Performance Analysis of Multiclass FIFO:
Motivation, Difficulty and a Network Calculus Approach

Yuming Jiang

Norwegian University of Science and Technology (NTNU)

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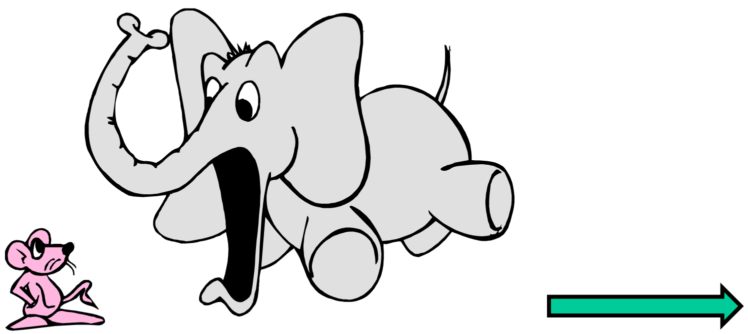
Outline

- Motivation
- Performance Analysis of Multi-Class FIFO: Difficulty with the Classic Queueing Theory
- Direct Analysis using Network Calculus
- A New Idea for Analysis using Network Calculus
- Concluding Remarks

Motivating Scenarios

- Internet packet size distribution
  - 40 (60%)
  - 1300-1500 (40%)

- Flows with different packet sizes sharing the same output link



Motivating Scenarios (cont')

- Downlink sharing in wireless networks *(e.g. DSCH – downlink shared channel)*

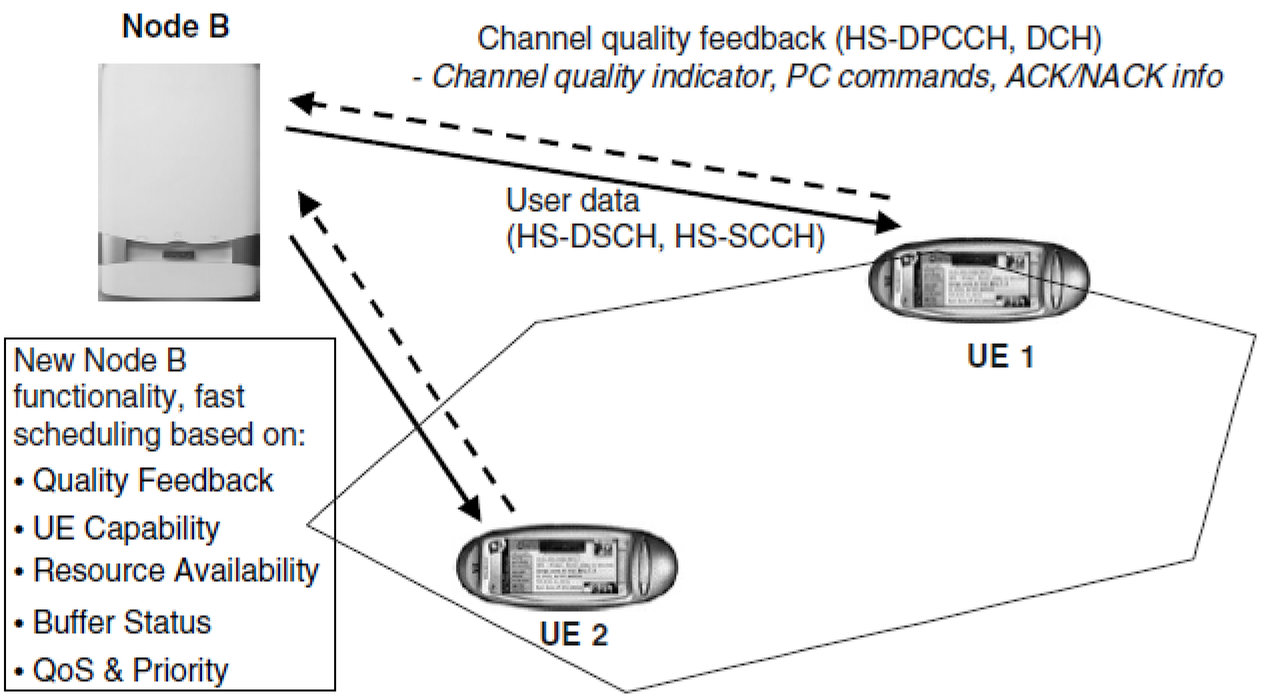
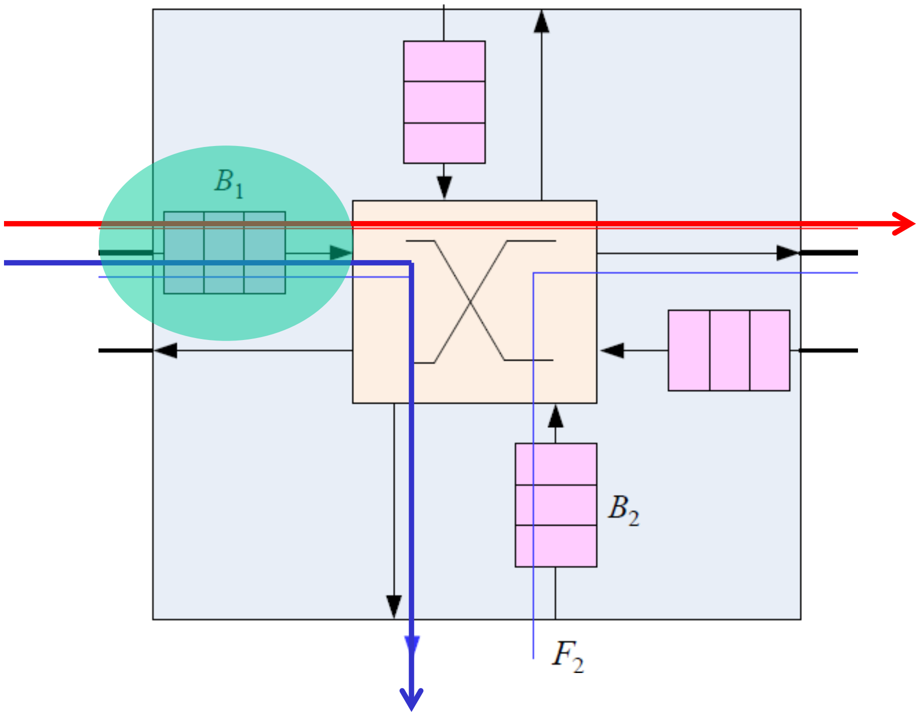


