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

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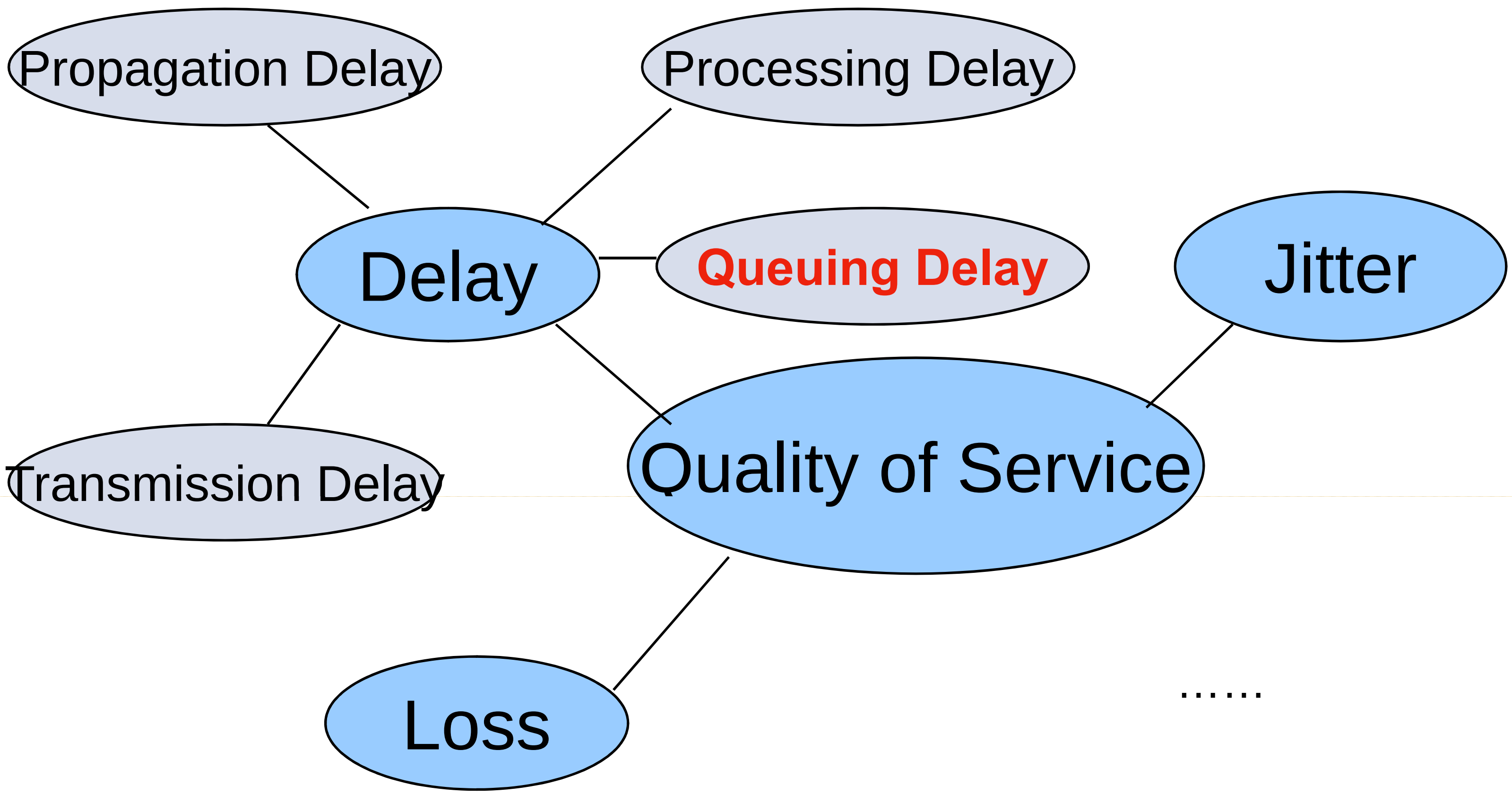
Outline

