Rate-Based Execution Models For Real-Time Multimedia Computing

On the Duality of Proportional Share and Liu & Layland Style Resource Allocation

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Proportional Share Resource Allocation
Outline

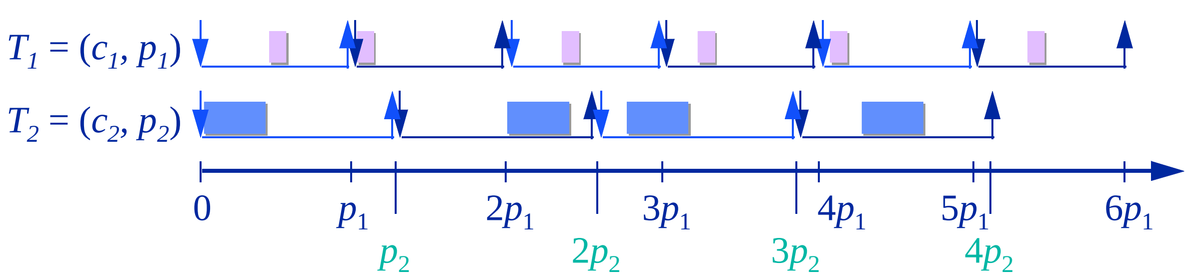
- Fluid-flow resource allocation models
  - » Packet schduling in a network
- Proportional share resource allocation models
  - » CPU scheduling in an operating system
- On the duality of proportional share and traditional real-time resource allocation models
  - » How to make a provably real-time general purpose operating system

On Proportional Share Allocation *v.* Traditional Real-Time Scheduling

- Proportional share allocation
  - » Uniform rate of execution
  - » "Firm" real-time response
  - » Provides fault containment in the time domain
  - » Easy to implement in an operating system
- Traditional real-time scheduling
  - » Hard-real-time response
  - » Isolation from non-real-time processes

The Essence of Real-Time Resource Allocation

- Real-time processes are allocated a *fraction* of the CPU's capacity (an *absolute share*)
  - » Canonical real-time, periodic process model: $f_i = \dfrac{c_i}{p_i}$
    - ❖ c_i is the execution time of process i
    - ❖ p_i is the period of process i
- Process i executes c_i time units every p_i time units



Integrating Proportional Share & Traditional Real-Time Resource Allocation

- Weights and shares are *duals*

$$f_i = \frac{w_i}{\sum_j w_j}$$

  - » Fixing the weight *w* results in proportional share allocation
  - » Fixing the share *f* results in real-time execution

- Therefore, characterize each process by a pair (*w*, *f*), where
  - » *w* — weight, the cost the process is willing to pay for execution
  - » *f* — fraction (share) of the CPU the process should receive

Exploiting the Weight/Share Duality

Predictability *v.* Cost

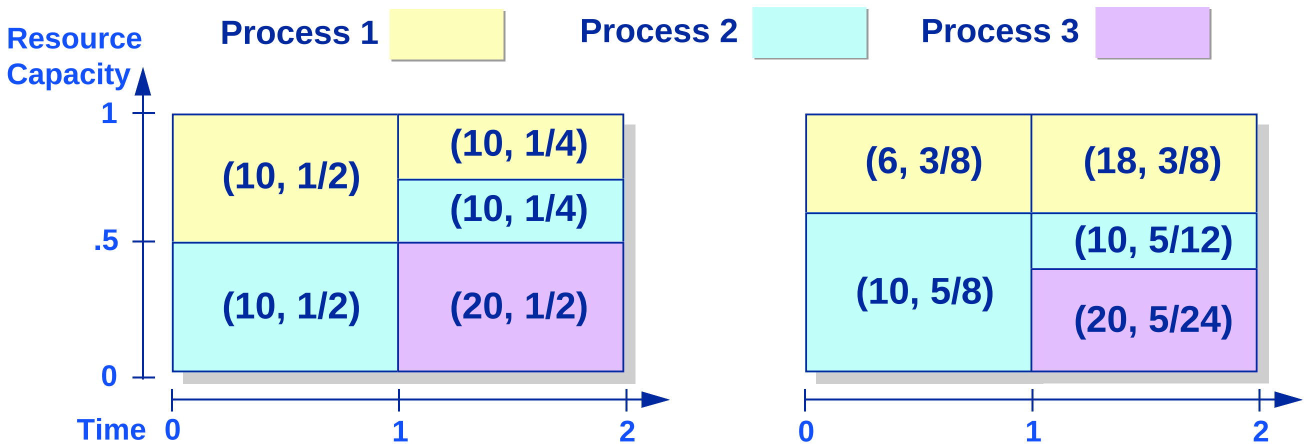
- Interpret *w* as the rate at which a process is charged for service
  - » A process with a fixed weight is charged $w \times \Delta t$ to use the resource over a time interval of length Δt

