

# **Exploring the Impact of Differentiated Services on Carrier Networks**

Masters Thesis Presentation  
July 10, 2000

Ajay Uggirala  
Information and Telecommunications Technology Center  
Department of Electrical Engineering and Computer Science  
University of Kansas

**Thesis Committee:** Dr. Victor S. Frost, Chair  
Dr. Douglas Niehaus  
Dr. Arvin Agah

# Organization

- Motivation.
- Introduction.
- Impact of Overbooking in DiffServ Networks.
- Impact of Number of DiffServ Classes.
- Conclusions and Lessons Learned.
- Future Work.

## **Motivation**

- Lack of detailed understanding of the characteristics and impact of Differentiated Services.
- The significance of Differentiated services to carrier networks is unknown.

## **Goal**

- To identify the problems associated in the deployment of Differentiated Services.
- To identify the target architectures, functional elements and parameters.

# Introduction

What is Differentiated Services ?

Differentiated services (DiffServ) are intended to provide service discrimination in the Internet.

Need for DiffServ:

- Demand for bandwidth due to increase usage of Internet
- Demand for QoS by voice and other mission critical applications.
- Scalable service discrimination.

Services and Per-Hop-Behavior (PHB)

- Service - Overall treatment of a subset of a customer's traffic.
- PHB - Service provided to a traffic aggregate.

## Introduction (contd...)

Type of Service field in Internet Protocol header value may be used to categorize flows into aggregates.

The DiffServ Code Point (DSCP) value may be used to select a particular PHB for an aggregate flow.

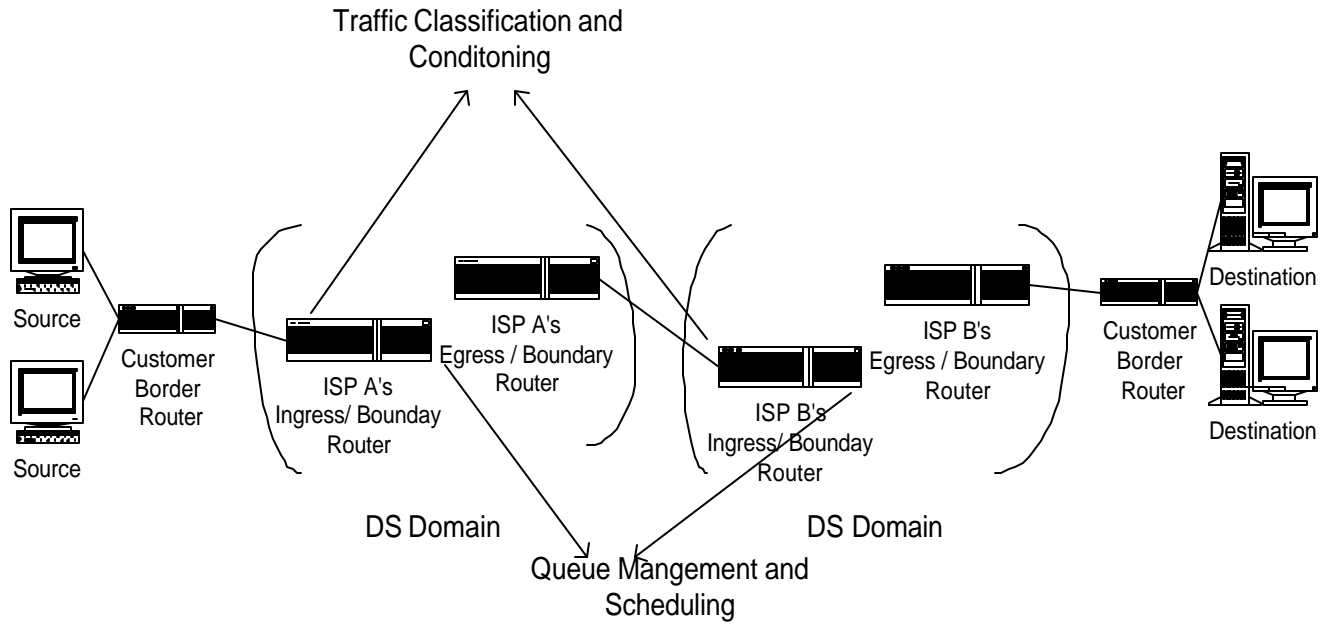
### Examples of PHBs

- Expedited Forwarding.
- Assured Forwarding.

### Examples of Services

- Premium Service - Van Jacobson.
- Assured Service - David Clark.

## Introduction (contd...)



An Example Architecture

## Introduction (contd...)

	Type of node	Type of interface	Functional Elements (FE).	Type of FEs.
DS domain	Boundary Node.	Input Interface.	<ul style="list-style-type: none"> <li>✍ Traffic classifier.</li> <li>✍ Traffic conditioners (TC)</li> </ul>	<ul style="list-style-type: none"> <li>✍ <b>BA</b> or MF classifier.</li> <li>✍ TCs for each PHB offered in domain are required.</li> <li>✍ <b>Three-ColorMarkers.</b></li> </ul>
		Output Interface.	<ul style="list-style-type: none"> <li>✍ Classifiers</li> <li>✍ Queue management</li> <li>✍ Scheduling</li> <li>✍ TC (optional)</li> </ul>	<ul style="list-style-type: none"> <li>✍ Mostly <b>BA</b> classifier.</li> <li>✍ <b>FIFO, RED, WRED</b> and <b>RIO</b> the choice mainly depends on the PHBs offered in domain</li> <li>✍ <b>FIFO, SPQ, or DRR.</b></li> <li>✍ TC is used particularly if <b>SPQ</b> is used.</li> </ul>
	Interior Node.	Input Interface.	<ul style="list-style-type: none"> <li>✍ Usually no special components are required.</li> </ul>	None.
		Output Interface.	<ul style="list-style-type: none"> <li>✍ Classifiers</li> <li>✍ Queue management</li> <li>✍ Scheduling</li> </ul>	<ul style="list-style-type: none"> <li>✍ Mostly <b>BA</b> classifier.</li> <li>✍ <b>FIFO, RED, WRED</b> or <b>RIO</b> mainly depends on the PHB that is being realized.</li> <li>✍ <b>FIFO, SPQ, or DRR.</b></li> </ul>

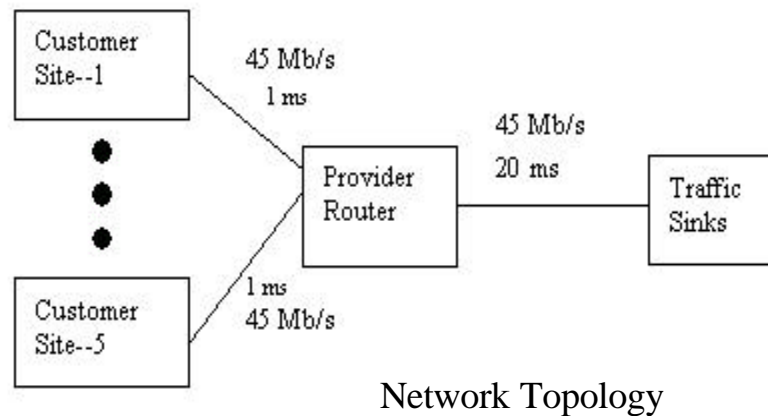
BA - Behavior Aggregate. MF - Multi Field.

RED -Random Early Drop. RIO - RED with IN OUT. WRED - Weighted RED.

FIFO - First In First Out. SPQ - Strict Priority Queuing. DRR - Deficit Round Robin.

