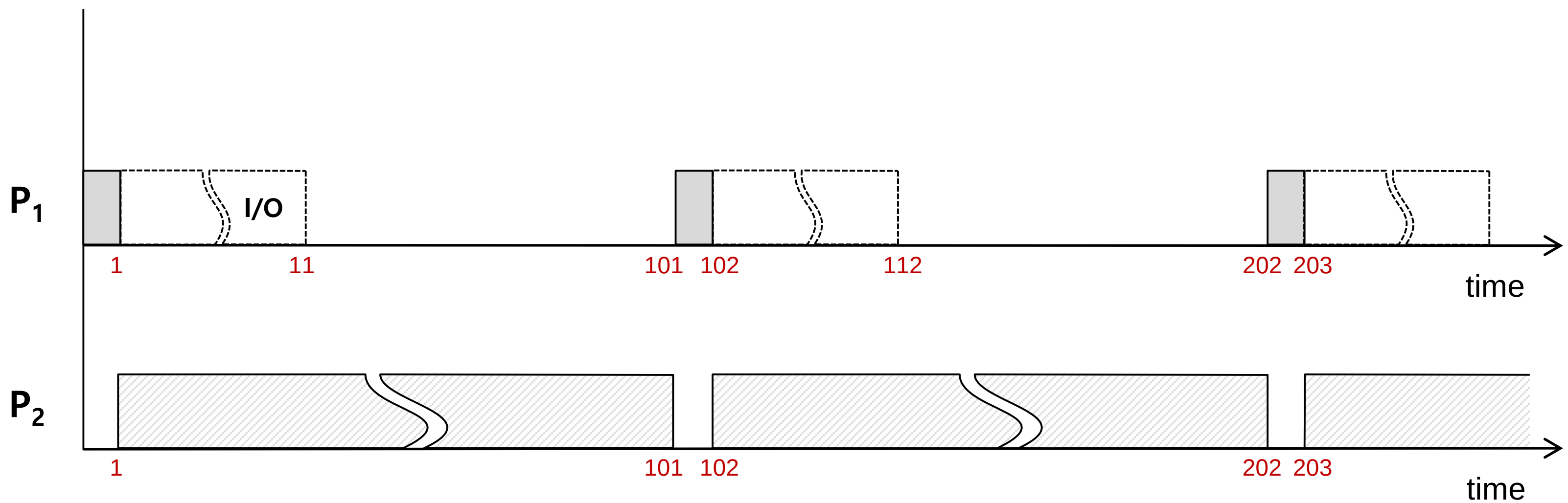
- Question: "*Is FIFO distinct from RR?*"
  - Answer: NO
  - We can unify FIFO with RR

3. Round Robin (6)

- Can we find the right size for the time slice?
  - Consider two processes
    - P_1: runs for 1 ms then waits for I/O for 10 ms
      - Represents *I/O-intensive* workload
    - P_2: no waiting, runs continuously
      - Represents *CPU-intensive* workload
  - Consider two execution scenarios
    1. Round robin with a 100 ms time slice
    2. Round robin with a 1 ms time slice

3. Round Robin (7)

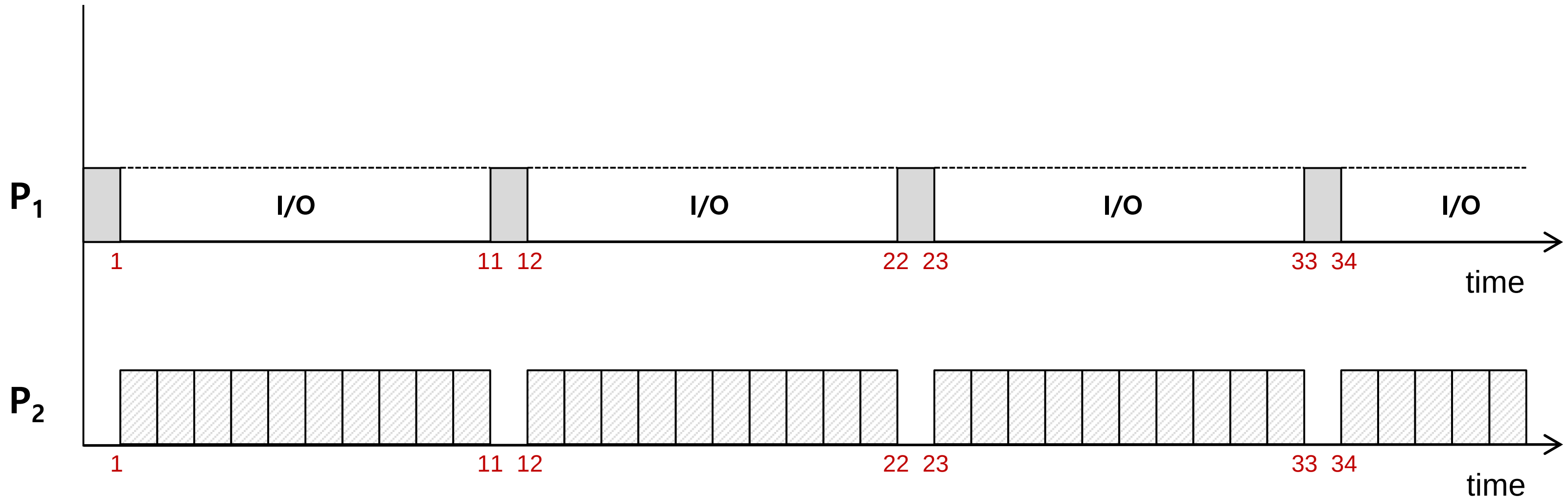
- Scenario 1
  - Round robin with a *100 ms time slice*



- U_{CPU} = 100%
- U_{IO} = 10/101 ≈ 10%

3. Round Robin (8)

- Scenario 2
  - Round robin with a *1 ms time slice*



- U_{CPU} = 100%
- U_{IO} = 10/11 ≈ 91%

3. Round Robin (9)

- Analyzing the two execution scenarios
  1. Round robin with a 100 ms time slice
     - I/O process *runs at 1/10th speed*
     - I/O devices are *only 10% utilized*
  2. Round robin with a 1 ms time slice
     - I/O process *runs at full speed*
     - CPU process suffers from 9 unwanted interrupts out of 10

- Revisit the question
  - Can we find the right size for the time slice?
    - It depends on the type of process

4. Multi-level Feedback Queue (1)

- Idea development behind MLFQ
  - STCF works quite nicely
  - Unfortunately, STCF requires knowledge of the future
    - Must use *past behavior* to predict *future behavior*
    - Example:
      - Long running process will probably take a long time more often
  - Use the dispatcher's priority mechanisms to disfavor long running processes