- Under proportional share resource allocation, *cost* is fixed and *execution rate* is variable
  - » a process knows how much it is charged over any future time interval, but doesn't know how much service time it will receive

- Under traditional real-time allocation, *execution rate* is fixed and *cost* is variable
  - » a process knows how much service time it will receive over any future time interval, but doesn't know how much it will be charged

Exploiting the Weight/Share Duality

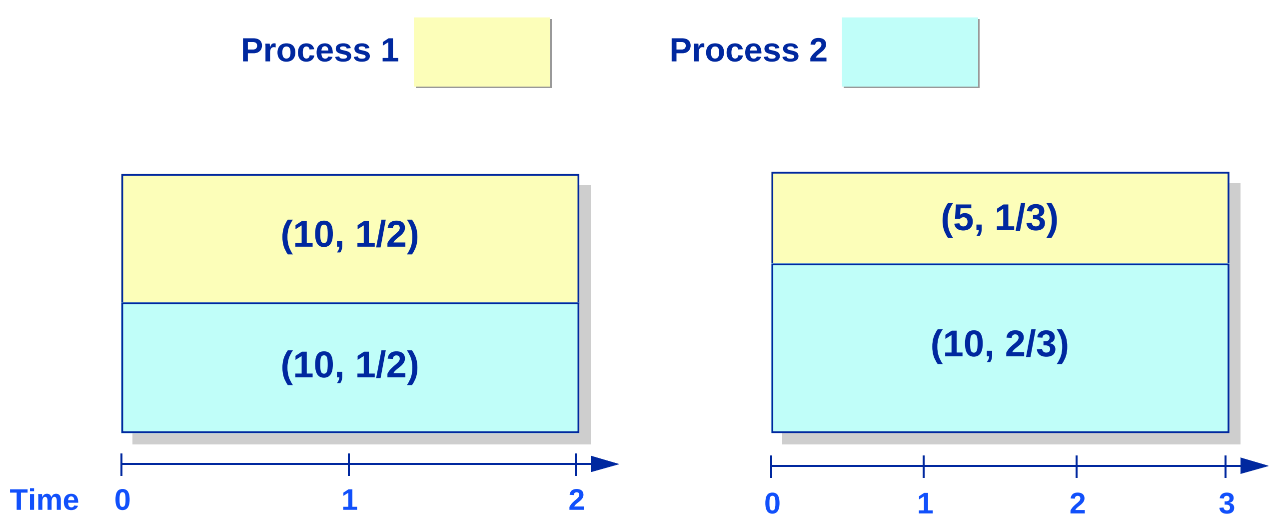
Trading off cost for quality-of-service



- Fix a *weight*, receive a variable share
  - » Process 1's:
    service time = 3/4
    cost = 20
- Fix a *share*, pay a variable cost
  - » Process 1's:
    service time = 3/4
    cost = 24