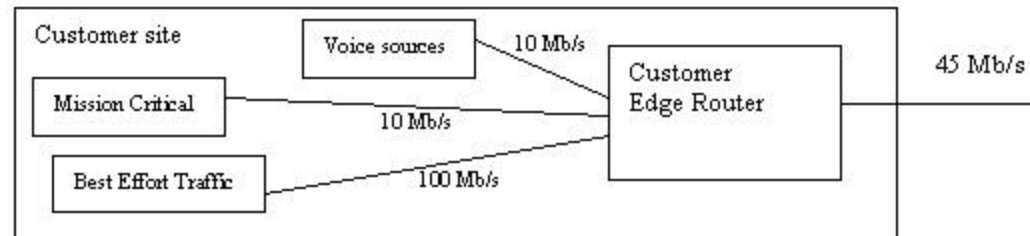
## Impact of Overbooking in DiffServ Networks

- To determine the impact of overbooking on end-to-end characteristics.
- Overbooking is achieved by increasing the number of customer sites served by a single provider edge router



- DRR and WRED in the Provider Edge Router.

- DRR and FIFO in the Customer Edge Router.





## Traffic Model

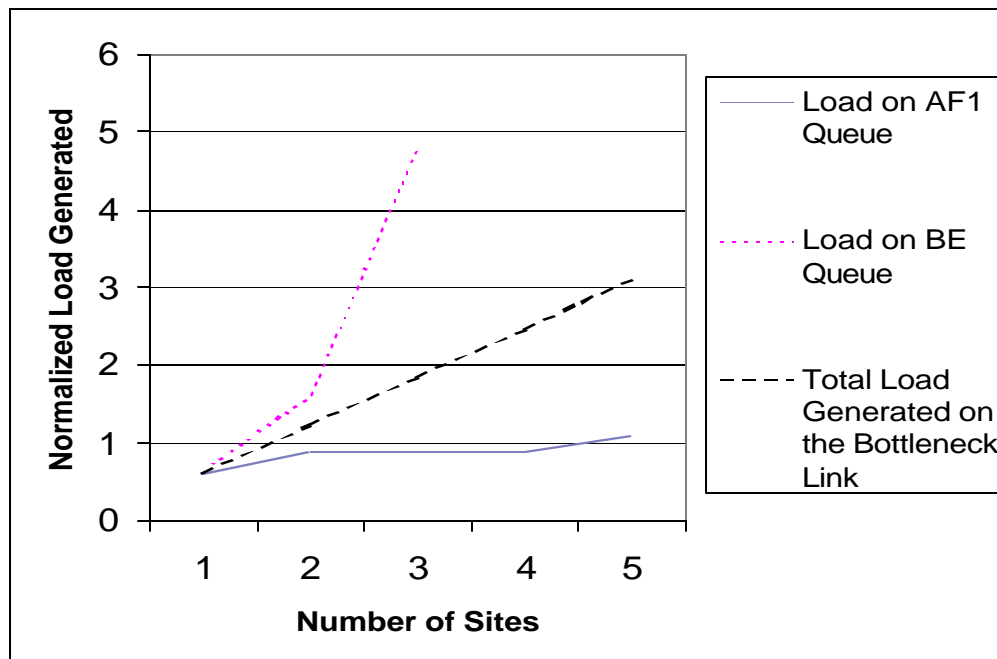
<b>Parameter</b>	<b>Voice</b>	<b>Mission Critical</b>	<b>Best Effort (BE)</b>
Packet Length (PL)	64 bytes	1500 bytes	1500 bytes
Packet Generation Rate (PGR)	10,000 Pks/sec	400 Pks/sec	1500 Pks/sec
Total Traffic	5.12 Mbps	4.8 Mbps	18.0 Mbps
Distribution for PL and PGR	Fixed	Exponential	Exponential
Class	AF1X	AF11	BE
Transport Protocol	UDP / TCP	TCP	TCP

Total AF1 traffic / site = 9.92 Mbps (22% of the DS3).    Total BE traffic / site = 18 Mbps (22% of the DS3).  
 Total traffic/site = 27.92 Mbps (62 % of a DS3).

# Parameters

DRR Parameters:

Provider router weights: 1 customer site	Provider router weights: 2 customer sites	Provider router weights: 3 customer sites	Provider router weights: 4 customer sites	Provider router weights: 5 customer sites
AF1 11.25 Mb/s	AF1 22.5 Mb/s	AF1 33.75 Mb/s	AF1 45.0 Mb/s	AF1 45.0 Mb/s
BE 33.75 Mb/s	BE 22.5 Mb/s	BE 11.25 Mb/s	BE 0 Mb/s	BE 0 Mb/s



## Parameters

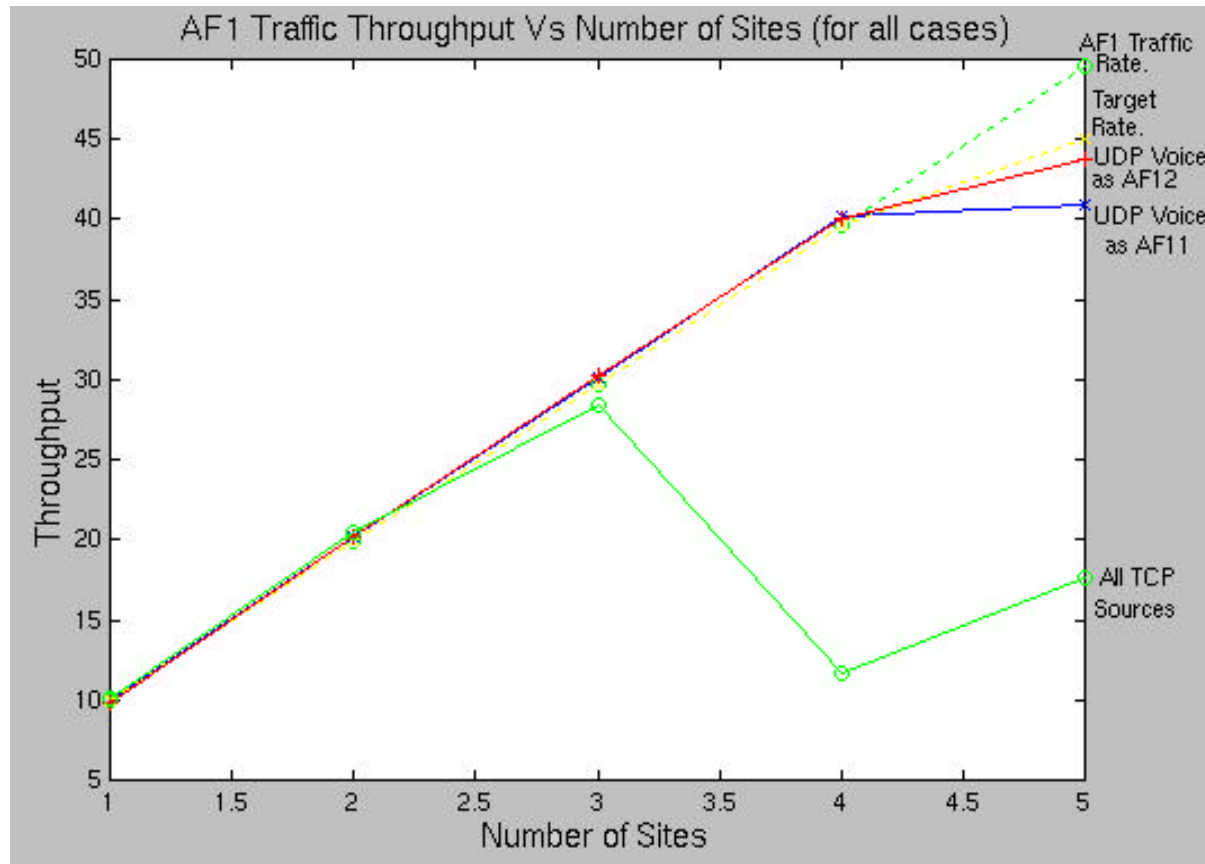
WRED Parameters:

<b>Class</b>	<b>Minimum Threshold (bytes)</b>	<b>Maximum Threshold (bytes)</b>	<b>Max. Drop Prob.</b>	<b>Traffic Type Queued</b>
AF11	238,846 bytes	477,692 bytes	0.02	Voice and MC
AF12	185,769 bytes	477,692 bytes	0.05	Voice
BE	135,000 (90 pks)	270,000(180 pks)	0.02	Best Effort

Performance Metrics:

- Average end-to-end delay per source,
- Jitter per source and
- Throughput per source and DSCP marking (are only presented).