4. Multi-level Feedback Queue (2)

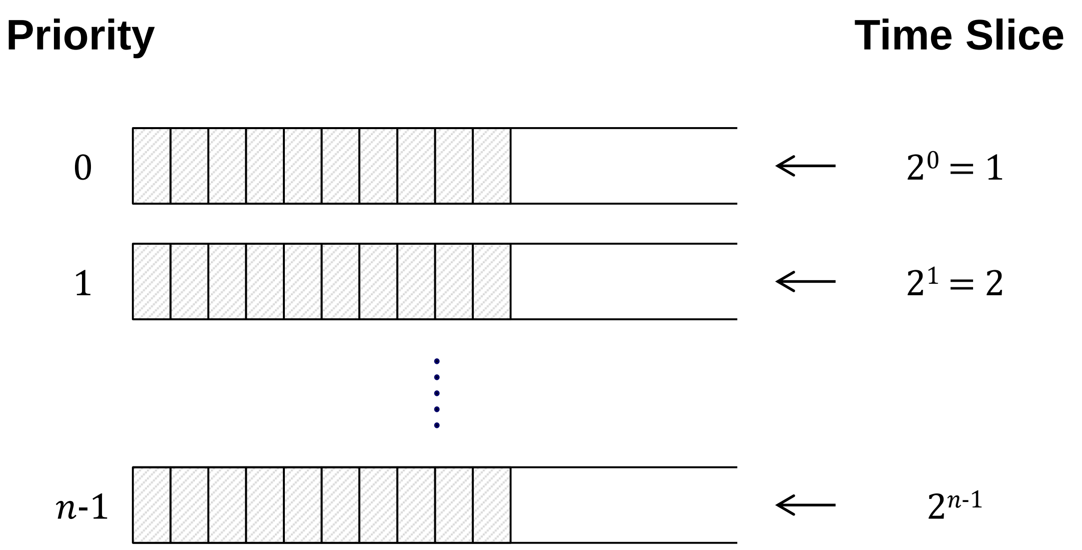
- Idea development behind MLFQ (cont'd)
  - Classify I/O processes and CPU processes
  - Assign higher priority to I/O processes
  - Give longer time slices to CPU processes

4. Multi-level Feedback Queue (3)

- Multi-level feedback queue scheduling
  - AKA *exponential queues scheduling*
  - Gives newly runnable processes a high priority and a very short time slice
    - Assumes new processes are I/O-intensive
  - If a process uses up the time slice without blocking
    - Decreases its priority by 1
    - Doubles time slice for the next round

4. Multi-level Feedback Queue (4)

- Runqueue structure of MLFQ



4. Multi-level Feedback Queue (5)

- Example:
  - P_1 runs for 1 ms and blocks
  - P_2 runs for 1 ms and doesn't block
    - P_2 gets priority 1, time slice 2
  - P_2 runs for 2 ms and doesn't block
    - P_2 gets priority 2, time slice 4
  - P_2 runs for 4 ms and doesn't block
    - P_2 gets priority 3, time slice 8
  - P_2 runs for 3 ms and gets preempted
  - P_1 runs for 1 ms and blocks
  - P_2 runs for 8 ms
  - ……
  - P_1 runs for 1 ms and blocks
  - P_2 runs until P_1 is ready and preempts it

4. Multi-level Feedback Queue (6)

- Techniques like this one are called *adaptive*
  - Common in interactive systems.
- The CTSS system (MIT around 1962) was the first to use exponential queues

5. Fair Share Scheduling

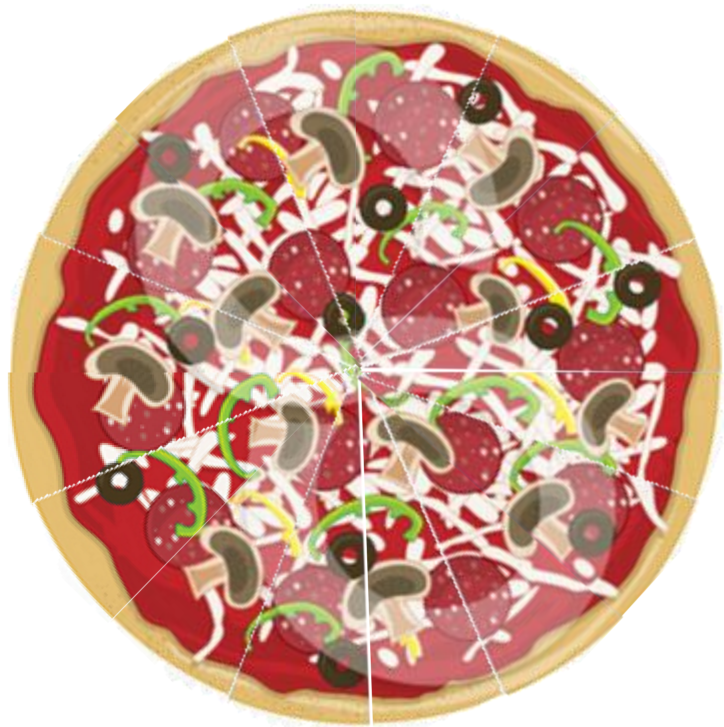
- Fair share scheduling (similar to what's implemented in Unix)
  - Keep history of recent CPU usage for each process
  - Give highest priority to process that has used the least CPU time recently
    - Highly interactive jobs, like editors, will use little CPU and get high priority
    - CPU-bound jobs, like compilers, will get lower priority
  - Can adjust priorities by changing "billing factors" for processes
    - E.g., to make high-priority process, only use half its recent CPU usage in computing history

III. Fair Share Scheduling of Linux

What is Fair Share Scheduling?
The Simpsons

Homer Simpson
(Task 1)
Weight: **4**

Bart Simpson
(Task 3)
Weight: **1**



Pizza **16 pieces**
(CPU time)

Marge Simpson
(Task 2)
Weight: **2**

Lisa Simpson
(Task 4)
Weight: **1**

Why Fair Share Scheduling?

- Many application domains need fairness guarantees

For Desktop Computing

Cause starvation and poor I/O performance under high CPU load

For Server/Cloud Computing

Cause inaccurate CPU resource provisioning and poor quality-of-service

For Real-Time Computing

Cause poor support for real-time applications
- Deadline miss

Formulation (1)

Terminology

N	The number of tasks in the system
Φ	Set of tasks $\Phi = \{\tau_1, \tau_2, \tau_3, \ldots, \tau_N\}$
$W(\tau_i)$	Weight (share) of task τ_i Numerical value which denotes a task τ_i's relative importance
S_Φ	Weight sum of tasks in Φ
$T_{\tau_i}(t_1, t_2)$	Time slice (=share) of task τ_i Amount of CPU time for which task τ_i is allowed to occupy CPU in a given interval (t_1, t_2)
$C_{\tau_i}(t_1, t_2)$	The amount of CPU time received by task τ_i during the time interval (t_1, t_2)

Formulation (2)

- Goal of fair share scheduling
  - Given a set of tasks with associated weights, a fair share scheduler should allocate resources to each task in proportion to its respective weight
    - Scheduler is perfectly fair if the following equation holds