Exploiting the Weight/Share Duality

Trading off cost for response time

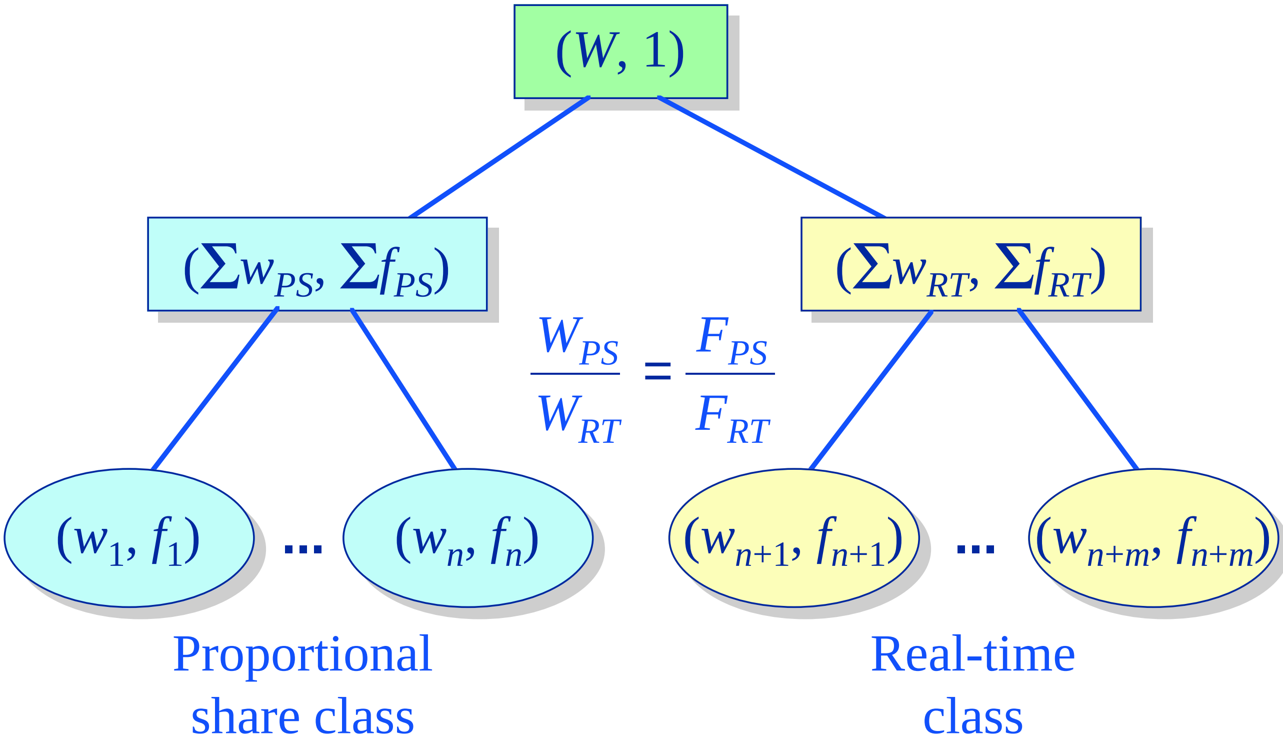


Process 1: Service time = 1
Cost = 20

Process 1: Service time = 1
Cost = 15

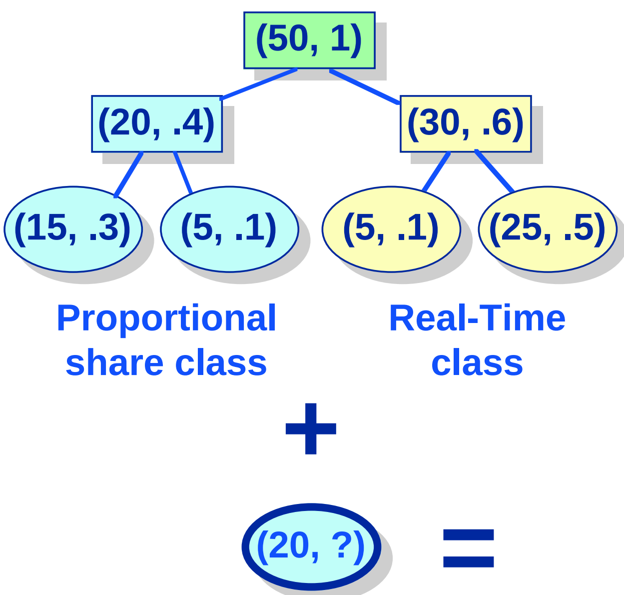
Exploiting the Weight/Share Duality

Scheduling class hierarchy



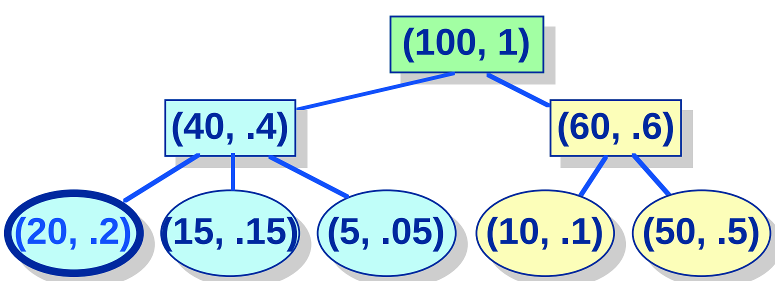
Scheduling Hierarchy Example

Admitting a new proportional share process



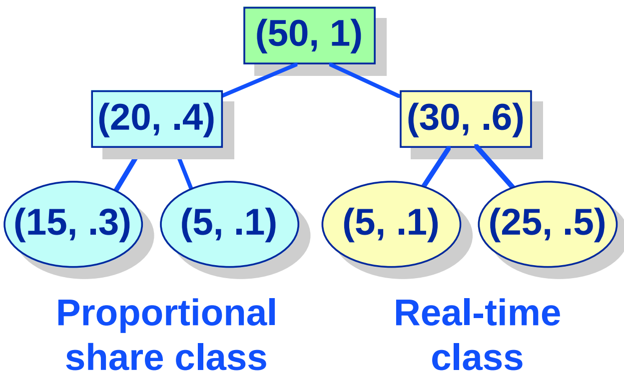
Adding a *PS* process *halves* the *execution rate* of other *PS* processes

» *doubles* the *cost* of real-time processes



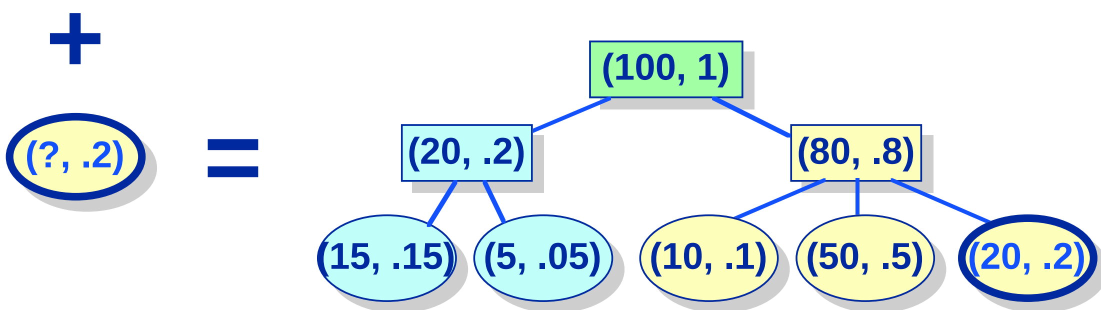
Scheduling Hierarchy Example

Admitting a new real-time process