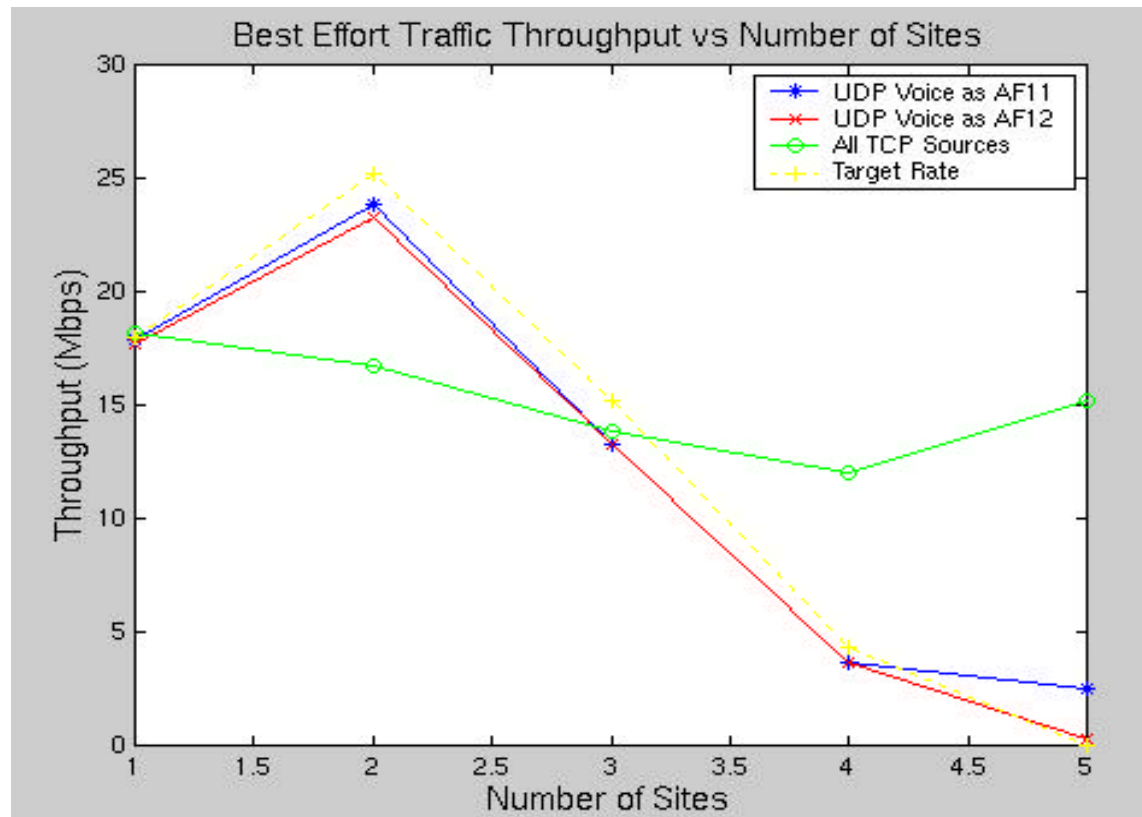
## Results



AF1 traffic end-to-end throughput

- AF1 traffic got the best performance when voice was configured as UDP and AF12.

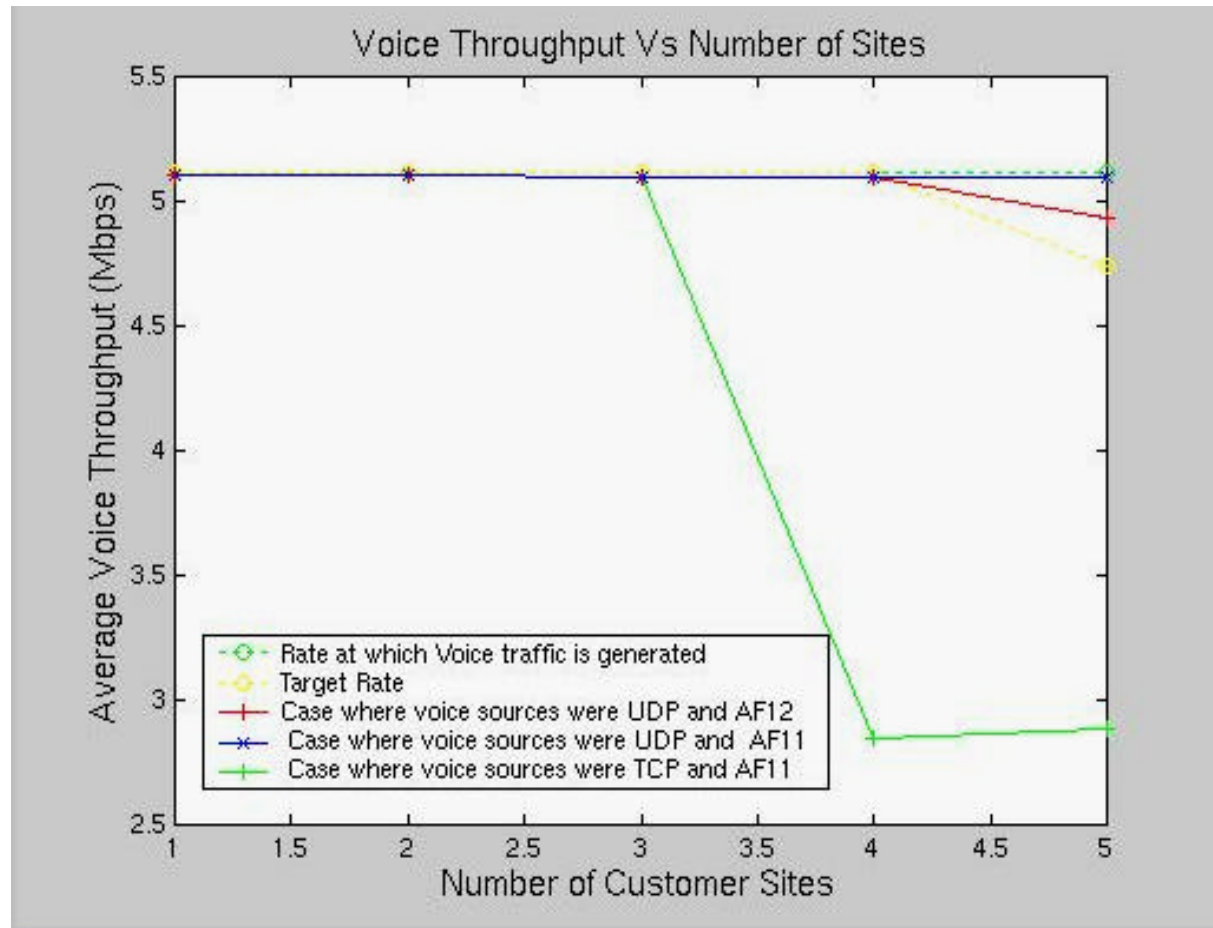
## Results (contd...)



BE Traffic Class Throughput

- The Throughput following close to the target rate when voice was configured as AF12 and to use UDP.