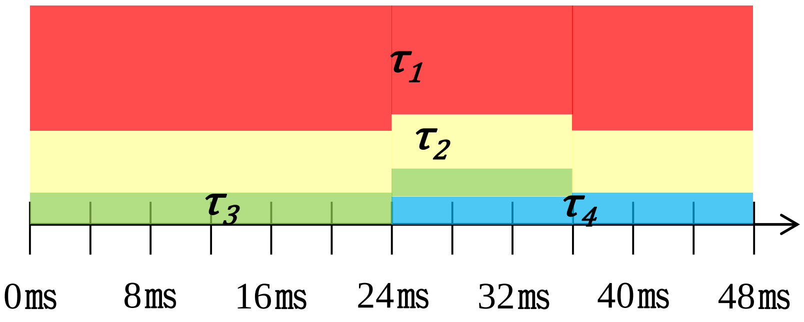
$$C_{\tau_i}(t_1, t_2) = \frac{W(\tau_i)}{S_\Phi} \times (t_2 - t_1) \qquad \textbf{(1)}$$

- $C_{\tau_i}(t_1, t_2)$: CPU time of τ_i
- $W(\tau_i)$: Weight of τ_i
- S_Φ: Total weight
- $(t_2 - t_1)$: Total CPU time

1. Generalized Processor Sharing (GPS) (1)

- Idealized scheduling algorithm that achieves perfect fairness
  - For any interval $[t_1, t_2]$ and for any task $\tau_i \in \Phi$, GPS always satisfies an equation (1)
  - Serve CPU to tasks in a round robin fashion
  - Schedule with infinitesimally small time quanta
    - Impossible to implement it since it assumes fluid-flow system

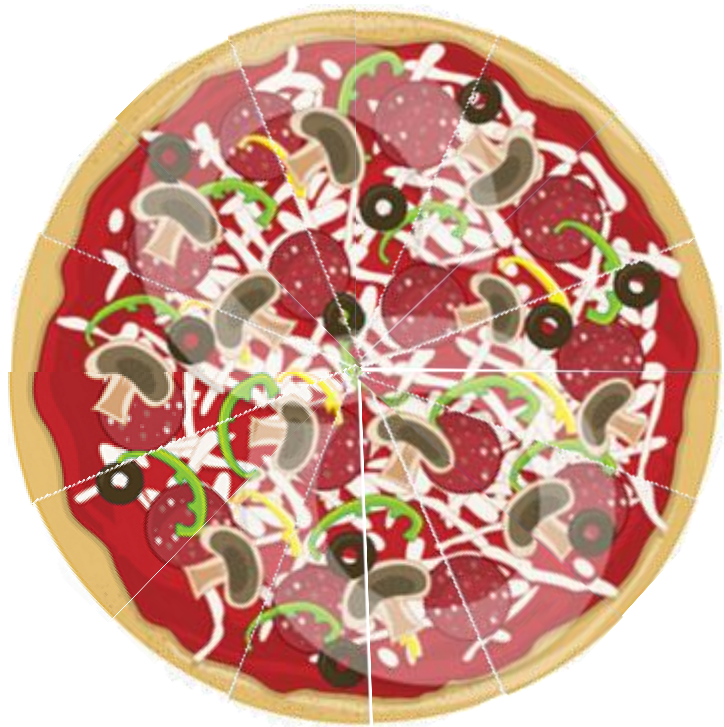
	$W(\tau_i)$	*Arrival time(ms)*	*Service time(ms)*
τ_1	4	0	48
τ_2	2	0	48
τ_3	1	0	36
τ_4	1	24	24



1. Generalized Processor Sharing (GPS) (2)

Homer Simpson
(Task 1)
Weight: **4**

Bart Simpson
(Task 3)
Weight: **1**



Marge Simpson
(Task 2)
Weight: **2**

Pizza
(CPU time)

Lisa Simpson
(Task 4)
Weight: **1**

Fairness Measurement

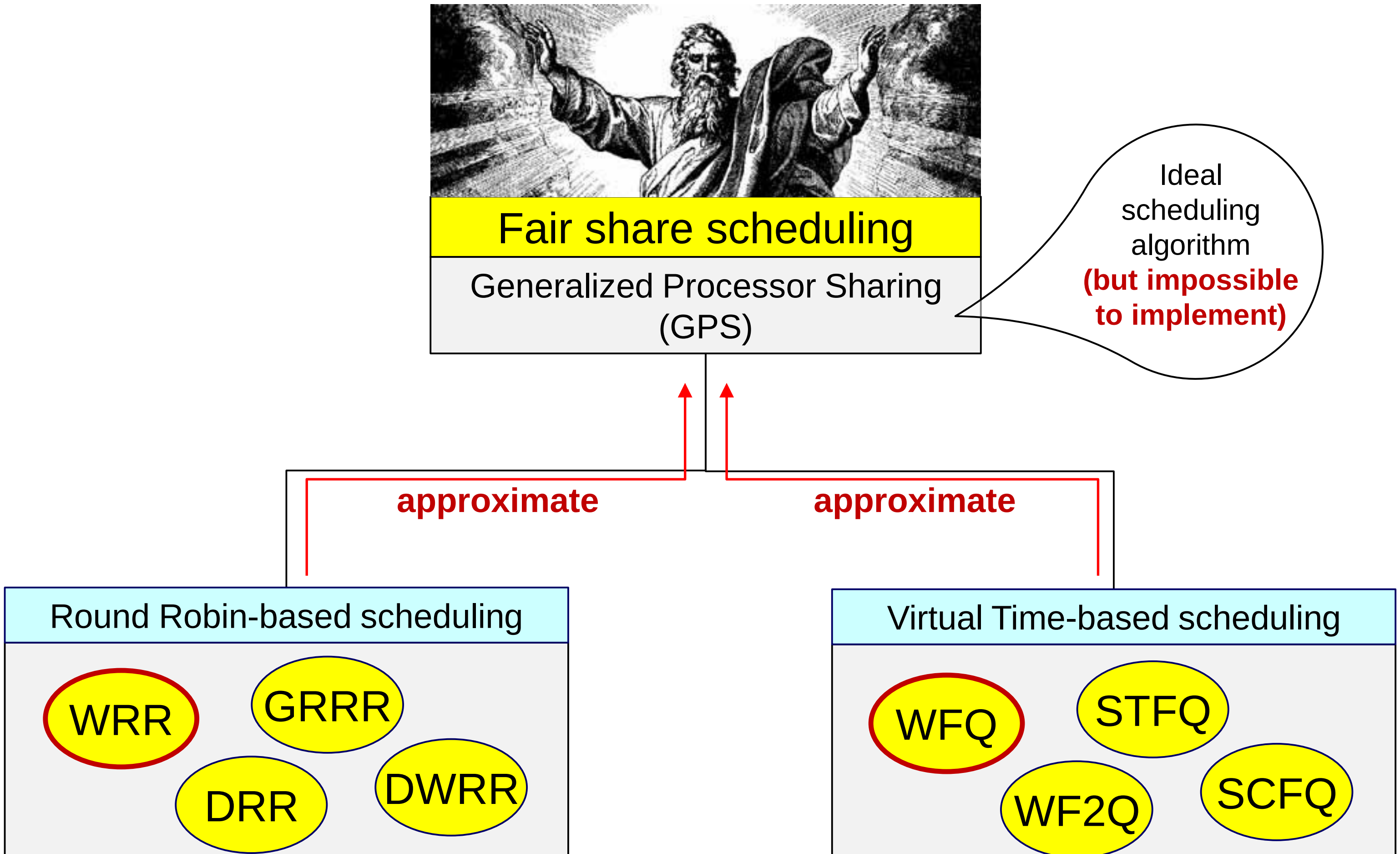
- CPU time lag
  - Assume that task τ_i has a fixed weight $W(\tau_i)$ in the time interval $[t_1, t_2]$
  - The lag of task τ_i at time $t \in [t_1, t_2]$ is

$$lag_{\tau_i}(t) = C_{\tau_i}(t_1, t) - \frac{W(\tau_i)}{S_\Phi} \times (t - t_1)$$