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

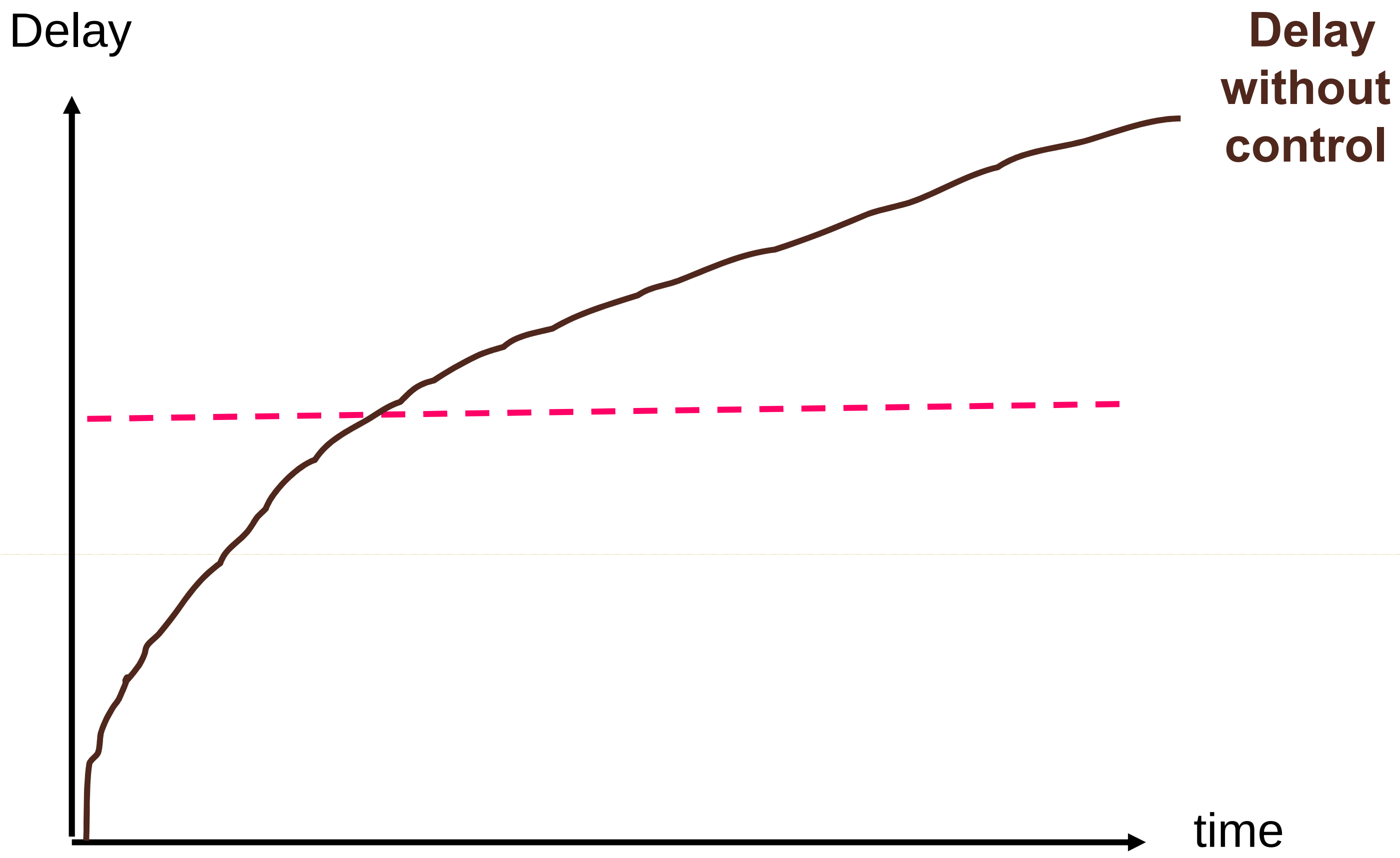
Introduction

- 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.

