Low Overhead Dynamic QoS Optimization Under Variable Task Execution Times

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November 3, 2010

Motivation

Large, unpredictable load variations

- Large
  - Complex set of applications
  - Not all functionality runs at all times
- Unpredictable
  - Complex hardware platform
  - Software may change during the lifetime of the system

Efficiency

- Not waste resources (power, memory, CPU time, cost . . .)
- Optimize some Quality-of-Service metric

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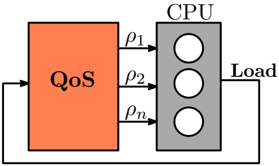
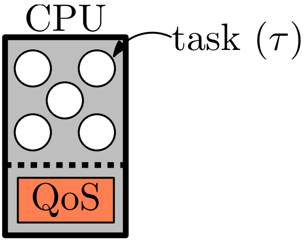


On-line approaches:

- Keep a certain reference Load
- Optimize Quality-of-Service
- Low Overhead

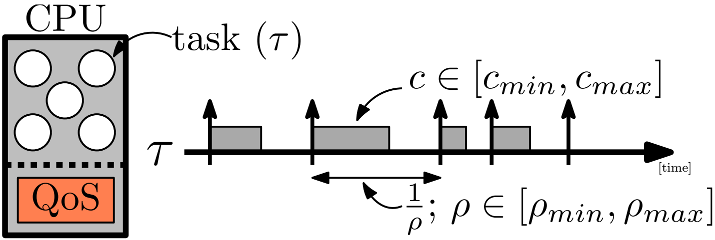
Outline

System Model



- Execution times vary in unknown ways
- Task rates are decided by the **QoS Controller**
- Jobs are scheduled through **EDF**

System Model



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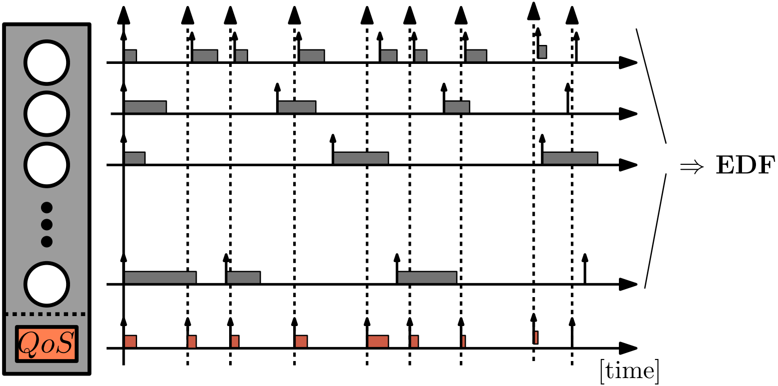
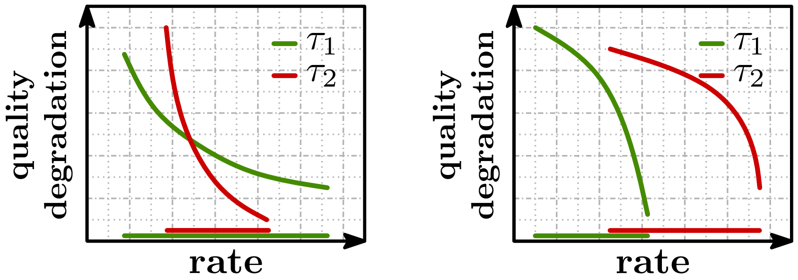


Quality-of-Service

Each task posseses an abstract **quality degradation** curve:

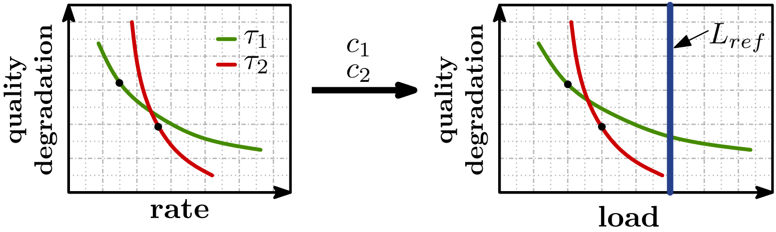
- functions of rate
- decreasing, strictly monotonic curves
- higher rates ⇒ better quality ⇒ lower quality degradation.