Adding a real-time process has the same effect

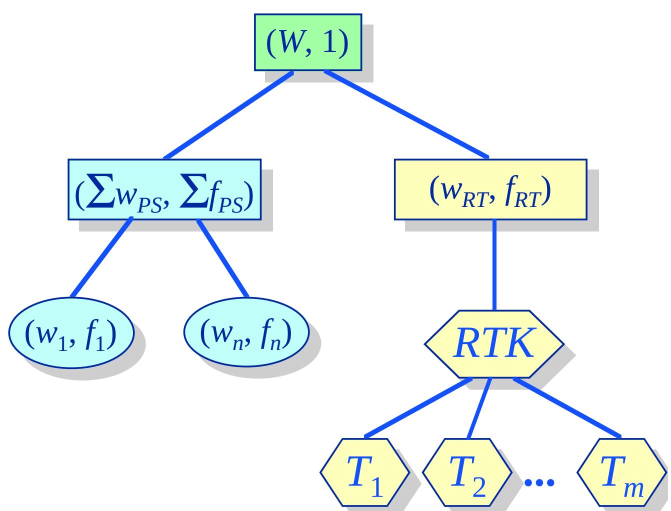
- » PS processes halve their share
- » real-time processes pay twice as much



Exploiting the Scheduling Hierarchy

Layering a real-time scheduler on top of a PS scheduler

- Proportional share scheduling can provide a virtual CPU abstraction to other operating systems
- Example: Execute a real-time operating system as a process within a general purpose, proportional share system



Exploiting the Scheduling Hierarchy

Layering a real-time scheduler on top of a PS scheduler

- Feasability test for a set of periodic tasks scheduled with an earliest deadline first scheduler on top of a proportional share scheduler:

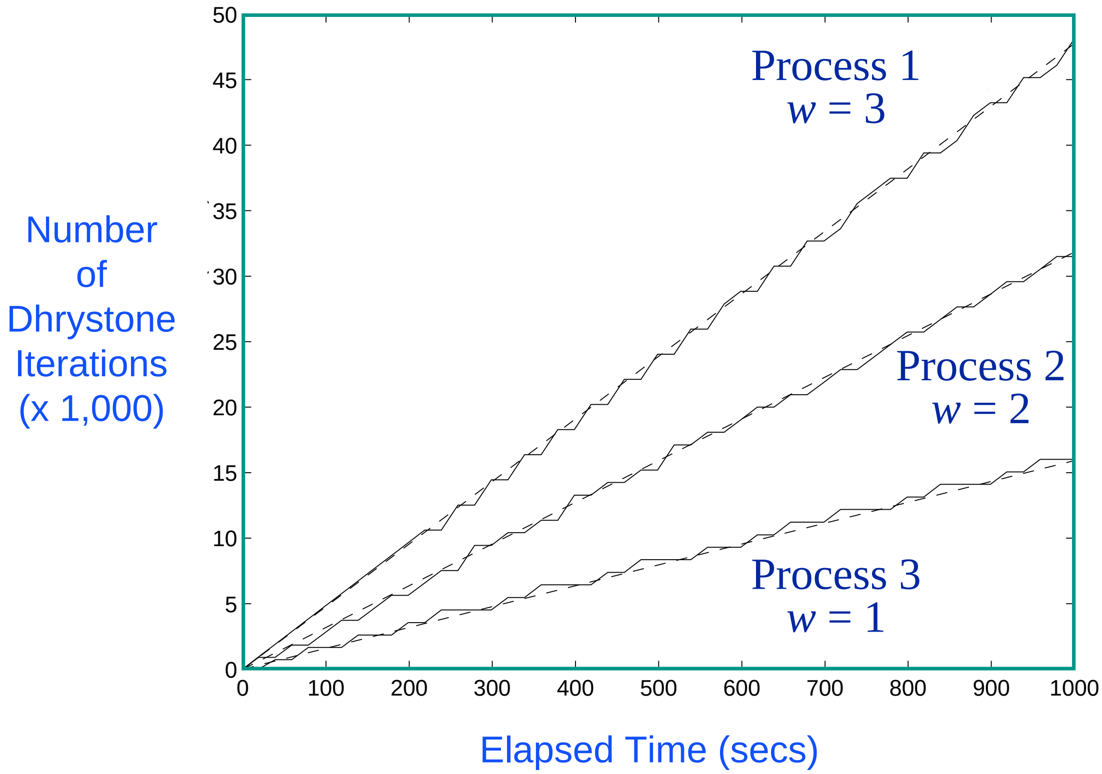
Experimental Evaluation

EEVDF Implementation in FreeBSD

- Platform
  - » PC compatible, 75 Mhz Pentium processor, 16 MB RAM
- Implementation
  - » Replaced FreeBSD CPU scheduler
  - » Time quantum = 10 ms
- Experiments
  - » Non-real-time tasks making uniform progress
  - » Speeding up and slowing down task progress by manipulating weights
  - » Real-time execution (of non-real-time programs!)