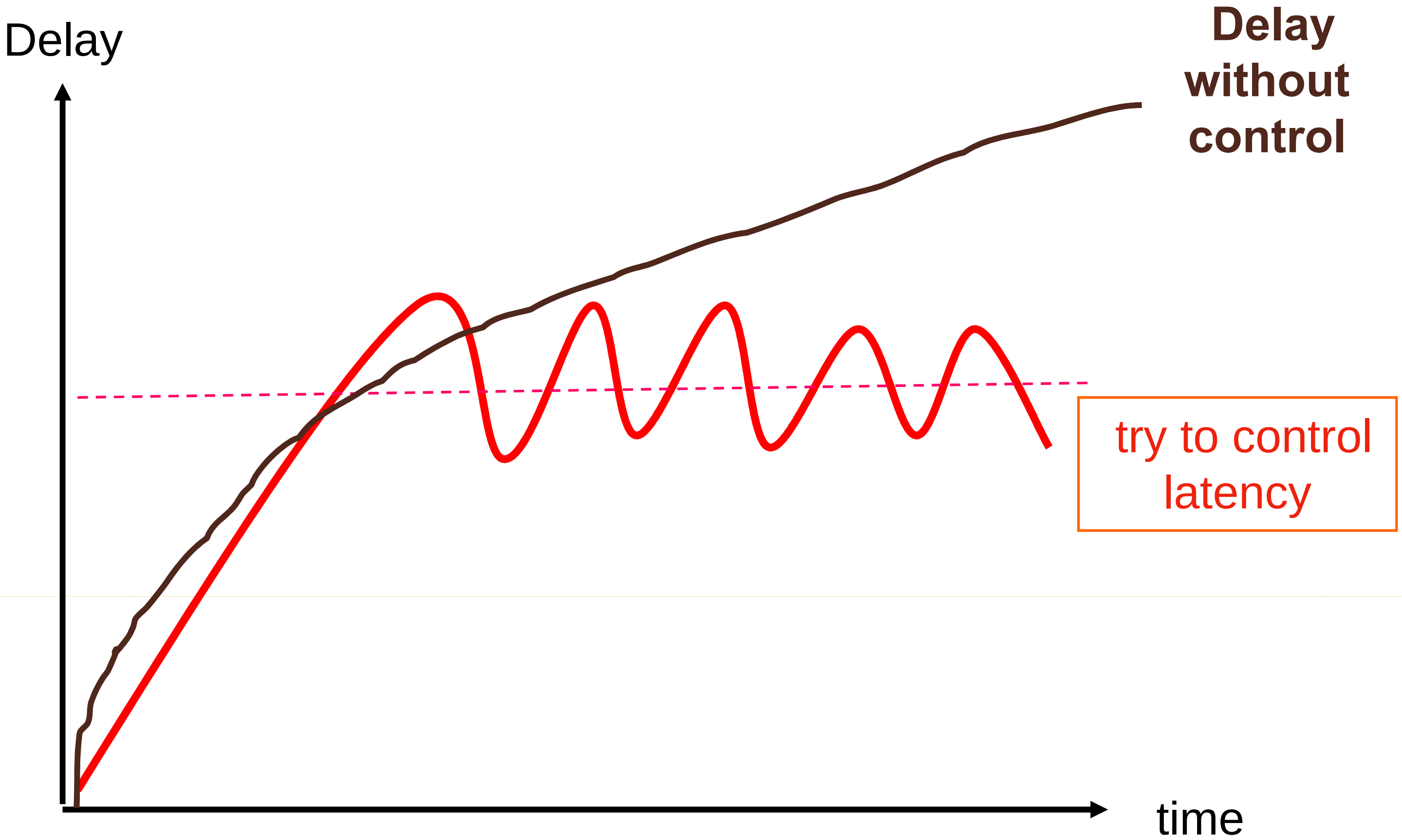
Network Delay Components



Queuing Delay



Queuing Delay

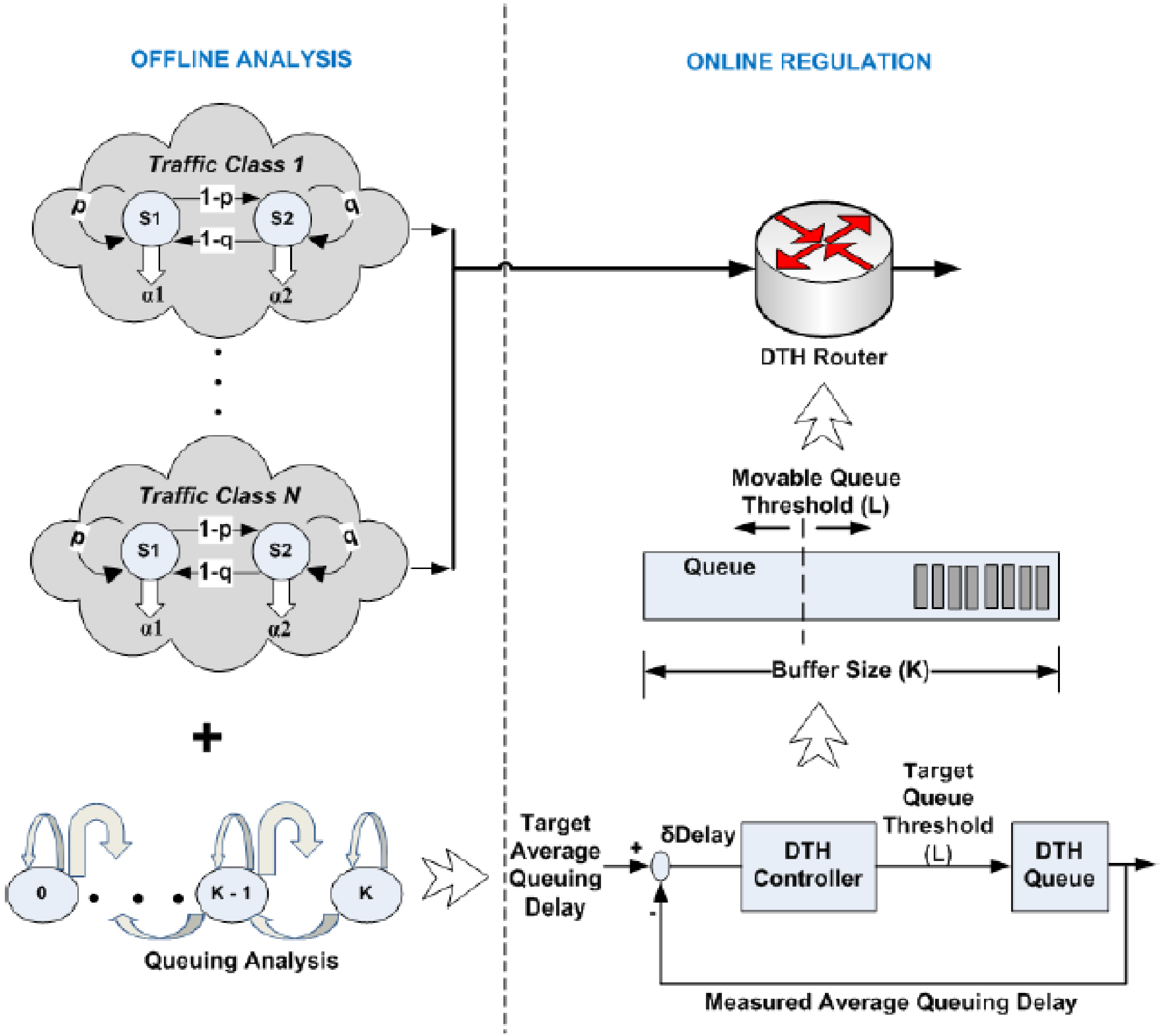


- Propose a new approach to bound average queuing delay using dynamic queue thresholds mechanism.