QoS Controller

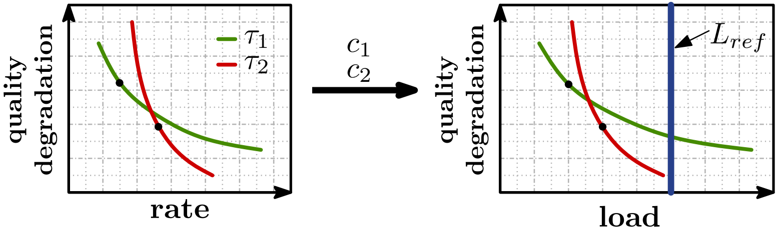
1. Determines task rates:
   - Maximize overall Quality-of-Service
   - Keep a reference CPU load given by the designer
     - determine execution times
     - determine number of jobs to be executed
2. Determines its next activation time.

QoS Controller



$$L = \sum_i c_i \cdot \rho_i$$

QoS Controller



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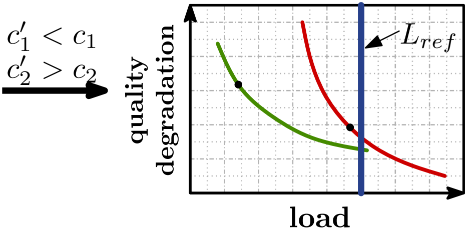
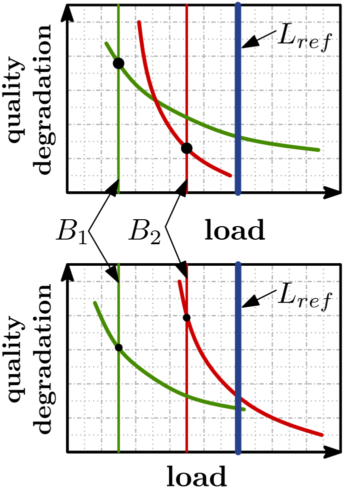


Approaches

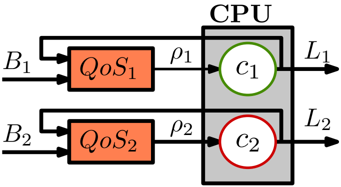
On-line approaches (QoS controllers):

- Constant Bandwidth
- Uniform QoS
- QoS Derivative
- Corner Case

Constant Bandwidth



- B_1, B_2 – bandwidth
- $\sum_i B_1 = L_{ref}$



Constant Bandwitdh

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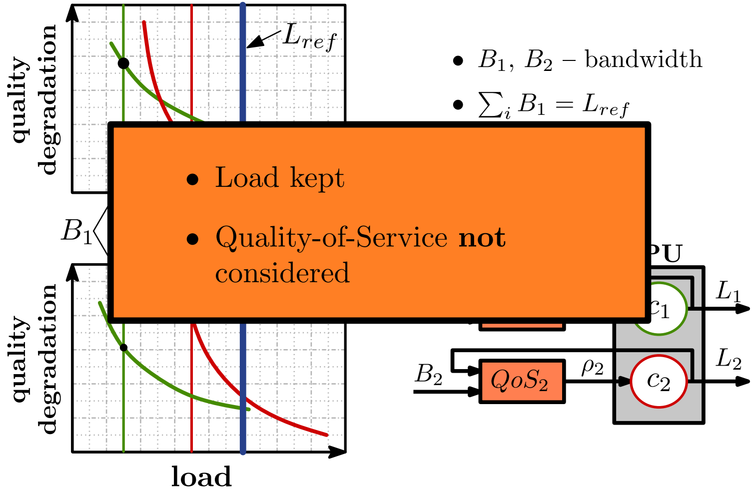
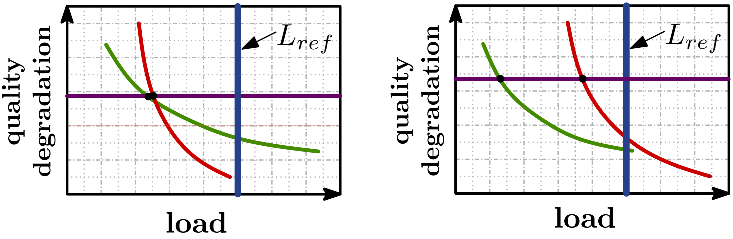
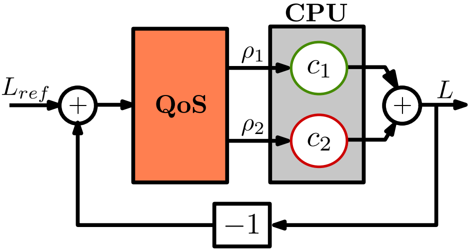


