Target-Based Power Control for Queueing Systems with Applications to Packet Switches

Benjamin Yolken, Dimitrios Tsamis, Nick Bambos
Stanford University

Introduction

Power consumption has become a major issue in modern data centers and thus power control has attracted a lot of attention. Many components of a data center, including packet switches, can be modeled as queueing systems. Jobs arrive at the system and wait for service. The system has a limited set of resources which can be deployed to service these jobs. At each point of time, the operator chooses a service configuration, i.e., a feasible combination of the device’s resources. Hence algorithms developed for packet switches can be generalized and applied to other components as well.

Notation

- \( Q \) parallel queues, indexed by \( q = 1, 2, \ldots, Q \)
- \( X(t) \): vector of job backlogs in each of the queues
- \( S(t) \): a service configuration (defines how many jobs are serviced from each queue)
- \( S \): set of possible service configurations
- \( A(t) \): vector of arrivals at time \( t \)

\[ X(t+1) = [X(t) - S(t)] + A(t) \]

Speed Modes

Assume:

\[ S = \{ S \mid S = kS_0, k \in \{0,1,\ldots,K\}, S_0 \in S \} \]

\( S_0 \) is a “base” configuration with only 0/1 elements

- \( k \) is the speed mode: as \( k \) increases more jobs are serviced from each queue

- \( k = 0 \) corresponds a “shutdown” of the switch

- By using a speed mode lower than the maximum one, less power is consumed, depending on the power profile of the switch.

- PCS will always choose the highest \( k \) – not ideal for power control

Target Based Power Control

Rule for choosing service configuration:

\[ S(t) = \arg \max \langle S, B(X(t) - b) \rangle \]

- \( b \) is a vector of backlog targets – set according to the relative delay sensitivities of the associated job flows

- Differentiated QoS is offered by playing with \( b \)

- Limited power savings when switch goes into shutdown mode

TP-PCS

Split space of possible backlog vectors in sub-spaces \( X_1, \ldots, X_K \)

- Where \( k \) denotes selected speed mode for the sub-space

- Simulations

- Great flexibility in choice!

Goal

Design a scheduling algorithm that offers the following:

- Stability
- Differentiated Quality of Service
- Power Control

Use existing algorithms as much as possible

==Projective Cone Scheduling==

- Rule for choosing service configuration:

  \[ S(t) = \arg \max \langle S, B(X(t)) - b \rangle \]

- Where \( B \) is a \( Q \times Q \) matrix with the following properties:
  - Positive Definite
  - Symmetric
  - Has non-positive off-diagonal elements

- \( B = I \) gives popular MWM algorithm [3]

- PCS is proven to be stable [1]

==Target-based PCS==

- Rule for choosing service configuration:

  \[ S(t) = \arg \max \langle S, B(X(t) - b) \rangle \]

- \( b \) is a vector of backlog targets – set according to the relative delay sensitivities of the associated job flows

- Differentiated QoS is offered by playing with \( b \)

- Limited power savings when switch goes into shutdown mode

==Simulations==

- 4x4 switch

  - Assume speed mode regions \( E_j \) are co-centric spheres around the point \( X = b \)

  - Use \( B = I \) (MWM) and \( K = 4 \) speed modes

  - Power profile: speed mode \( k \) uses power \( k^2 \)

- Packet arrival model:

  - For each VOQ sample from a binomial distribution with parameters \( (K, a/4) \)

  - Utility \( = 1 - (B^T \beta)^k \)

- Backlog targets:

  - \( \beta \) where \( \beta > 0 \)

Bibliography