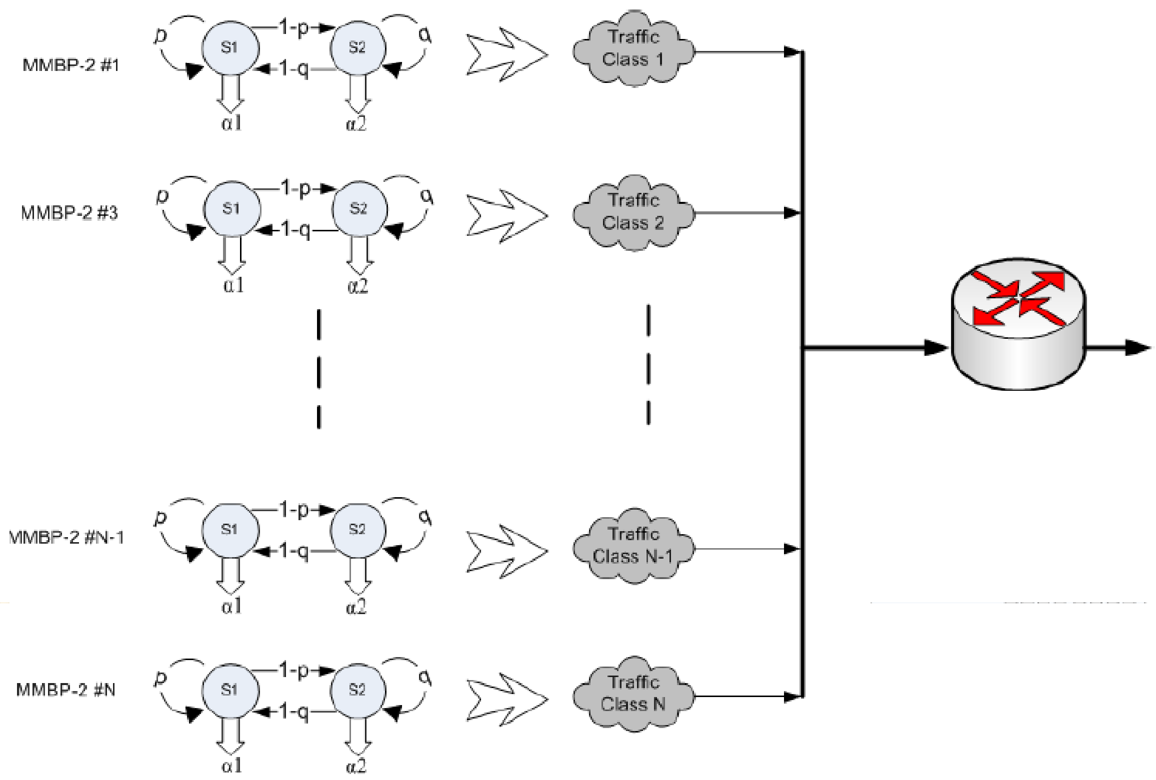
DTH Overview

- 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

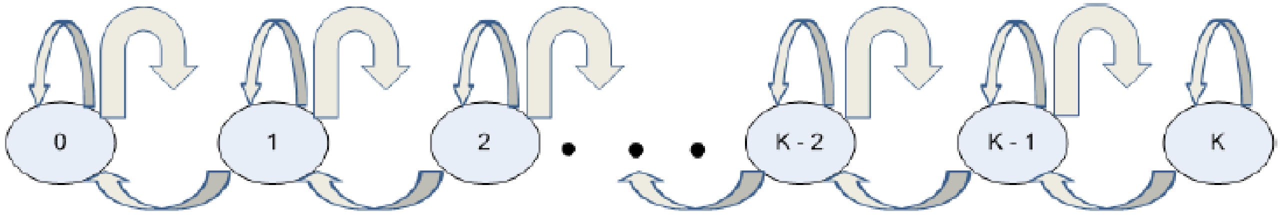


MMBP-2 Traffic Model



- N MMBP-2 is used to represent aggeregated Internet traffic formed by traffic flows from various traffic classes (e.g. CBR, VBR, voice).

Analytical Model



$$\begin{bmatrix} R' & Q(1)' & Q(2)' & Q(3)' & Q(4)' & 0 & 0 & 0 \\ D & R & Q(1) & Q(2) & Q(3) & Q(4) & 0 & 0 \\ 0 & D & R & Q(1) & Q(2) & Q(3) & Q(4) & 0 \\ 0 & 0 & D & R & Q(1) & Q(2) & Q(3) & Q(4)'' \\ 0 & 0 & 0 & D & R & Q(1) & Q(2) & Q(3)^* \\ 0 & 0 & 0 & 0 & D & R & Q(1) & Q(2)^* \\ 0 & 0 & 0 & 0 & 0 & D & R & Q(1)^* \\ 0 & 0 & 0 & 0 & 0 & 0 & D & R^* \end{bmatrix}_{(K+1,K+1)} \quad for\ N < K$$