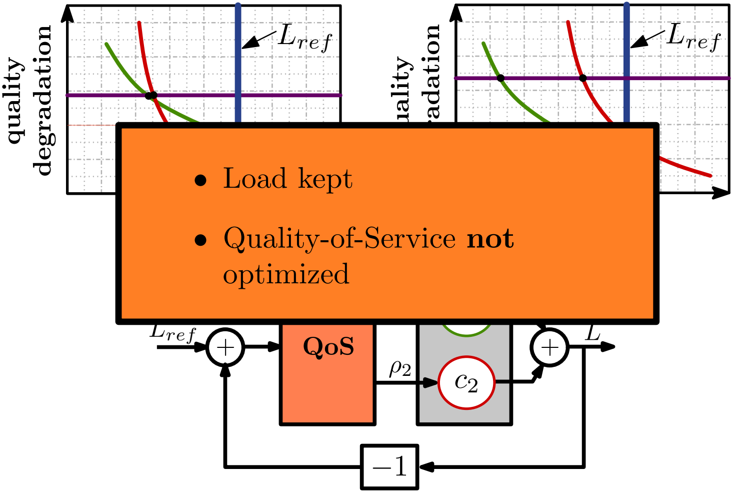
- Load kept
- Quality-of-Service **not** considered

Uniform QoS


quality degradation
L_{ref}
load
quality degradation
L_{ref}
load

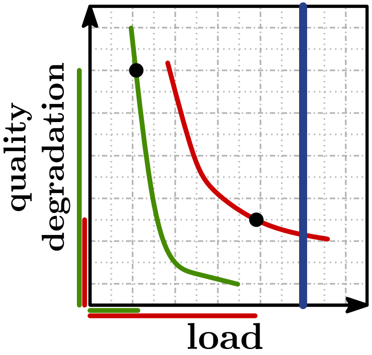

CPU
L_{ref}
QoS
ρ_1
ρ_2
c_1
c_2
L
-1

Uniform QoS

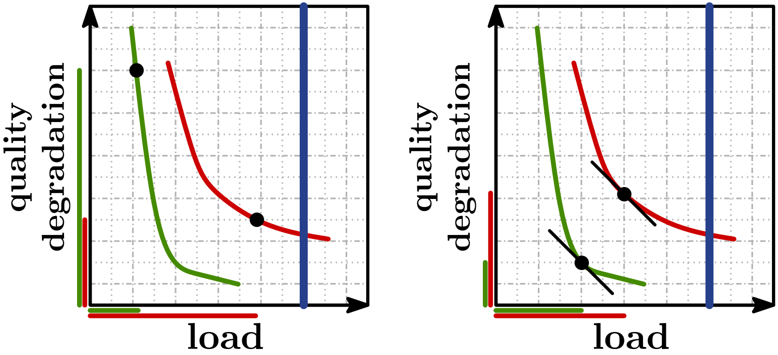


- Load kept
- Quality-of-Service **not** optimized

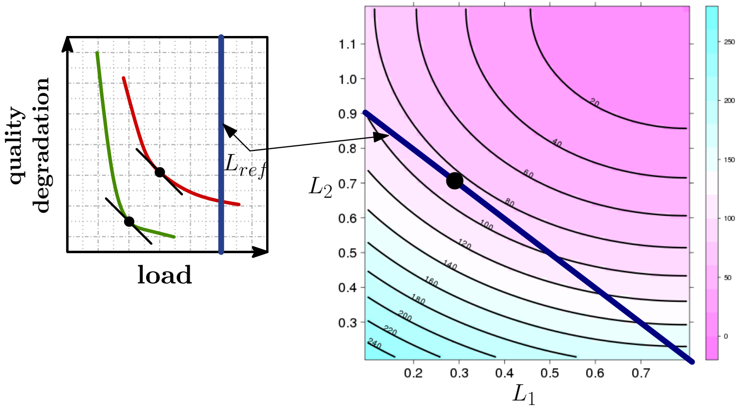
QoS Derivative



QoS Derivative

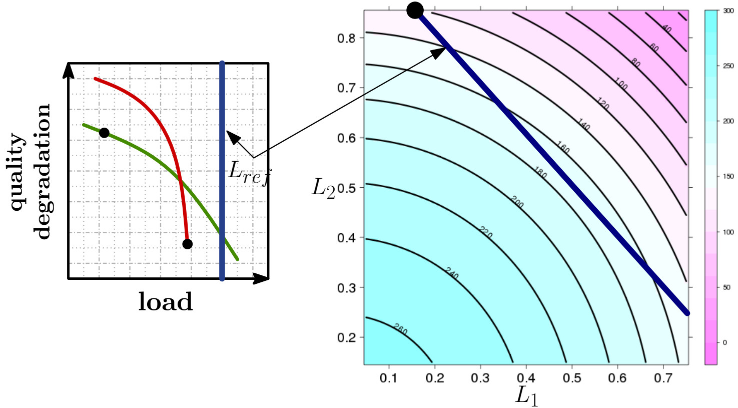


QoS Derivative



- Optimum approach for **convex** quality degradation curves