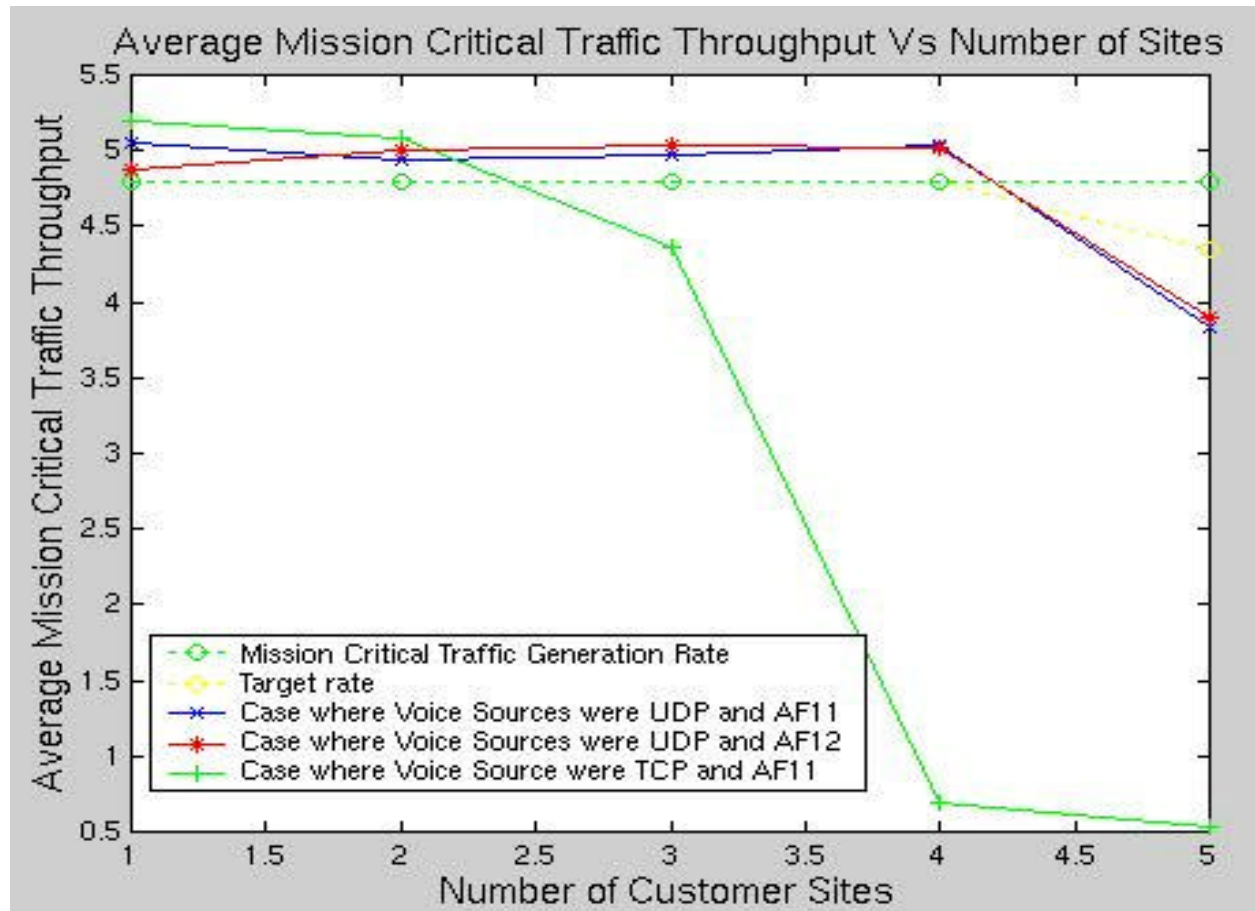
## Results (contd...)



Average End-to-End Throughput for Voice Source

- The throughput achieved was effected badly when voice was configured to use TCP.

## Results (contd...)



Average End-to-End Throughput for Mission Critical Source

- Treated unfairly when queue by voice traffic, badly effected when voice was changed to TCP.

## Conclusions from Overbooking Study

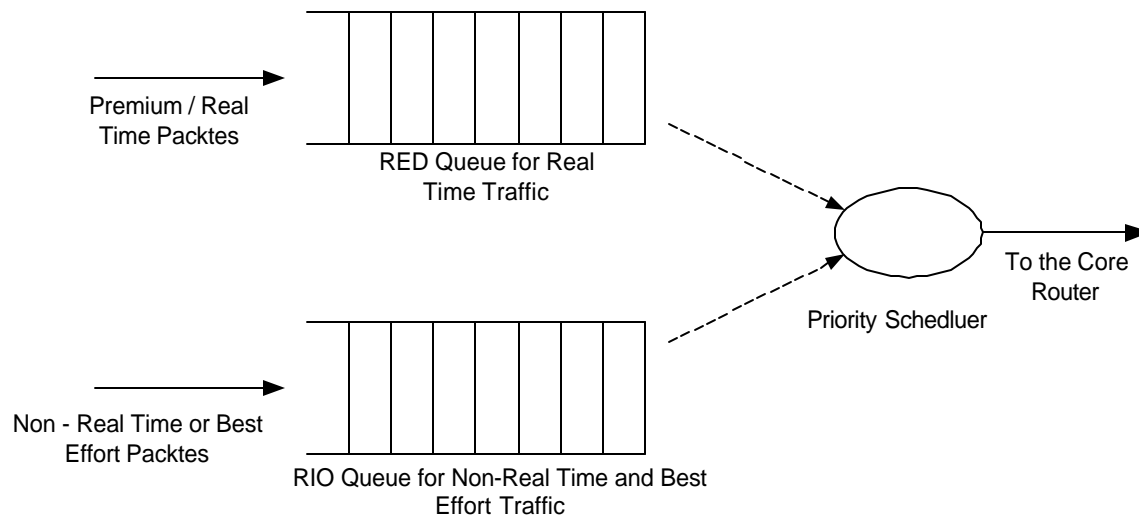
- AF1 traffic achieved end-to-end results even when the link was overloaded.
- When Voice sources were using UDP, mission critical traffic was treated unfairly.
- Mission Critical traffic was protected to certain extent by assigning higher drop precedence to voice traffic.
- Both Mission Critical and Voice traffic got good performance results till the number of sites were four, when was using UDP.
- When Voice was using TCP, performance started degrading when the number of sites were only four.
- RED treated larger size Mission Critical packets unfairly in byte mode.



## **Evaluation of the Performance Impact of the Number of DiffServ Classes**

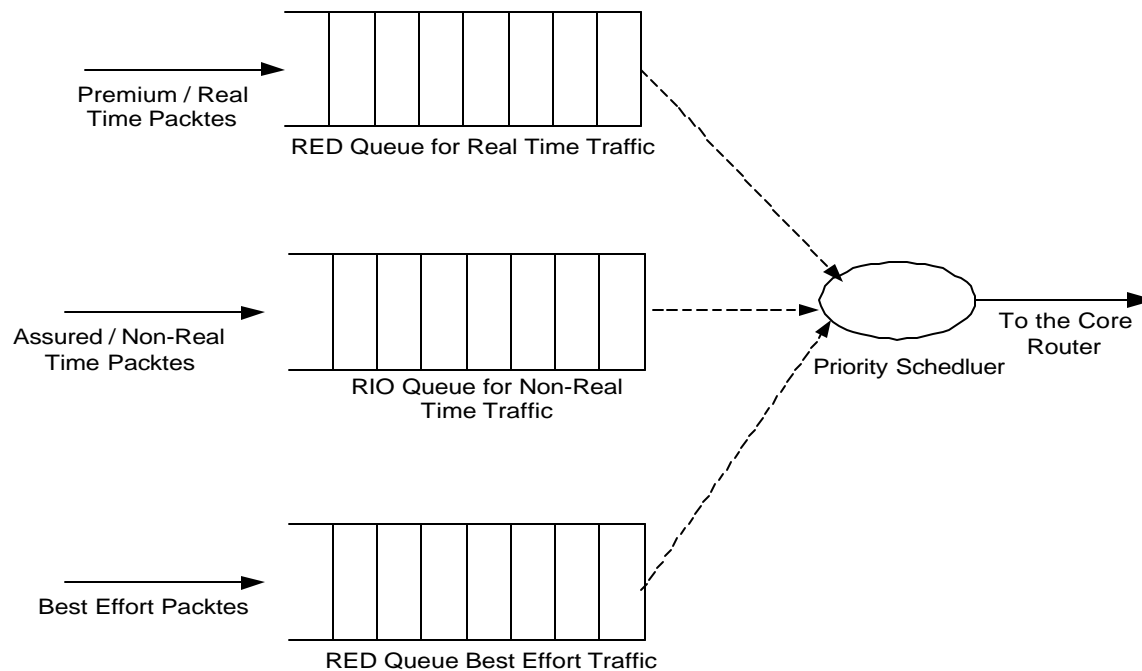
- To compare performance of the two-queue model and the three-queue model in the provider's core.
- To study the impact of scheduler in the customer edge.
- Three types of traffic are considered.
  - Real Time (RT) (Premium).
  - Non-Real Time (NRT) (Better than Best Effort / Assured).
  - Best Effort (BE) (Best Effort).
- Two types of scheduling schemes in the customer edge.
  - FIFO (no bandwidth allocations).
  - DRR (bandwidth allocations).