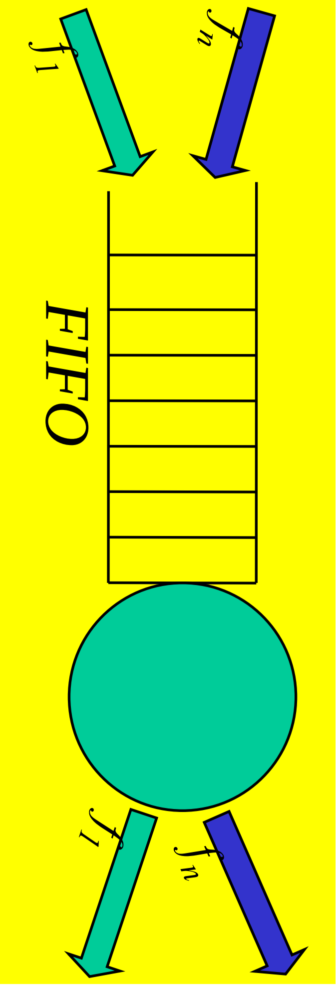
Figure from *"WCDMA for UMTS"*, edited by Harri Holma and Antti Toskala, 2002

Motivating Scenarios (cont')

- Input queueing in switches / routers

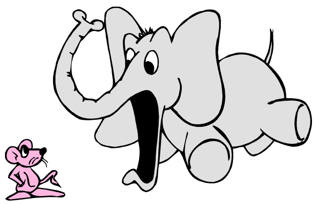


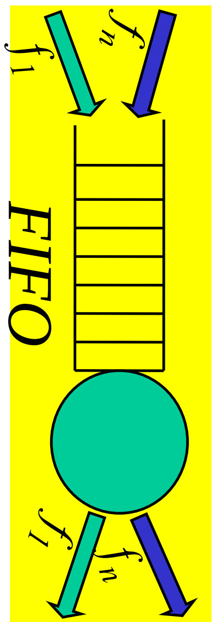
Performance Analysis of Multi-Class FIFO: System Model

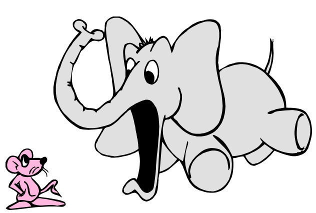


- A packet-switched network node serve packets in FIFO manner.
- There are N traffic classes.
- The service rate of each class is constant C_n in bps.