$$\begin{bmatrix} R' & Q(1)' & Q(2)' & Q(3)' & Q(4)' & Q(5)' & Q(6)' & Q(7)' \\ D & R & Q(1) & Q(2) & Q(3) & Q(4) & Q(5) & Q(6)^* \\ 0 & D & R & Q(1) & Q(2) & Q(3) & Q(4) & Q(5)^* \\ 0 & 0 & D & R & Q(1) & Q(2) & Q(3) & Q(4)^* \\ 0 & 0 & 0 & D & R & Q(1) & Q(2) & Q(3)^* \\ 0 & 0 & 0 & 0 & D & R & Q(1) & Q(2)^* \\ 0 & 0 & 0 & 0 & 0 & D & R & Q(1)^* \\ 0 & 0 & 0 & 0 & 0 & 0 & D & R^* \end{bmatrix}_{(K+1,K+1)} \quad for\ N = K$$

$$\begin{bmatrix} R' & Q(1)' & Q(2)' & Q(3)' & Q(4)' & Q(5)' & Q(6)' & Q(7)'^* \\ D & R & Q(1) & Q(2) & Q(3) & Q(4) & Q(5) & Q(6)^* \\ 0 & D & R & Q(1) & Q(2) & Q(3) & Q(4) & Q(5)^* \\ 0 & 0 & D & R & Q(1) & Q(2) & Q(3) & Q(4)^* \\ 0 & 0 & 0 & D & R & Q(1) & Q(2) & Q(3)^* \\ 0 & 0 & 0 & 0 & D & R & Q(1) & Q(2)^* \\ 0 & 0 & 0 & 0 & 0 & D & R & Q(1)^* \\ 0 & 0 & 0 & 0 & 0 & 0 & D & R^* \end{bmatrix}_{(K+1,K+1)} \quad for\ N > K$$

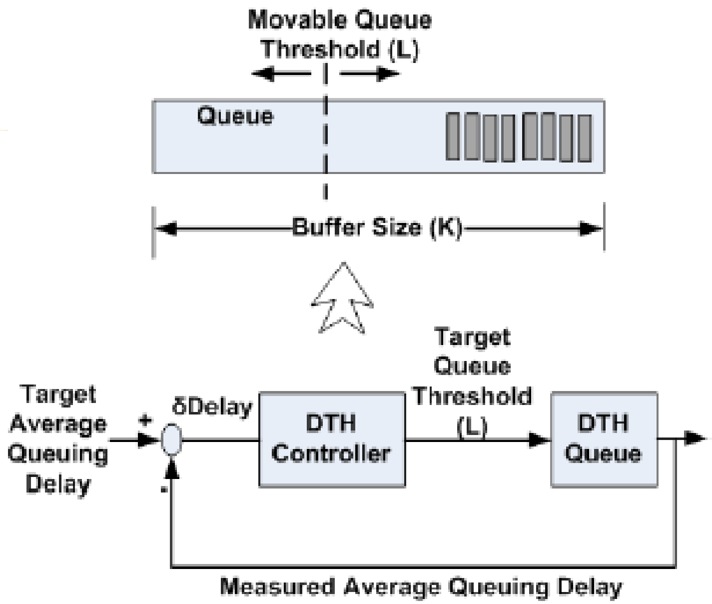
- Too complex to derive a closed-form function for relationship between delay and threshold, numerical analysis is used instead.