## Two Queue Model



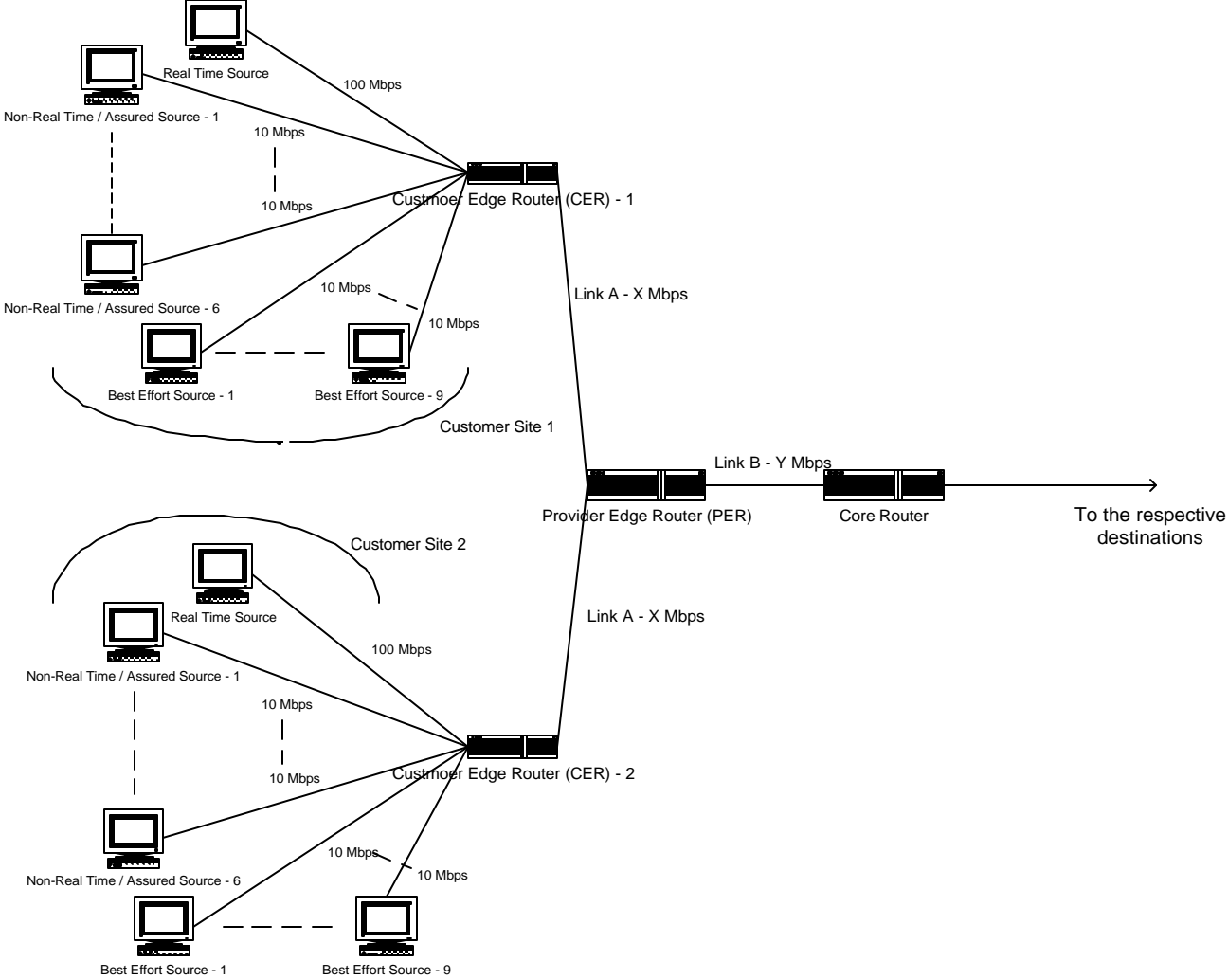
- Strict Priority Scheduler is used to serve the queues.
- "Better than Best Effort" (BBE) and Best Effort (BE) packets are queued in the same queue.
- RED with In and Out (RIO) is used to provide service discrimination.

## Three Queue Model



- Separate queues for each class.
- Strict Priority Scheduler to serve the queues.
- RIO to discriminate OUT packets from IN packets for BBE class.

# Network Topology



## Scenarios

- Different Scenarios for the two-queue and the three-queue model.

Queuing Scheme in CER	Load on the link between CER and PER.	Load on the link between PER and the Core Router.
FIFO	80%	80% to 110%
	90%	80% to 110%
	110%	80% to 110%
DRR	80%	80% to 110%
	90%	80% to 110%
	110%	80% to 110%

# Parameters

- Traffic Model:

Parameter	Real Time	Non-Real Time	Best Effort
Pkt Length	64 Bytes	1024 Bytes	1024 bytes
Pkt Transmission Rate	20,896.1 Pkts/sec	130.4 Pkts/sec.	130.4 Pkts/sec.
Distribution	Constant	Exponential	Exponential
Total Traffic (Mbps)	10.6875	$6 * 1.068 = 6.408$	$9 * 1.068 = 9.612$
Transport Protocol	UDP	TCP	TCP
Class	Premium	Assured	Best Effort

- Two Color Marker:

- For NRT flows

Parameter	Value
Token Rate	$2 * 6.408 = 12.816$ Mbps.
Bucket Size	51,200 bytes / 50 Pkts.

## Parameters (contd...)

- Parameters at the Output Interface of the CER.

- For DRR:

Queue Type	Queue Size	Scheduler Weight
Real Time	102,400 bytes / 200 pks	10.7 Mbps
Non-Real Time	163,840 bytes / 160 pks	6.7 Mbps
Best Effort	163,840 bytes / 160 pks	Variable

Best Effort Queue weight depends on the load on the outgoing link.

- For FIFO:

- Queue Size = 430,080 bytes.

- Parameters at the Output Interface of the PER:

For all the queues a weight of 0.005 was used for RED.

- For Two-Queue Model:

Queue Type	Marking	Minimum Threshold	Maximum Threshold	Max Drop Probability
Real Time	Premium	25.6 KB / 400 Pkts	51.2 KB / 800 Pkts	0.02
Assured and Best Effort	Assured	46.08 KB / 45 Pkts	81.92 KB / 80 Pkts	0.02
	Best Effort	40.96 KB / 40 Pkts	8.192 KB / 80 Pkts	0.05

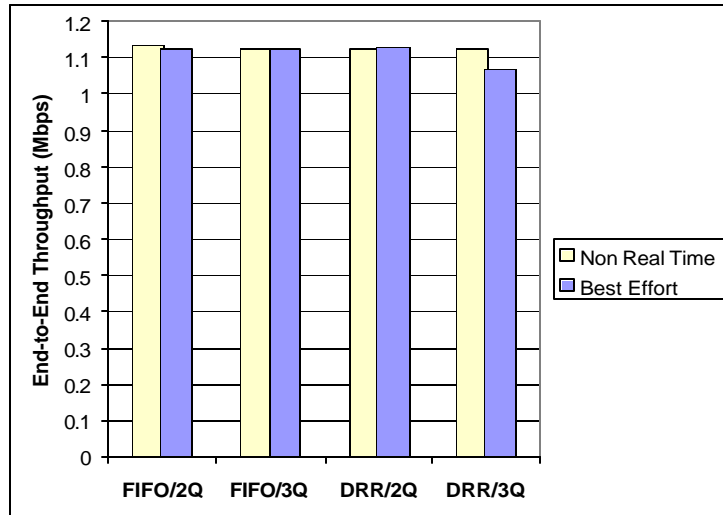
## Parameters (contd...)