- Convex optimization problem

Corner Case

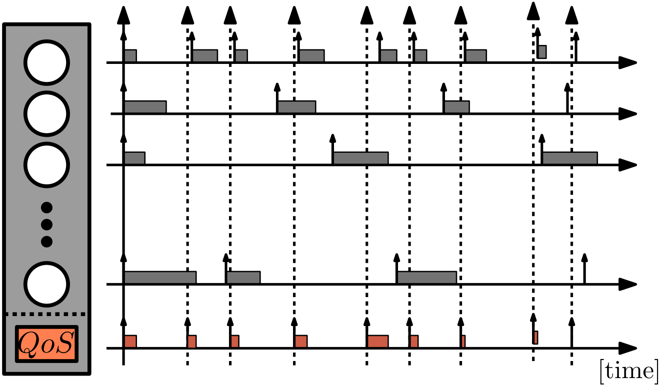


- For **concave** quality degradation curves, the optimum is one of the corner cases

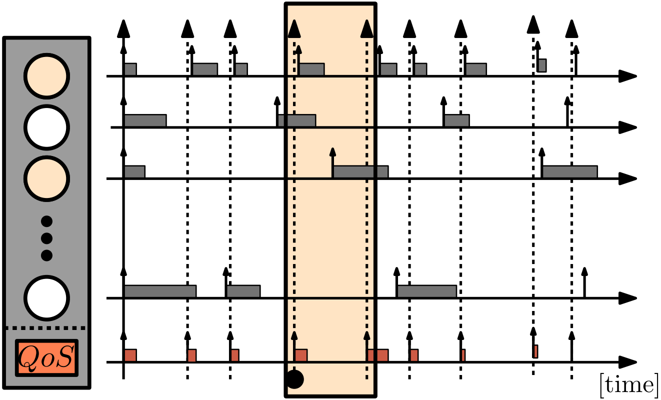
Overhead

- Active set of tasks (no. of tasks to be considered)
- Complexity

Active Set of Tasks



Active Set of Tasks



QoS Controller Complexity

QoS Controller	Complexity
Constant Bandwidth	$n \cdot O(1)$
Uniform QoS	$O(n \cdot O(q))$
QoS Derivative	$O(n \cdot O(q))$
Corner Case	$O(n \cdot log(n))$