Actual CPU time — CPU time under GPS

    - Positive lag: τ_i has received more service than under GPS
    - Negative lag: τ_i has received less service than under GPS
  - The goal of fair share scheduling is to minimize lag over all time intervals

Fair Share Scheduling Disciplines



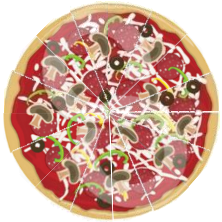
WRR (Weighted Round Robin) (1)

- Key for fair share scheduling
  - Time slice
    - Time interval for which the task is allowed to run without being preempted
      - Each task is assigned a time slice proportional to its weight

$$TS_{\tau_i} = \frac{W(\tau_i)}{S_{\Phi}} \times \text{round\_robin\_interval\_period}$$

System-wide constant

= 1 pizza

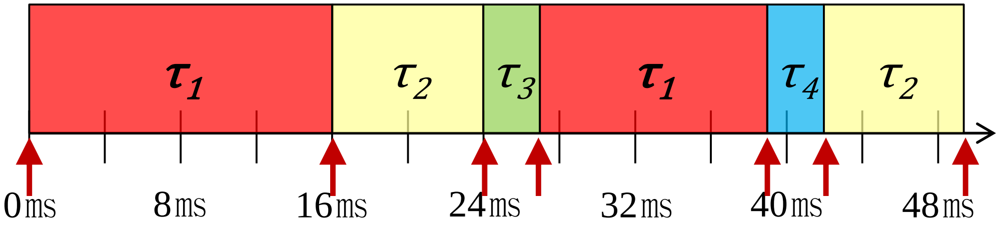


WRR (Weighted Round Robin) (2)

- Approximation of GPS using time slice
- Assigns weighted time slice to each task
- Schedules tasks in round robin manner
  - A task executes for one unit of time slice

round robin interval period=28㎳

	weight	Arrival time(㎳)	Service time(㎳)	Time slice (㎳)
τ_1	4	0	48	14/16
τ_2	2	0	48	7/8
τ_3	1	0	36	3.5/4
τ_4	1	24	24	3.5



WRR (Weighted Round Robin) (3)

Homer Simpson
(Task 1)
Weight: **4**
Time Slice = 4

Bart Simpson
(Task 3)
Weight: **1**
Time Slice = 1

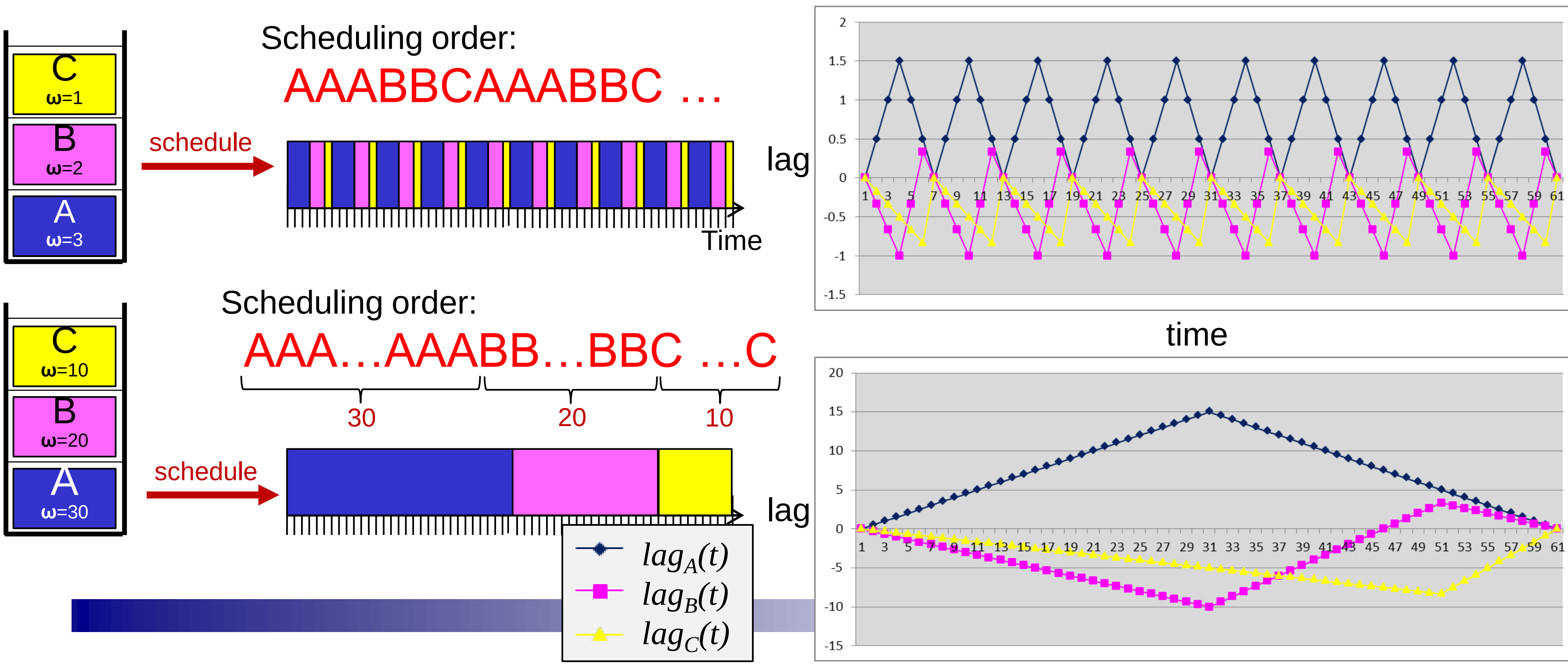
Pizza
(CPU time)
round robin interval = 8

Marge Simpson
(Task 2)
Weight: **2**
Time Slice = 2

Lisa Simpson
(Task 4)
Weight: **1**
Time Slice = 1

WRR (Weighted Round Robin) (4)