- For Three-Queue Model:

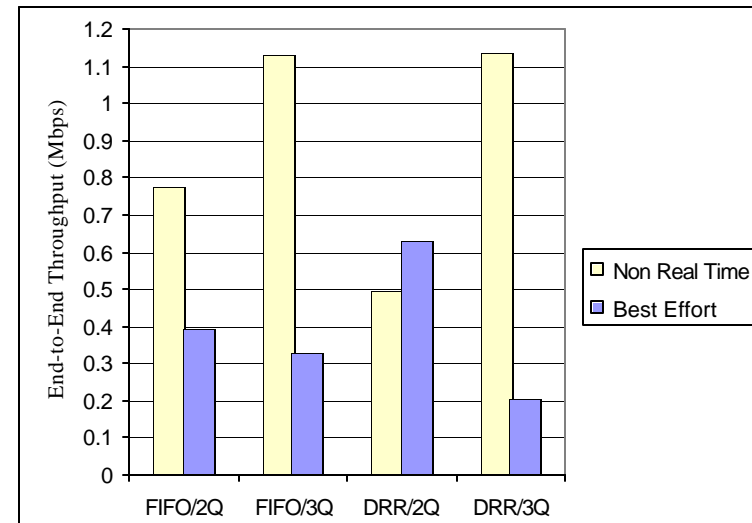
Queue Type	Marking	Minimum Threshold	Maximum Threshold	Max Drop Probability
Real Time	Premium	25.6 KB / 400 Pkts	51.2 KB / 800 Pkts	0.02
Assured with 2 DP*	Higher DP	46.08 KB / 45 Pkts	81.92 KB / 80 Pkts	0.02
	Lower DP	40.96 KB / 40 Pkts	8.192 KB / 80 Pkts	0.05
Best Effort	Best Effort	40.96 KB / 40 Pkts	8.192 KB / 80 Pkts	0.05



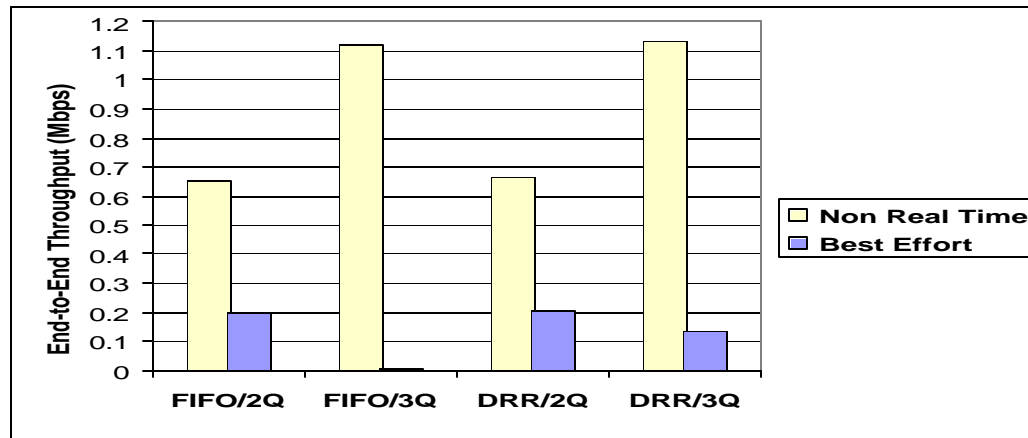
## Results for 0.8 load on the link between CER and PER



Load of 0.8 between PER and Core Router

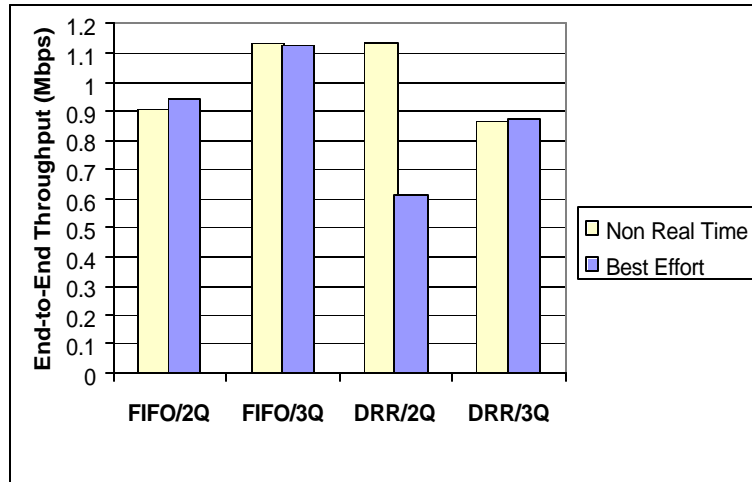


Load of 0.9 between PER and Core Router

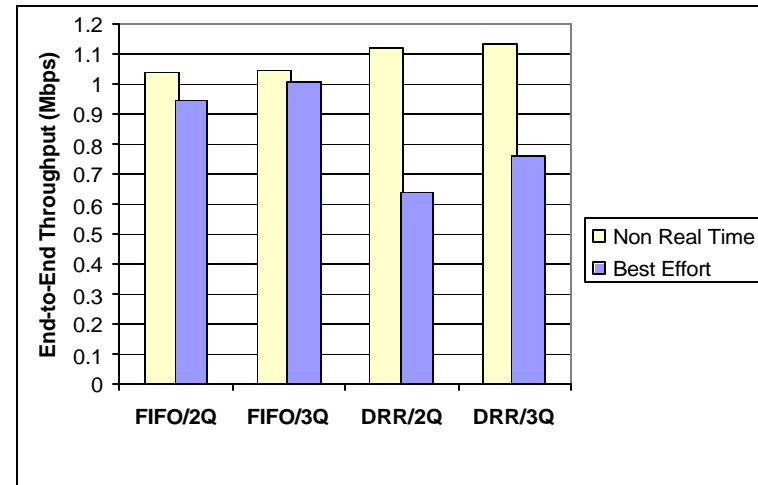


Load of 1.1 between PER and Core Router

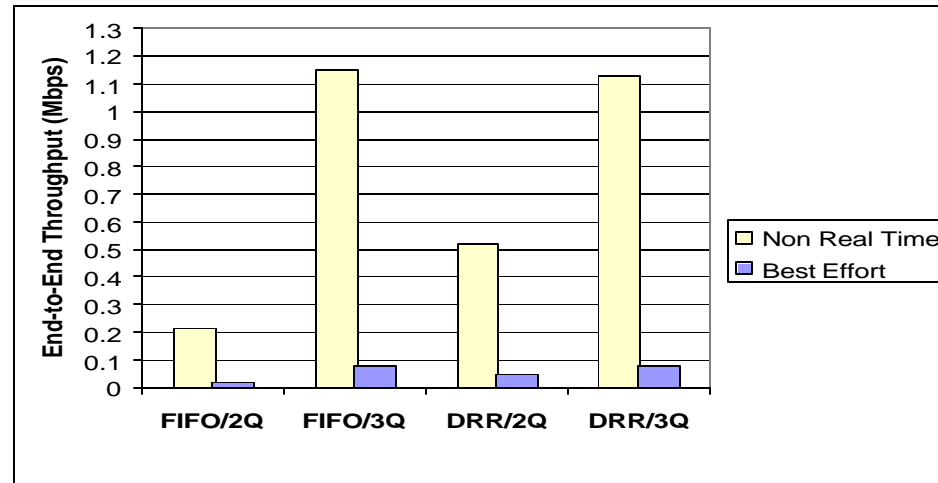
## Results for 0.9 load on the link between CER and PER