DTH Online Regulation

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

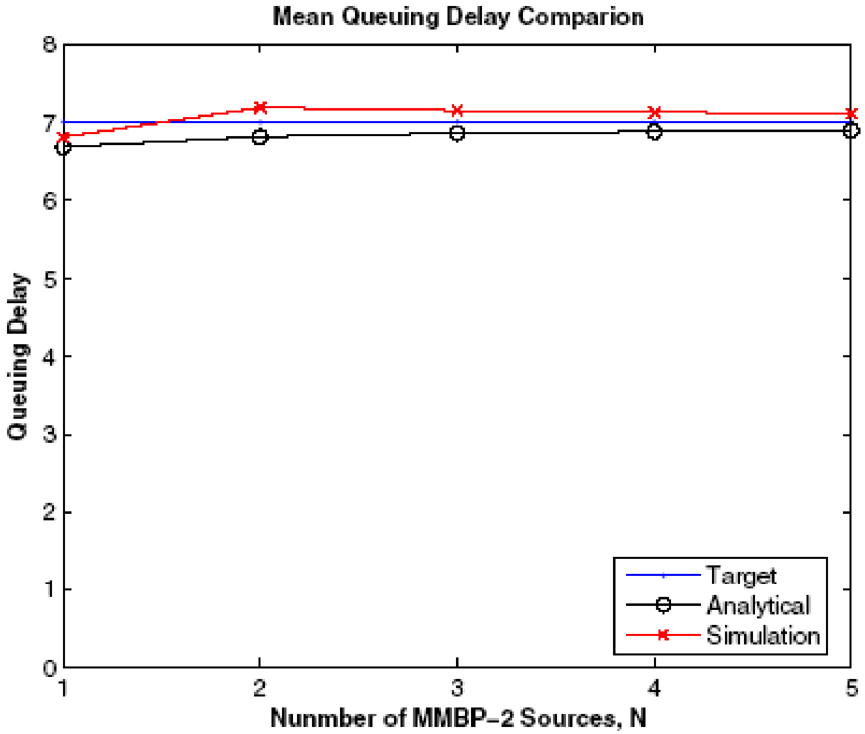
$$D_r = \frac{D_1 + D_2 + \cdots + D_k + \hat{D}_{k+1}}{k+1}$$

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



- 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.