Analysis using Queueing Theory: Difficulty

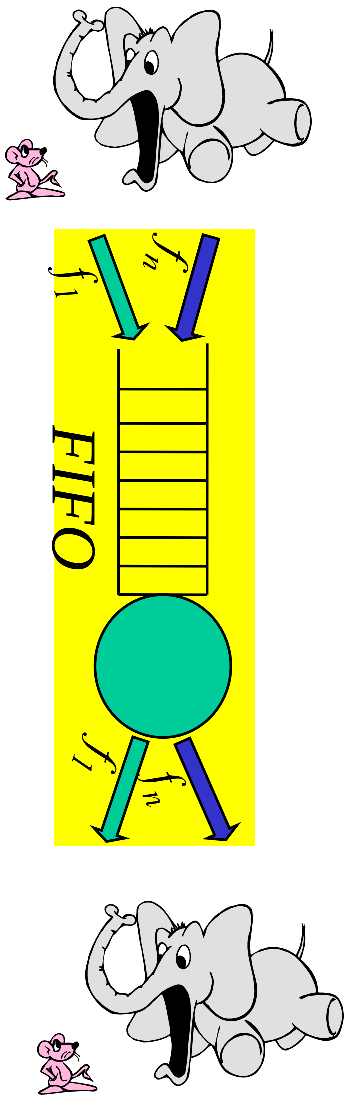






- How to define system states? Is (# of each class packet in queue) sufficient? If not, what else?
- Assume Poisson arrival process and exponentially distributed packet lengths of each class. What is the state transition diagram? Or, ***is it possible to get one***?
- If interarrival times are not exponentially distributed, or packet times are not exponentially distributied, how to do the analysis?

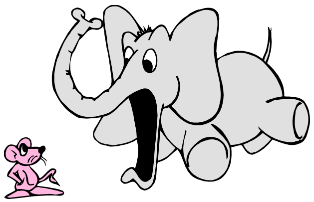
Analysis using Network Calculus

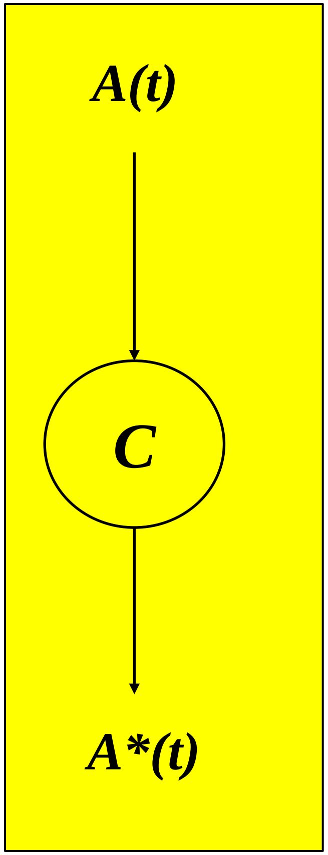


- Assumption: The traffic flow of each class is (σ, ρ)-constrained:

$$A_n(s,t) \leq \sigma_n + r_n(t-s)$$

Direct Results from Network Calculus



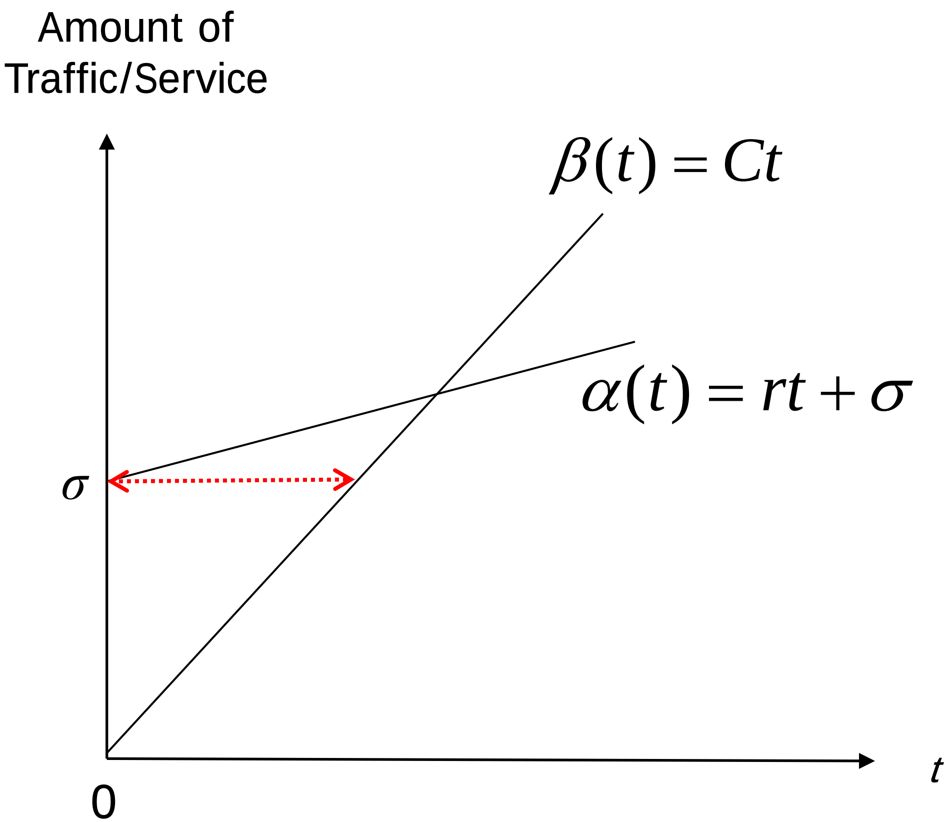


- If the service rates to all classes are the same C, the system becomes the normal single-class FIFO;

- The total input A(t) is constrained by:

$$A(s,t) \le \sum_n \sigma_n + \sum_n r_n (t - s)$$

Direct Delay Bound from Network Calculus (*with ignoring the "last" packetizer effect*)

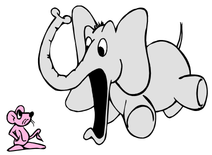


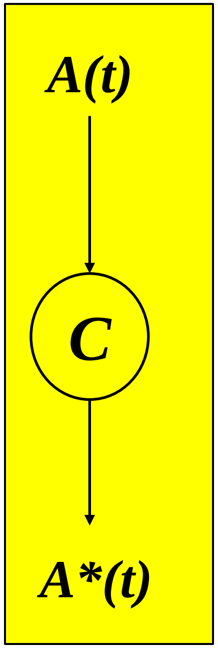
- If the total arrival rate is smaller than C, the delay of any packet is bounded by:

$$D \le \frac{\sum_n \sigma_n}{C}$$

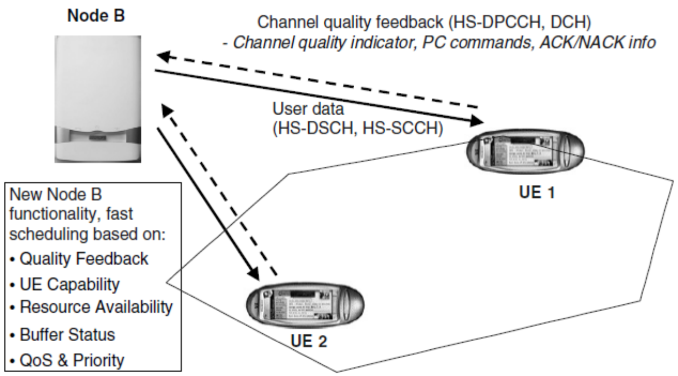
Analysis of Multiclass FIFO: Network Calculus Approach