Load of 0.8 between PER and Core Router

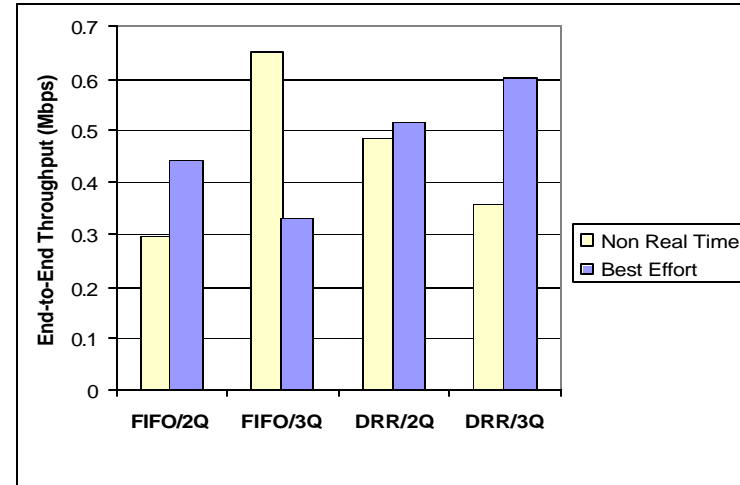
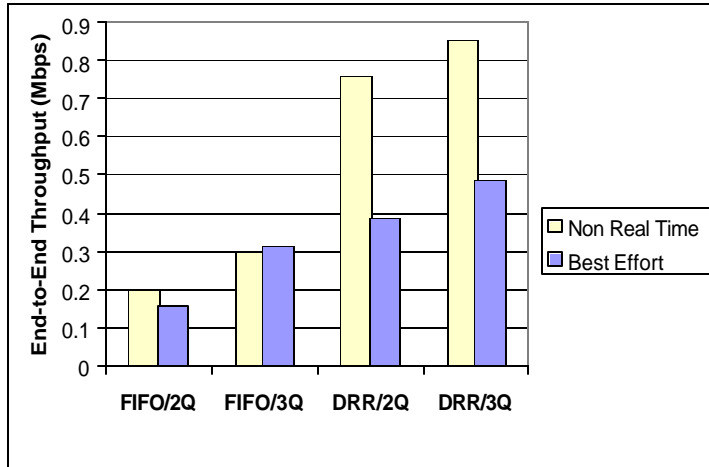