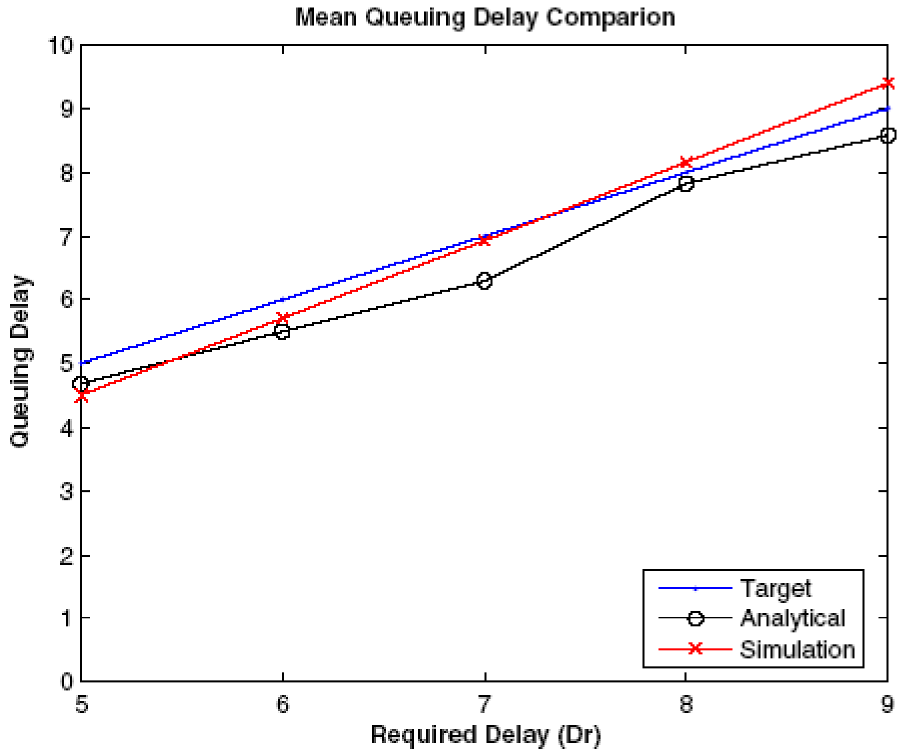
Scenario 1: Different number of sources



N	SCV	MSE
1	0.1229	0.1599
2	0.1554	0.1895
3	0.3177	0.3392
4	0.3485	0.3642
5	0.3281	0.3406

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, $D_r = 7$

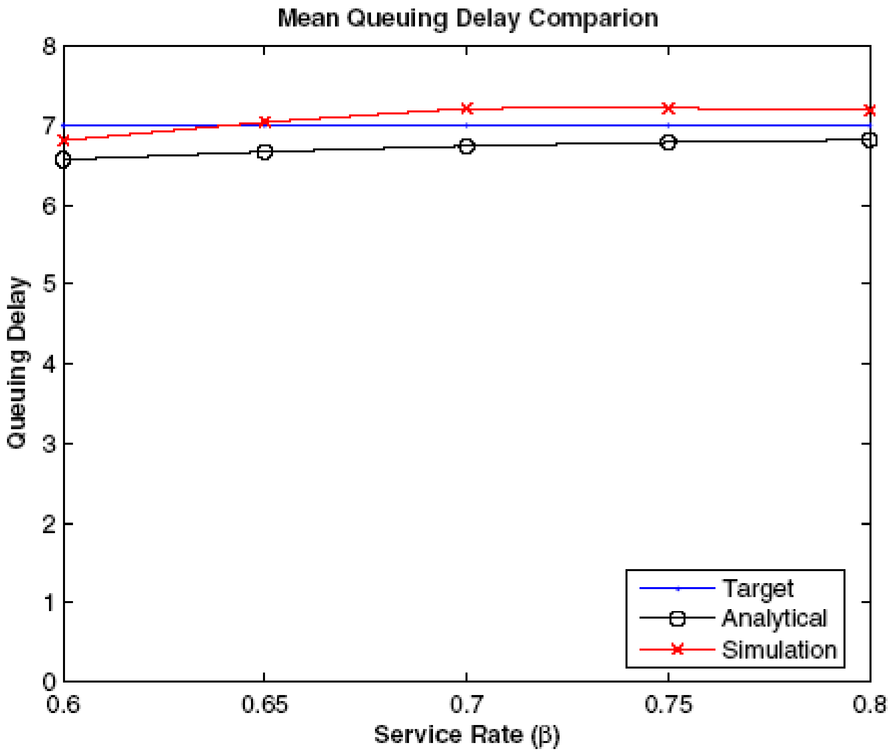
Scenario 2: Different required delay



Dr	SCV	MSE
5	0.3233	0.4392
6	0.2181	0.2279
7	0.1382	0.1471
8	0.2095	0.2233
9	0.3884	0.4649

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

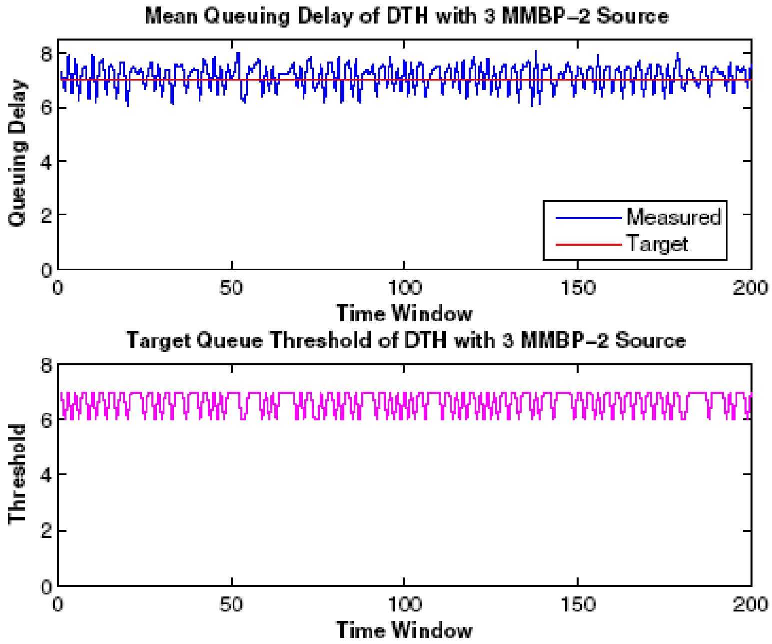
Scenario 3: Different service rate



β	SCV	MSE
0.60	0.3845	0.6324
0.65	0.3370	0.4225
0.70	0.2872	0.2922
0.75	0.2405	0.2655
0.80	0.4643	0.6223

Scenario 3	• 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, $D_r = 7$

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