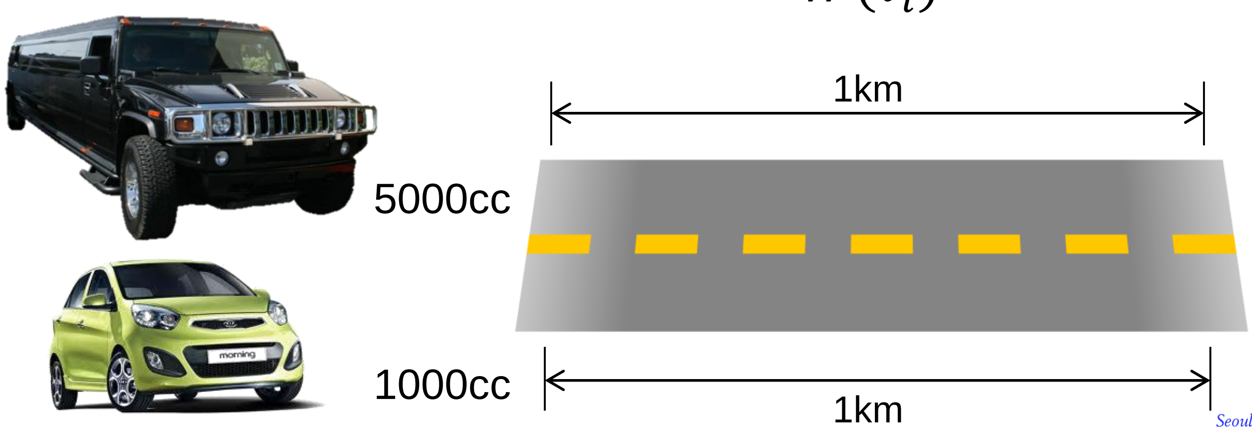
- Evaluation
  - Low scheduling overhead : O(1)
  - Weak fairness guarantee
    - Lag can be quite large, especially when the weights are large



WFQ (Weighted Fair Queuing) (1)

- Key for fair share scheduling
  - Virtual CPU time (VCT)
    - Measure of the degree to which a task has received its proportional allocation, relative to others
    - The grow rate of a task's VT is inversely proportional to the task's weight

$$VCT_{\tau_i}(t) = \frac{C_{\tau_i}(0,t)}{W(\tau_i)}$$



WFQ (Weighted Fair Queuing) (2)

- Preemption tick period
  - Time interval for which the scheduler checks for preemption

= 1 pizza slice

- Virtual finish time (VFT)
  - VCT that the task would have after executing for one preemption tick period T

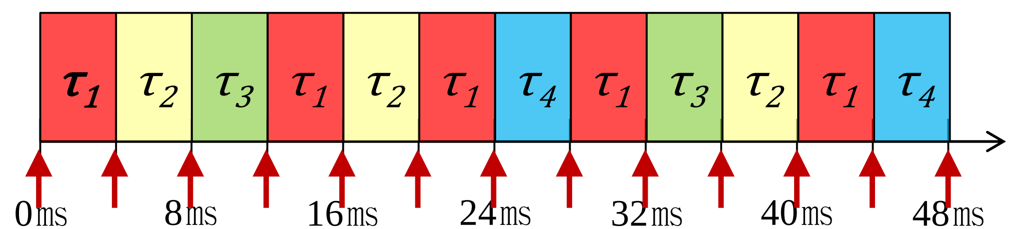
$$VFT_{\tau_i}(t) = VCT_{\tau_i}(t+T) = VCT_{\tau_i}(t) + \frac{T}{W(\tau_i)}$$

WFQ (Weighted Fair Queuing) (2)

- Approximation of GPS using virtual time
- Computes virtual finish time on every preemption tick
- Schedules tasks in increasing order of virtual finish time

preemption tick=4㎳

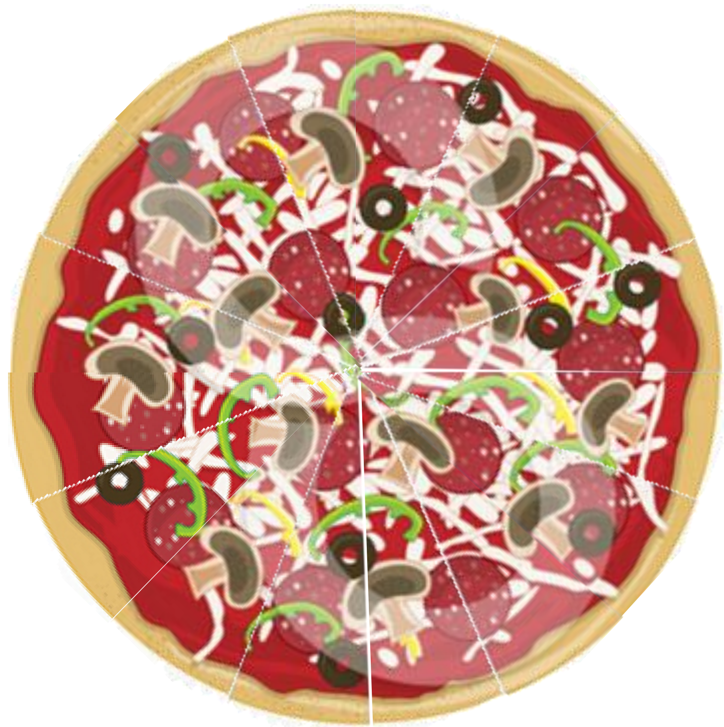
	weight	*Arrival time(㎳)*	*Service time(㎳)*	*Virtual finish time*
τ_1	4	0	48	[illegible]
τ_2	2	0	48	[illegible]
τ_3	1	0	36	[illegible]
τ_4	1	24	24	[illegible]



WFQ (Weighted Fair Queuing) (3)