Load of 0.9 between PER and Core Router



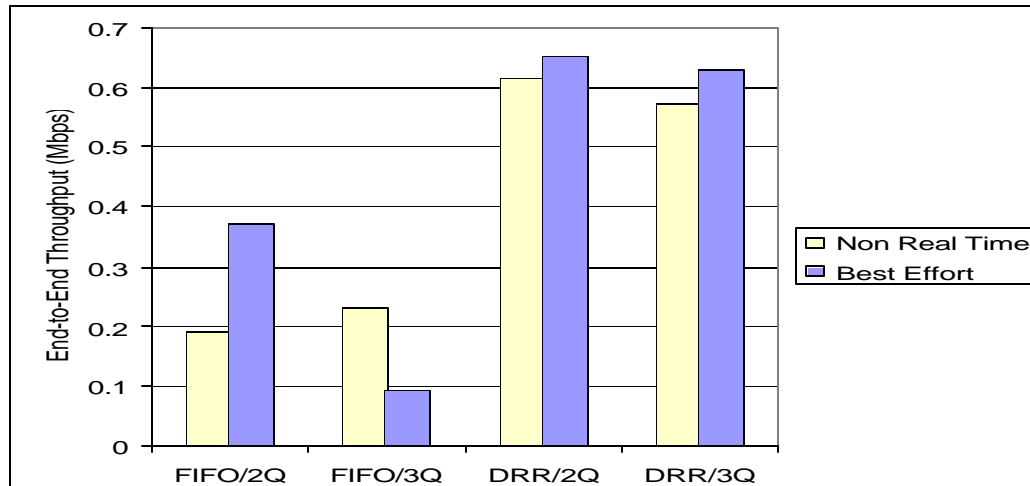
Load of 1.1 between PER and Core Router

## Results for 1.1 load on the link between CER and PER



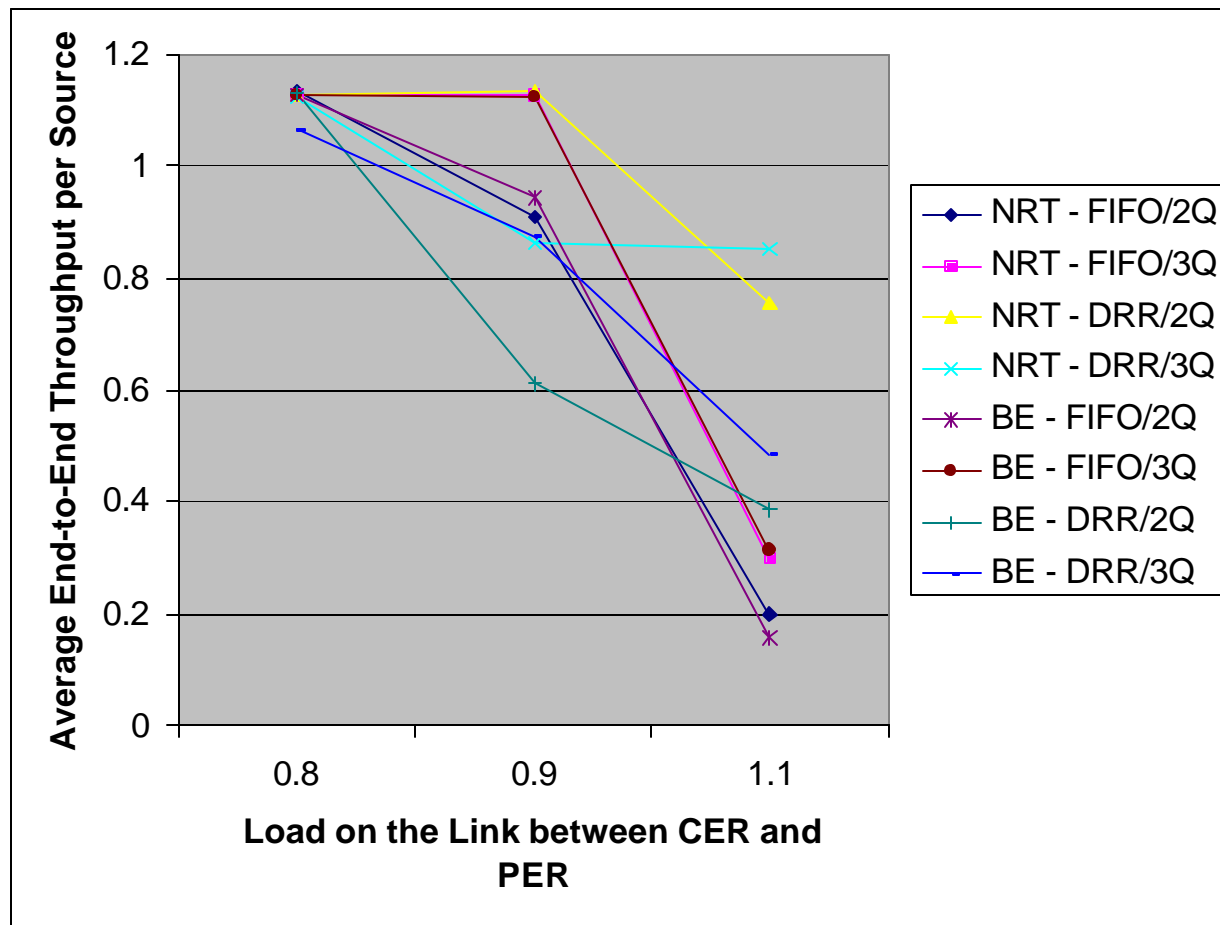
Load of 0.8 between PER and Core Router

Load of 0.9 between PER and Core Router

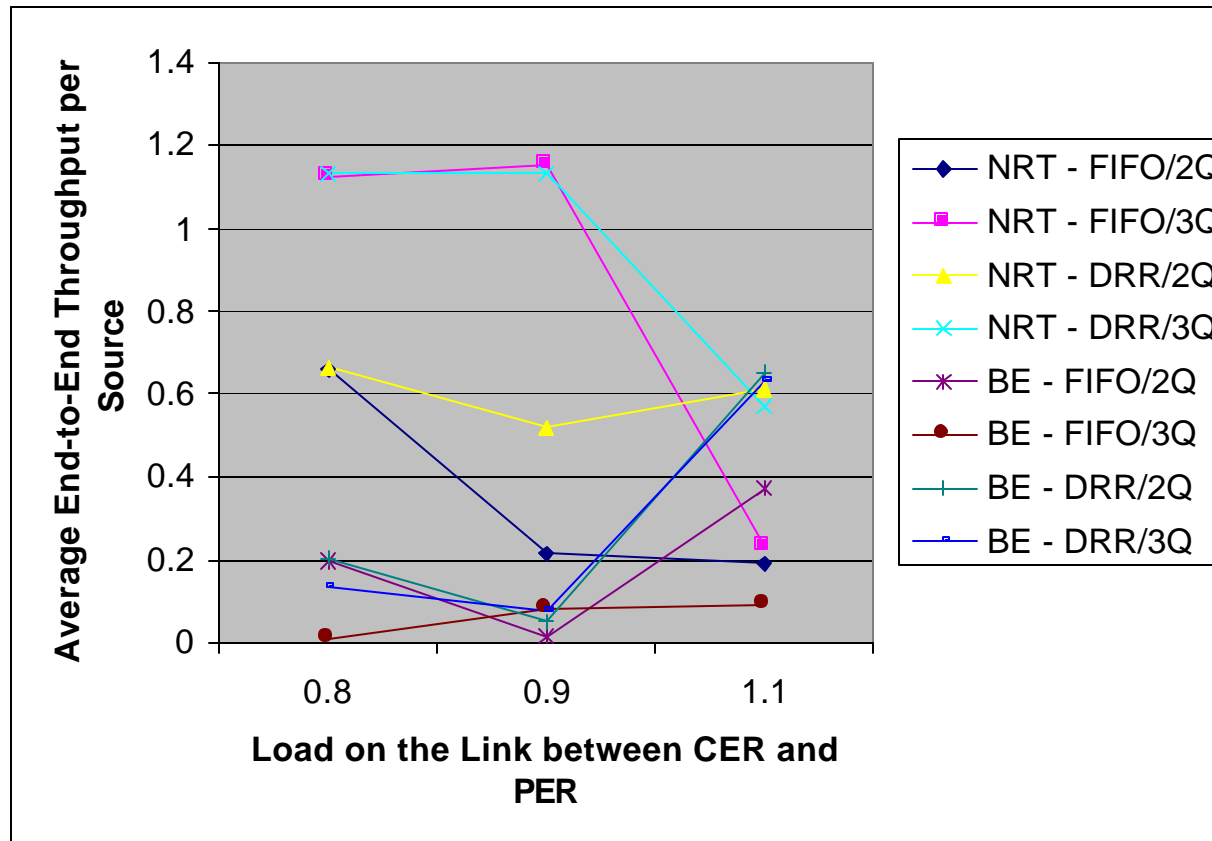


Load of 1.1 between PER and Core Router

## Results with a load of 0.8 on the link between PER and Core Router



## Results with a load of 1.1 on the link between PER and Core Router



## Conclusions from Classes Study

A*	B*	FIFO/2Q	FIFO/3Q	DRR/2Q	DRR/3Q
0.8	0.8	G-NRT G-BE	G-NRT G-BE	G-NRT G-BE	G-NRT G-BE
0.8	0.9	M-NRT P-BE	G-NRT P-BE	M-NRT M-BE	G-NRT M-BE
0.8	1.1	M-NRT P-BE	G-NRT P-BE	M-NRT P-BE	G-NRT M-BE
0.9	0.8	M-NRT M-BE	G-NRT G-BE	G-NRT M-BE	M-NRT M-BE
0.9	0.9	G-NRT M-BE	G-NRT M-BE	G-NRT M-BE	G-NRT M-BE
0.9	1.1	P-NRT P-BE	G-NRT P-BE	P-NRT P-BE	G-NRT P-BE
1.1	0.8	P-NRT P-BE	P-NRT P-BE	M-NRT P-BE	M-NRT P-BE
1.1	0.9	P-NRT P-BE	M-NRT P-BE	P-NRT P-BE	P-NRT P-BE
1.1	1.1	P-NRT P-BE	P-NRT P-BE	M-NRT M-BE	M-NRT M-BE

A\* - Load on the link between CER and PER, B\* - Load on the link between PER and Core Router.

- The Real Time traffic was able get the offered throughput for all the cases.
- End-to-End throughput of the NRT flows were better when three-queue model was used.
- In some cases Best Effort traffic got better throughput values than Non-Real time traffic for the Two-Queue model .
- DRR scheme in the customer edge helped to obtain better throughput values.

## Conclusions and Lessons Learned

- Service level guarantees can be provided to higher service classes to certain extent even in an overloaded situation.
- UDP vs TCP
  - The performance for TCP flows is badly effected when they are queued with UDP flows.
  - TCP traffic could be protected to certain extent by marking UDP traffic to higher drop precedence.
  - If performance results are critical for TCP traffic and congestion is expected, than it is highly desirable to mark UDP traffic to a separate class.

## Conclusions and Lessons Learned (contd...)

### UDP Flows

- It has been seen throughout the studies that the high priority UDP traffic was always able achieve good performance.
- Providing guarantees to UDP flows is less complex than to TCP flows (hard service guarantees).
- Service provider can charge more for UDP flows because of their non responsive nature.

### TCP Flows

- TCP flows are very sensitive to packets dropped.
- Parameters should be configured carefully as TCP flows are complex, i.e., TCP bursts, fragmentation etc.
- Hard service guarantees can be provided to TCP flows but extreme caution should be taken in configuring the parameters and in protecting them from UDP flows.



## Conclusions and Lessons Learned (contd...)

- RED performs better in byte mode than packet mode, but still discriminates based on packet lengths.

### Classes Study:

- The three queue model was found to perform better than three queue model.
- It was found that better service guarantees can be provided if DRR is used in customer edge rather than FIFO.
- For two queue model the OUF of profile packets were dropped, which effected the whole flow.
- It can be recommended that marking packets to higher drop precedence values should be investigated further especially for TCP flows.

## **Conclusions and Lessons Learned (contd...)**

- Differentiated services can be deployed into network with small number of classes or PHBs.
- The SLAs can be built based on the PHBs being offered and their expected performance.
- The network configuration should be tested thoroughly for parameter values and performance results.
- A service provider can offer service guarantees to customers whose flows are marked as high priority.

## Future Work

- Models to provide better service guarantees to TCP flows can be investigated.
- A variation to the TCP protocol for differentiated services is good topic for research.
- The parameters of the components used to provide service guarantees to TCP flows can also be investigated under different scenarios.
- To determine the performance if the OUT of profile packets are shaped instead of being marked.
- The trade off between the shaper buffer sizes in the edge routers and the throughput gained can be investigated.
- Research could be done on resource allocation methods to provide harder service guarantees.

Thanks You!

Questions?