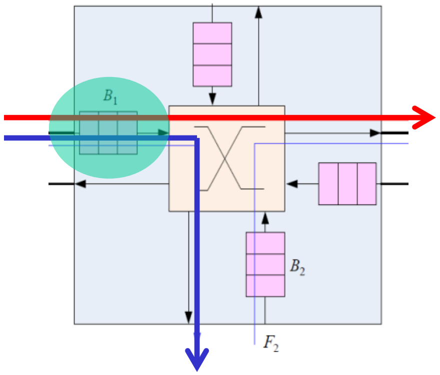
- Easy ☺



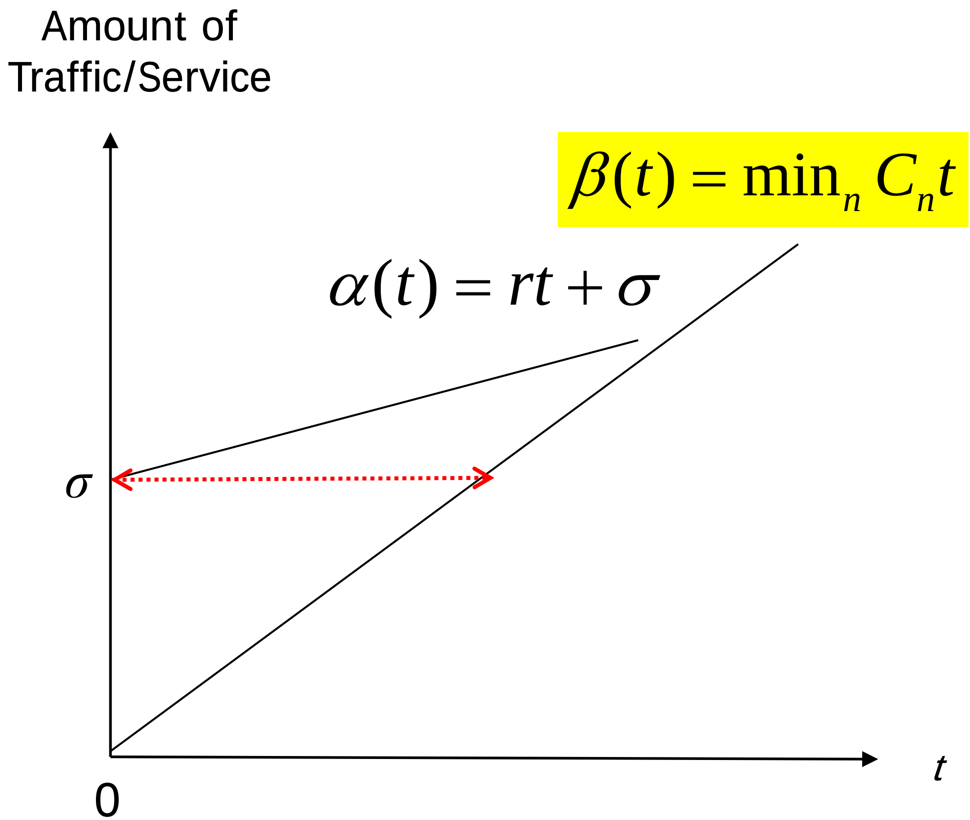


- But, wait: What if the service rate (in bps) for each class is different ?





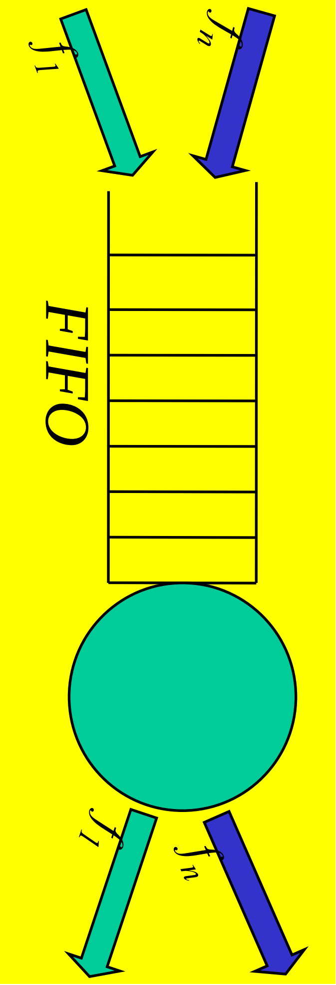
Direct Delay Bound from Network Calculus



- For multiclass FIFO, the minimum service rate to any class is ***$\min_n C_n$***.
- If the total arrival rate is smaller than *$\min_n C_n$*, the delay is bounded:

$$D \le \frac{\sum_n \sigma_n}{\min_n C_n}$$

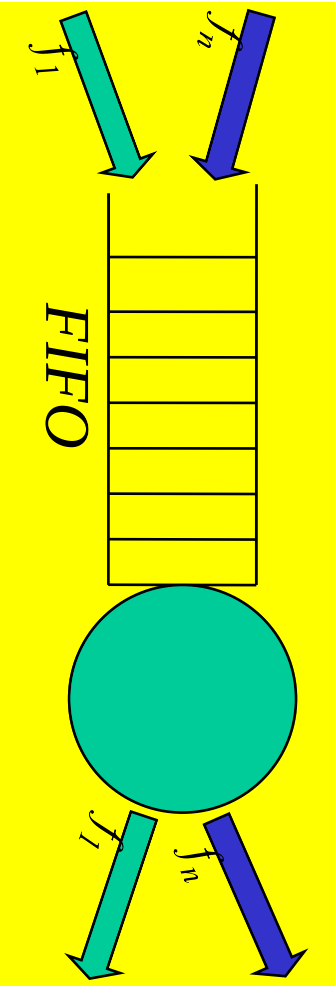
Analysis of Multi-Class FIFO:
A new idea for the network calculus approach



- Inequality: For any packet arriving at *t*, its delay is bounded by:

$$D \le \sum_n \frac{\sup_{s \le t}[A_n(s,t) - r_n(t-s)]}{C_n}$$

Improved Delay Bound



- Suppose the following condition holds

$$\sum_n \frac{r_n}{C_n} < 1$$

- The delay of any packet is bounded by:

$$D \leq \sum_n \frac{\sigma_n}{C_n}$$

- The bound is tight!