Homer Simpson
(Task 1)
Weight: **4**
VFT: **1**

Bart Simpson
(Task 3)
Weight: **1**
VFT: **1**



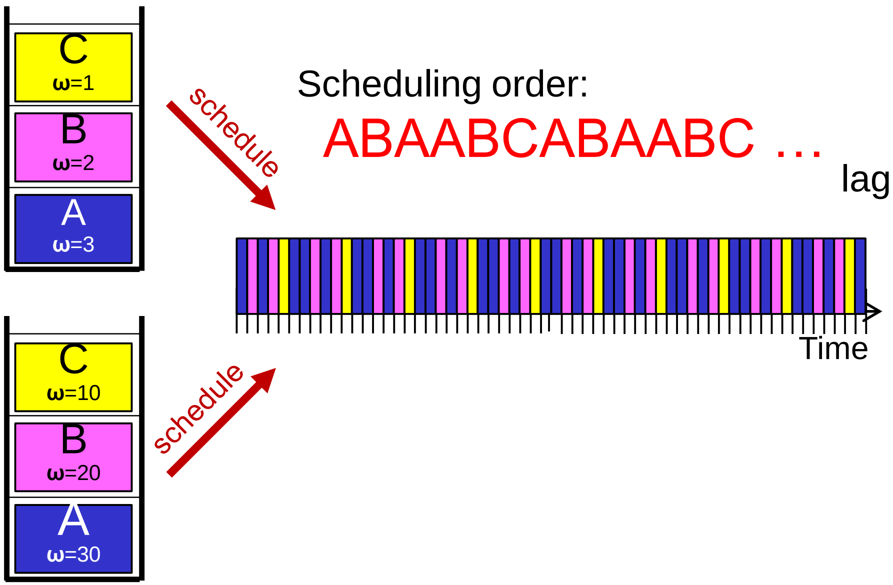
Pizza
(CPU time)
preemption tick = 1

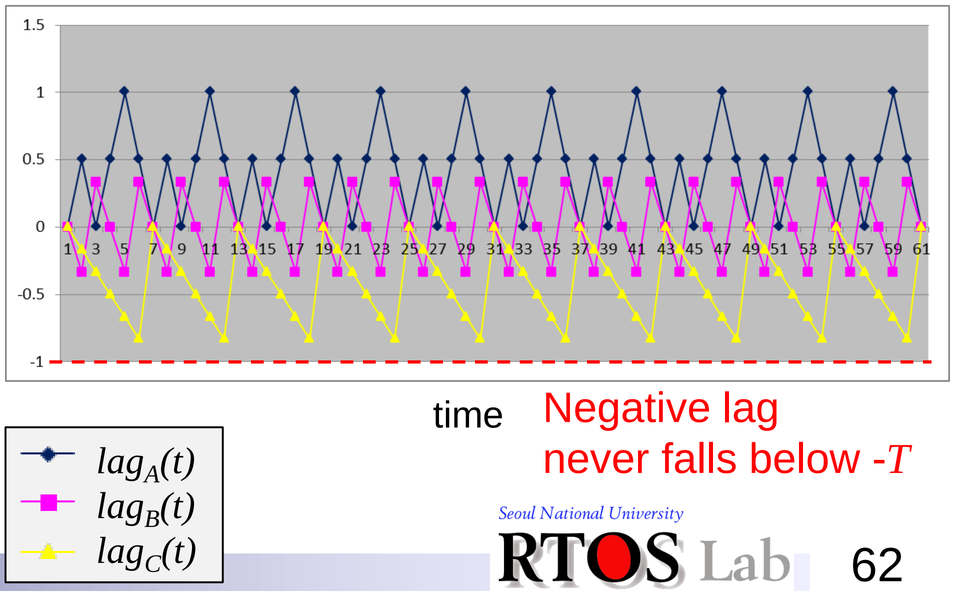
Marge Simpson
(Task 2)
Weight: **2**
VFT: **1**

Lisa Simpson
(Task 4)
Weight: **1**
VFT: **1**

WFQ (Weighted Fair Queuing) (4)

- Evaluation
  - Quite high scheduling overhead : O(N) or O(log N)
    - Might incur too much context switching overhead
  - Strong fairness guarantee
    - Independent from weight set





Negative lag never falls below -T

Completely Fair Scheduler: RR or VT?

Fair share scheduling

Generalized Processor Sharing (GPS)

approximate ↑ | ↑ approximate

Round Robin-based scheduling
- WRR
- GRRR
- DRR
- DWRR

Virtual Time-based scheduling
- WFQ
- STFQ
- WF2Q
- SCFQ

CFS ?

2. Rotating Staircase Deadline Scheduler (RSDL)

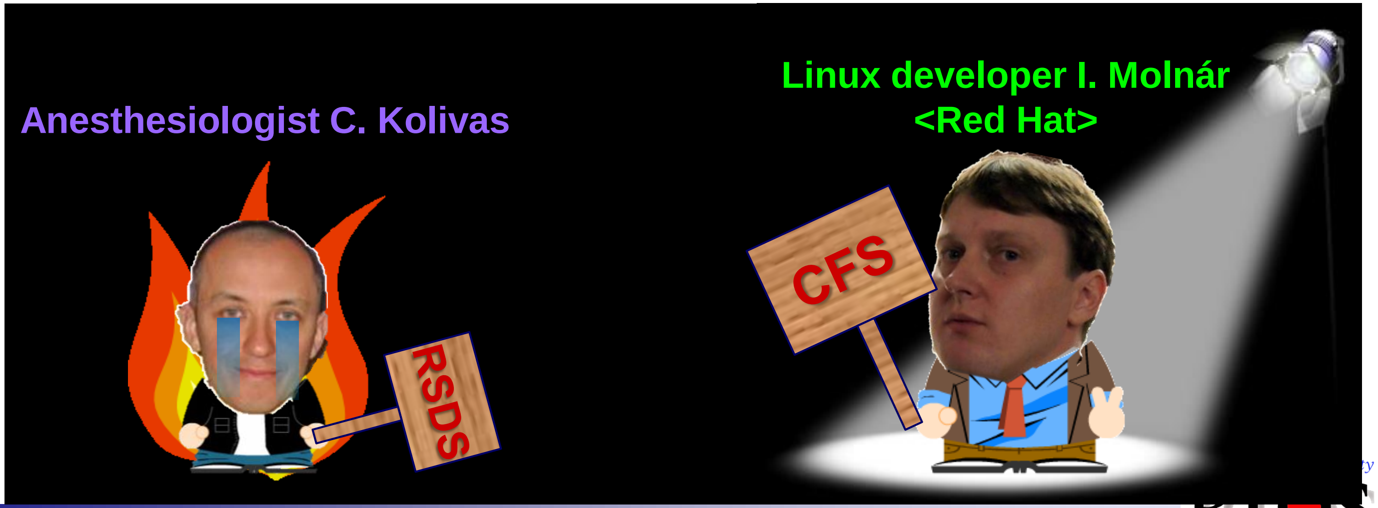
Con Kolivas **(Australian anaesthetist, known for his programming work on the Linux kernel in his spare time)**

3. Completely Fair Scheduler (CFS) (1)

Ingo Molnár **(Hungarian Linux hacker, employed by Red Hat)**

3. Completely Fair Scheduler (CFS) (2)

- Primary task scheduler of the mainline Linux kernel since its 2.6.23 release
  - Designed and developed by Ingo Molnár
    - Inspired by Con Kolivas's work
  - The first Implementation of fair share scheduling widely used in a general-purpose OS (Linux)



3. Completely Fair Scheduler (CFS) (3)

1. Providing fair share scheduling by giving each task CPU time proportional to its weight
   - For a given time interval [t_1, t_2], CFS attempts to provide the following amount of CPU time for a task τ_i

$$C_{\tau_i}(t_1, t_2) = \frac{W(\tau_i)}{S_\Phi} \times (t_2 - t_1)$$

Weight of τ_i — Total weight — Total CPU time

2. Efficiently utilizing CPU resource in multicore system

(1) Virtual Runtime

- Definition
  - The task's cumulative execution time inversely scaled by its weight

$$VR(\tau_i, t) = \frac{W_0}{W(\tau_i)} \times PR(\tau_i, t)$$

    - W_0 : the weight of nice value 0
    - $PR(\tau_i, t)$: Actual runtime of task τ_i in time interval $[0, t]$

  - Used to approximate the GPS (perfect fair share scheduling)
    - CFS assigns each task virtual runtime to account for how long a task has run and thus how much longer it ought to run

