Constraining Queuing Delay in a Router based on Superposition of N MMBP Arrival Process

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Outline

- Introduction
- DTH (Dynamic THreshold) Overview
- Performance Evaluation
- Conclusions
- Future Work
Introduction

• Quality of Service (QoS) is very important and normally being measured through metrics such as:
  • Network delay
  • Packet loss
  • Throughput
  • Fairness

• Network delay is critical for delay sensitive applications; therefore constraining end-to-end delay is a key QoS requirement nowadays.
Network Delay Components

- Propagation Delay
- Processing Delay
- Queuing Delay
- Transmission Delay
- Jitter
- Quality of Service
- Loss

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Queuing Delay

![Graph showing Queuing Delay vs time with and without control.](image-url)
Propose a new approach to bound average queuing delay using dynamic queue thresholds mechanism.
DTH Overview

- DTH (Dynamic Threshold) is a control theoretic queue management scheme which aims to bound the average queuing delay in a core router.

- A closed-loop feedback control is used to adjust target queue threshold dynamically based on the average queuing delay observed in the system.
DTH System Diagram

Offline Analysis:
- Traffic Class 1
  - S1
  - S2
  - Transition probabilities:
    - p
    - 1-p
    - 1-q
    - q

Traffic Class N
- S1
- S2
- Transition probabilities:
  - p
  - 1-p
  - 1-q
  - q

Offline Analysis:
- Queuing Analysis
- δDelay
- Target Queueing Delay
- Measured Average Queuing Delay

Online Regulation:
- DTH Router
- Movable Queue Threshold (L)
- Queue
- Buffer Size (K)
- DTH Controller
- Target Queue Threshold (L)
- DTH Queue
N MMBP-2 is used to represent aggregated Internet traffic formed by traffic flows from various traffic classes (e.g. CBR, VBR, voice).
Too complex to derive a closed-form function for relationship between delay and threshold, numerical analysis is used instead.
DTH Online Regulation

\[ G_k = kD_r - \sum_{i=1}^{k} D_i \quad ; \quad k = 1, 2, \ldots \]
\[ = D_r - D_k + G_{k-1} \]

\[ D_r = \frac{D_1 + D_2 + \cdots + D_k + \hat{D}_{k+1}}{k+1} \]

\[ \hat{D}_{k+1} = 2D_r - D_k + G_{k-1} \quad ; \quad k = 1, 2, \ldots \quad \& \quad G_0 = 0 \]

- Average queuing delay is calculated periodically and compared with required delay to get the delay delta.
- The target queuing delay for next time window is then estimated based on delay delta.
- Queue threshold is then adjusted based on the target queuing delay for the next time window.
Scenario 1: Different number of sources

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<td>5</td>
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Scenario 1
- MMBPs with same configuration, \( N = [1..5] \)
- \( \alpha_1 = \frac{0.4}{N} \); \( \alpha_2 = \frac{0.5}{N} \); \( p = 0.9999 \); \( q = 0.9999 \)
- Departure probability, \( \beta = 0.5 \)
- Required delay, \( D_r = 7 \)
Scenario 2: Different required delay

Scenario 2
- MMBPs with different configuration, $N = 3$
- MMBP #1:
  - $\alpha_1 = 0.1; \alpha_2 = 0.25; p = 0.9999; q = 0.9999$
- MMBP #2: $\alpha_1 = \alpha_2 = 0.2; p = 0.9; q = 0.9$
- MMBP #3: $\alpha = 0.15; \alpha_2 = 0; p = 0.5; q = 0.5$
- Departure prob., $\beta = 0.5$
- Required delay, $D_r = [5.9]$ with stepping 1

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<td>9</td>
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Scenario 3: Different service rate

- MMBPs with different configuration, N = 3
  - MMBP #1: $\alpha_1 = 0.30$; $\alpha_2 = 0.45$; $p = 0.9999$; $q = 0.9999$
  - MMBP #2: $\alpha_1 = \alpha_2 = [0.1..0.3]$ with stepping 0.05; $p = 0.9$; $q = 0.9$
  - MMBP #3: $\alpha = 0.15$; $\alpha_2 = 0$; $p = 0.5$; $q = 0.5$
- Departure prob., $\beta = [0.6..0.8]$ with stepping 0.05
- Required delay, $D_r = 7$

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Simulation Results

- Queuing threshold is movable to maintain queuing delay to its specific target.
- Packets are dropped when queue length > queue threshold; packet loss event becomes implicit feedback to the sources to regulate its transmission rate.
Conclusions

- A discrete-time analytical model which uses N MMBP-2 to represent multi-class traffic is developed to derive relationship between queuing threshold and queuing delay.

- A control strategy with dynamic queue thresholds is used to control queuing delay at a specified value.

- Packet loss event served as implicit congestion indication to the sources in order to regulate the sending rates.
Future Work

- Implement DTH mechanism into programmable network processor platform.
- Performance analysis on a real-time test-bed.
Thank You