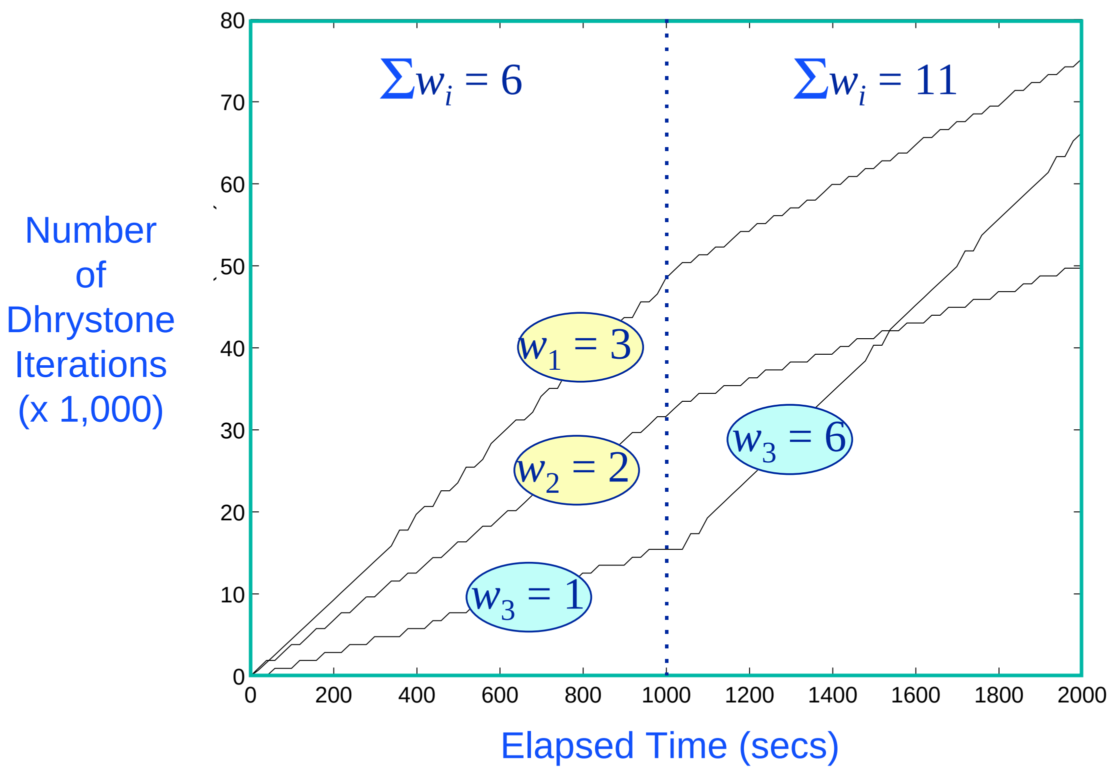
Proportional Share Scheduling Example

Uniform allocation to non-real-time processes



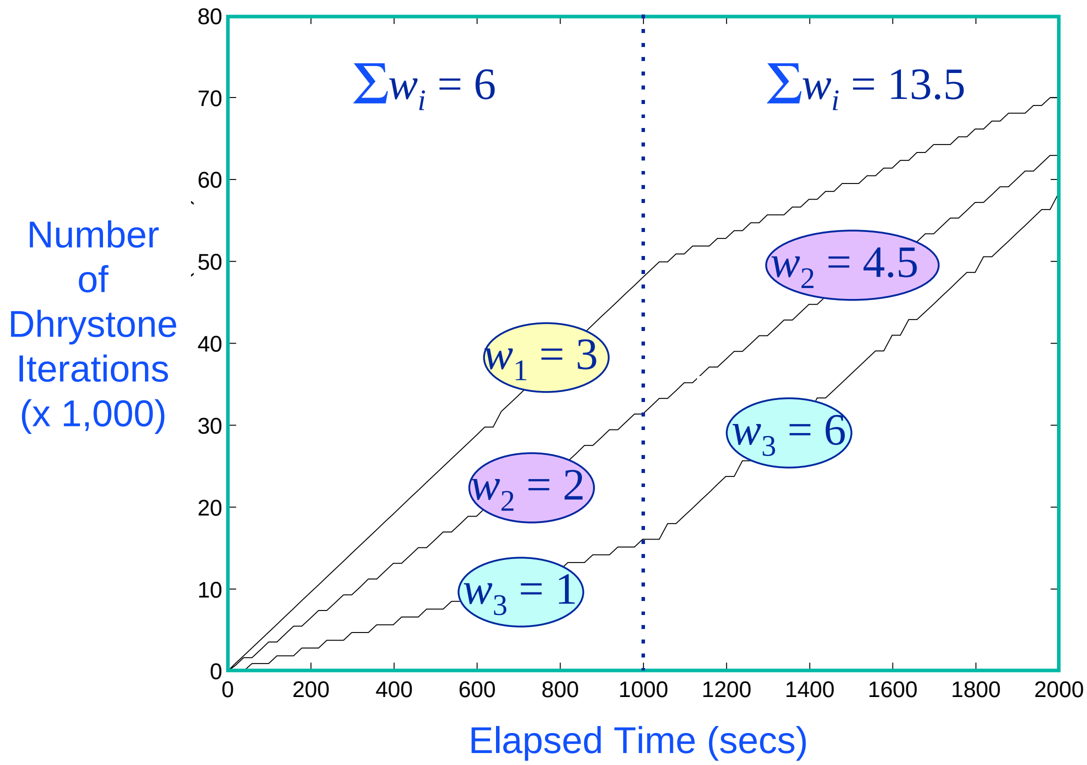
Proportional Share Scheduling Example

Dynamic share redistribution



Proportional Share Scheduling Example

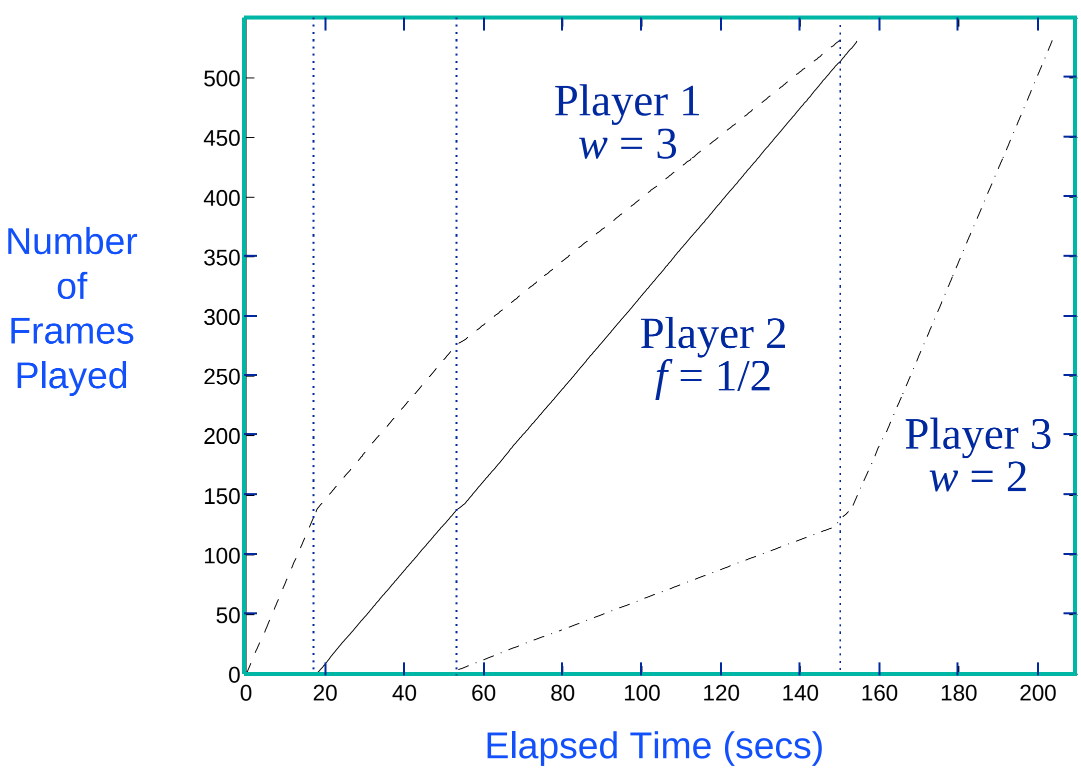
Mixed workload: 1 real-time & 2 ps processes



Process 2's share remains fixed throughout at 1/3

MPEG Player Example

2 Proportional share players, 1 real-time player



Summary & Conclusions
Proportional share *v.* traditional real-time scheduling

- Weights and shares are duals
- There exists a simple framework to integrate proportional share and real-time resource allocation
  - » Subsumes traditional priority and real-time scheduling
- By using EEVDF, we've implemented a CPU scheduler that provides support for
  - » real-time
  - » interactive, &
  - » batch applications

Rate-Based Execution Models For Real-Time Multimedia Computing

Summary

- Multimedia services are greatly enhanced by the existence of real-time communication and computation support
- Traditional approaches to real-time OS support are too hard to apply and don't fit requirements well
- We're experimenting with new programming models and new implementation paradigms
- Stay tuned!

Rate-Based Execution Models For Real-Time Multimedia Computing

Summary

- Rate-based execution models are more robust models for real-time multidedia computing
  - » Seamless integration of real-time & non-real-time requirements
  - » Simple “tuning knobs”
  - » Graceful degradation
  - » A dual of existing periodic models
- Easy to implement

  (In the case of proportional share allocation)