(2) Time Slice

- Definition
  - Time interval for which the task is allowed to run without being preempted
    - The length of task τ_i's time slice is proportional to its weight

$$TS_{\tau_i} = \frac{W(\tau_i)}{S_{\Phi}} \times P$$

– S_{Φ} : the set of runnable tasks in a run queue

– P : the constant for a given workload

Targeted preemption latency for CPU-bound tasks

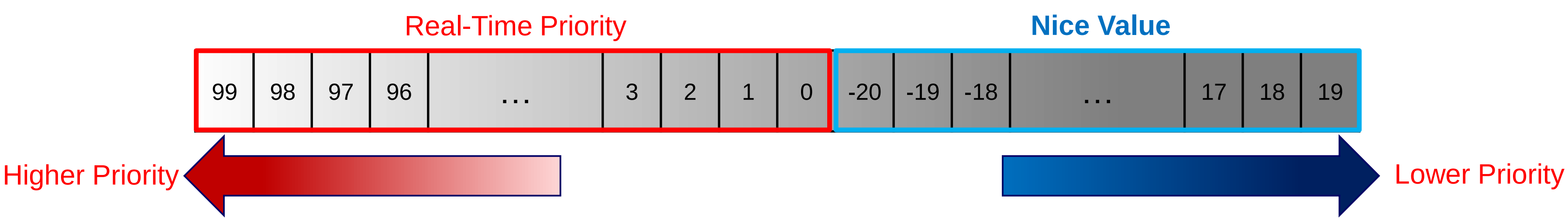
$$P = \begin{cases} \text{sched\_latency} & \text{if n < nr\_latency} \\ \text{min\_granularity} \times n & \text{otherwise} \end{cases}$$

Minimum preemption granularity for CPU-bound tasks

– n : the number of tasks

(3) Task Priority and Weight

- Linux priority range
  - Nice value (**`-20~19`**, default of **`0`**)
    - Standard priority range used in all Unix systems
    - Priority for normal (time-sharing) tasks
    - Larger nice value corresponds to a lower priority
  - Real-time priority (**`0~99`**)
    - Priority for real-time tasks
    - Higher real-time priority value corresponds to greater priority
    - Real-time tasks have priority over normal tasks



(3) Task Priority and Weight

- Calculating Linux priority (**`PR`**)
  - Ranges from **`-100`** to **`39`**
    - The lower the **`PR`**, the higher the priority of the task is
  - Real-time tasks: **`-100~-1`**
    - **`PR = -1 - real_time_priority`**
  - Normal tasks: **`0~39`**
    - **`PR = 20 + NI`**

(3) Task Priority and Weight

- Nice-to-weight mapping
  - Recycle nice values to represent the weight values of tasks
  - “10% effect” mapping rule: 55% vs. 45%
    - From any nice level,
      - If you go up one level, it's -10% CPU usage
      - If you go down 1 level, it's +10% CPU usage

kernel/sched.c

```
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,
};
```

(3) Task Priority and Weight

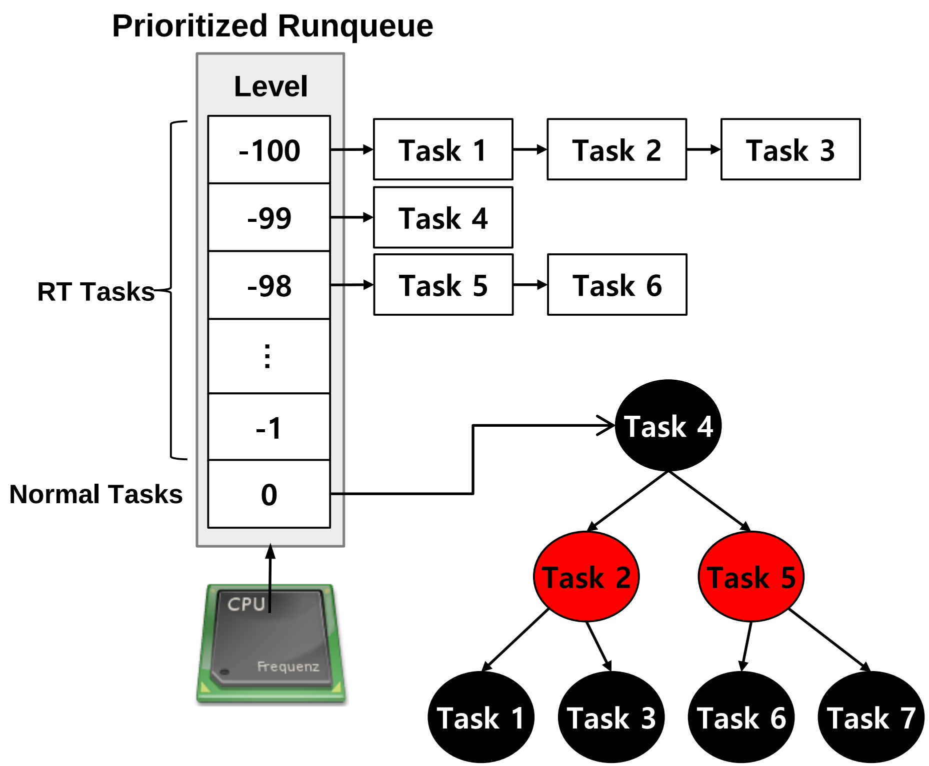
- Each task stores weight value

include/linux/sched.h

```
struct load_weight {
    unsigned long weight, inv_weight;
};
```

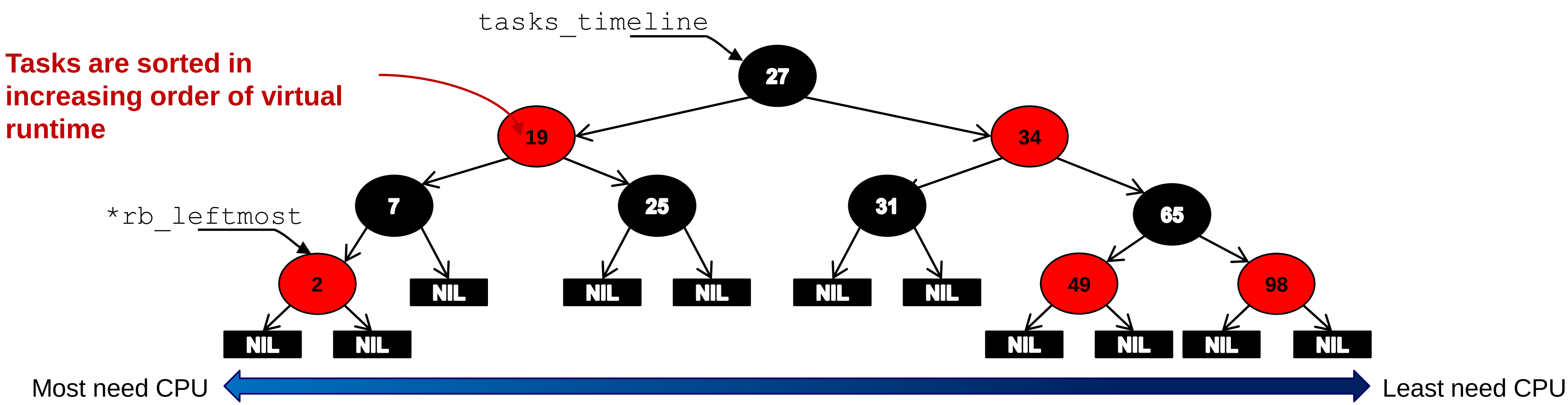
(4) Run Queue Structure

- Each CPU owns its run queues
  - Red-black tree for the normal tasks, array for the RT tasks