- **n** – number of tasks (in the active set)
- **O(q)** – complexity of calling the quality degradation function for a value

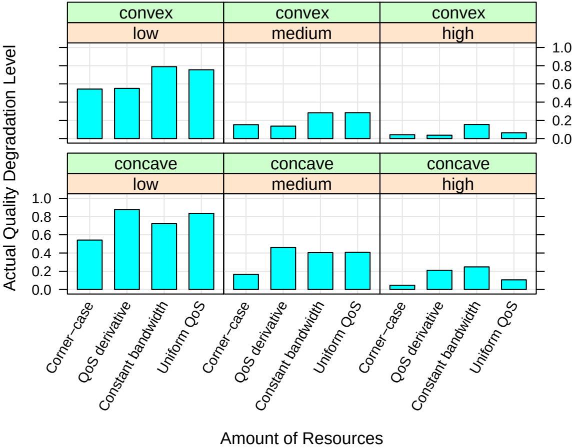
Other Problems

- Measure execution times
- Determine the number of jobs to execute (in the case of overload)
- Determine the QoS Controller's next activation point

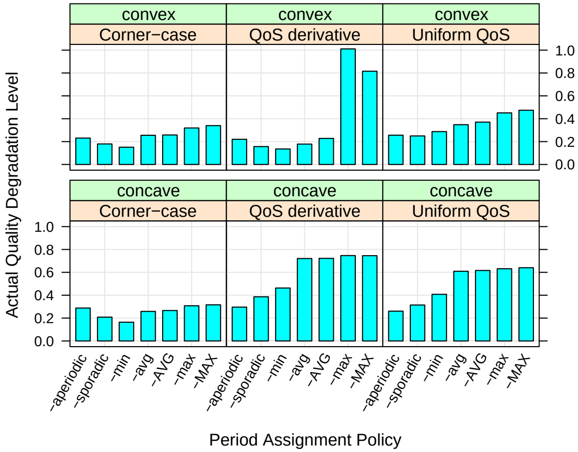
Setting

- 240 randomly generated test-cases with convex or concave quality degradation curves
- 5 to 100 tasks
- execution times variation $[c_{min}, c_{max}] = [c_{min}, 100 \cdot c_{min}]$
- 3 different processors (*low*, *medium*, *high*)
- 6 different overhead setting ($P1$ to $P6$)

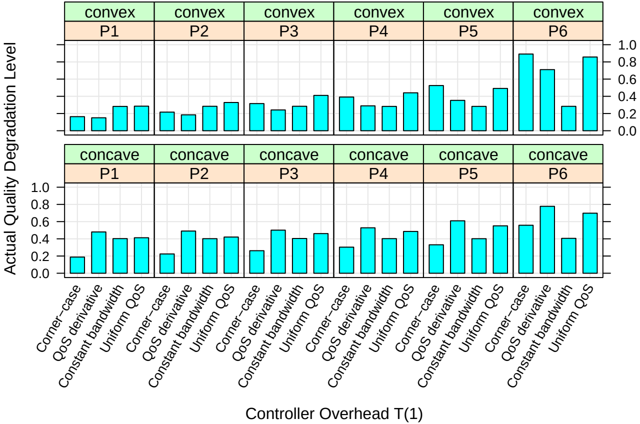
On-line Approaches



Period Assignment



Active Task Set and Overheads



Conclusions

- Solved the QoS problem for mono-processor systems with independent tasks
- Proposed approaches for **convex** and **concave** quality degradation curves
- Determined Controller complexity
- Considered overheads
- Considered other practical problems

Future Work

- More complex architectures
- Other types of resources
- More optimization criteria
- Stability

Questions???