Comparison of Delay Bounds

- Condition:

$$\sum_n \frac{r_n}{\min_n C_n} < 1$$

- Condition:

$$\sum_n \frac{r_n}{C_n} < 1$$

- Direct bounded:

$$D \le \sum_n \frac{\sigma_n}{\min_n C_n}$$

- Improved Bound:

$$D \le \sum_n \frac{\sigma_n}{C_n}$$

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Comparison of Delay Bounds

- Two classes
- C1 = 10 Mbps
- C2=100 Mbps

- Each class has one flow.
- Each flow is (σ, ρ)-constrained with burstiness parameter 1KB and rate parameter 100 Kbps.

$$A_i(s,t) \le 8Kb + 100Kbps \times (t-s)$$

- Condition: $\sum_2 \frac{100Kbps}{10Mbps} < 1$
- Direct bounded:

$$D \le \sum_2 \frac{8Kb}{10Mbps} = 1.6ms$$

- Condition:

$$\frac{100Kbps}{10Mbps} + \frac{100Kbps}{100Mbps} < 1$$

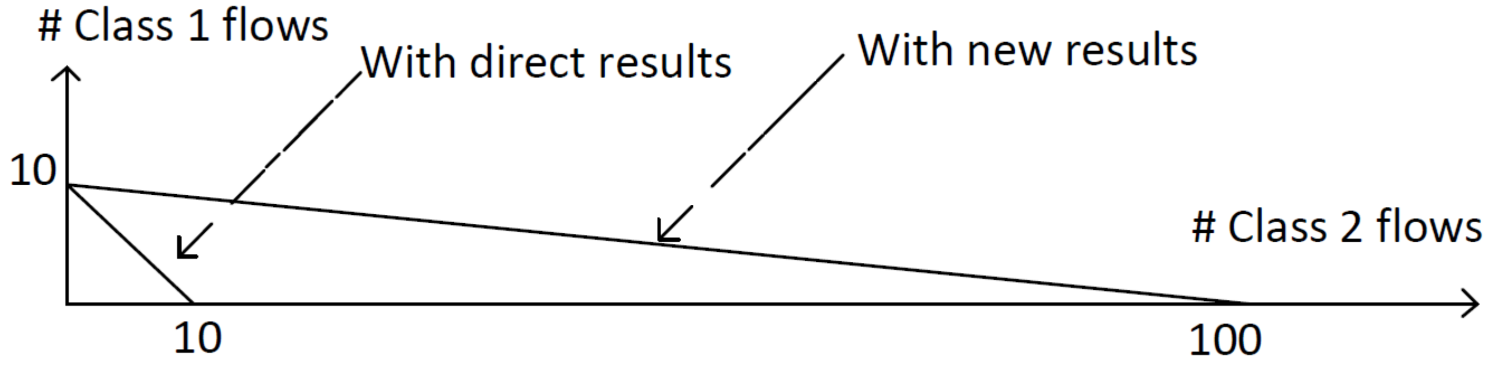
- Improved Bound:

$$D \le \frac{8Kb}{10Mbps} + \frac{8Kb}{100Mbps} = 0.88ms$$

Implication of the Delay Bound Difference

- Suppose the same 2-class FIFO system.
- Question: How many Class 1 & Class 2 flows, *(M_1, M_2)*, may be admitted if a delay bound of 8ms needs to be guaranteed?

Must consider both the condition and the corresponding delay bound in finding the region for *(M_1, M_2)*.



Concluding Remarks

- **Surprisingly difficult to analyze multi-class FIFO using Queueing Theory.**
- Network calculus approach may be used directly, but with limited application scenarios and/or loose bounds.
- A new idea for the network calculus approach can improve the bounds.
- The analysis has been extended to stochastic and network cases.
- The analysis has been extended for other performance metrics e.g. backlog and leftover service, but more diffficult and has room to improve.
- *Part of the results were presented at 2nd European Teletraffic Seminar (ETS), Sept 2013, and included in arXiv (http://arxiv.org/abs/1306.4773).*