(4) Run Queue Structure

- "*Red-black tree*" is the time-ordered run queue structure of CFS for storing normal tasks
  - No path in the tree will ever be more than twice as long as any other (self-balancing)
  - Operations on the tree occur in $O(\log n)$ time
    - Inserting or deleting a task is quick and efficient

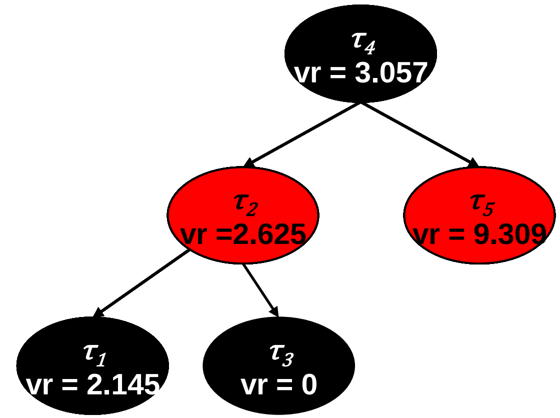


(5) Running Example

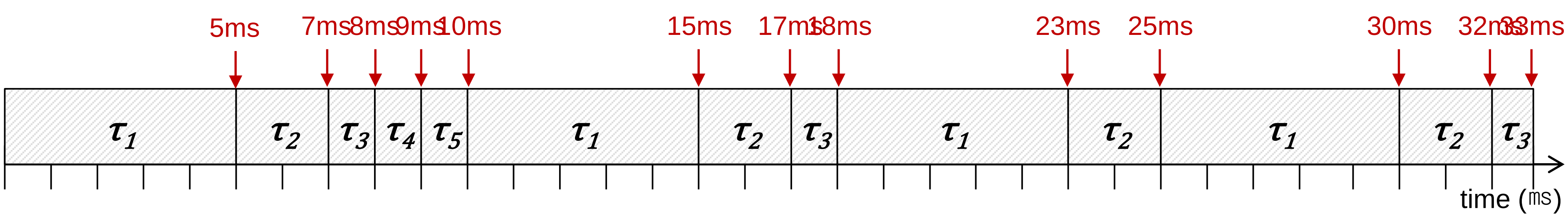
Scheduling tick: 1㎳ **(HZ = 1000)**

Task description

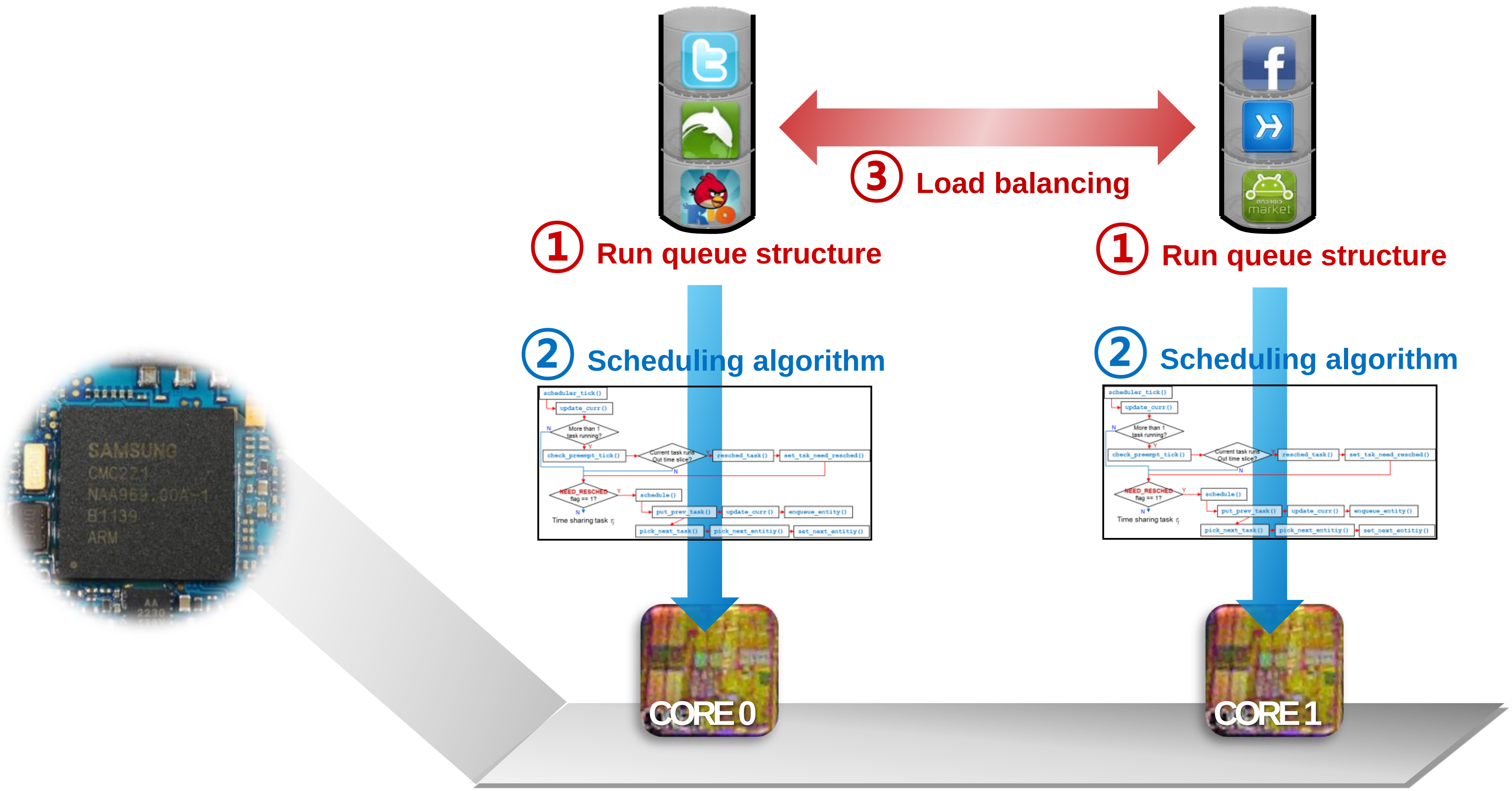
	nice	$W(\tau_i)$	$\frac{W(\tau_i)}{S_\Phi}$	time slice
τ_1	-10	9548	0.6753	4.0518
τ_2	-5	3121	0.2208	1.3248
τ_3	0	1024	0.0724	0.4344
τ_4	5	335	0.0237	0.1422
τ_5	10	110	0.0078	0.0468
total		14138	1.000	6



Currently running:



(6) Load Balancing



IV. Summary

Evolution of Scheduling Policies