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Running Integrated Services over Differentiated Service Networks: Quantitative Performance Measurements

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Integrated Services (IntServ)

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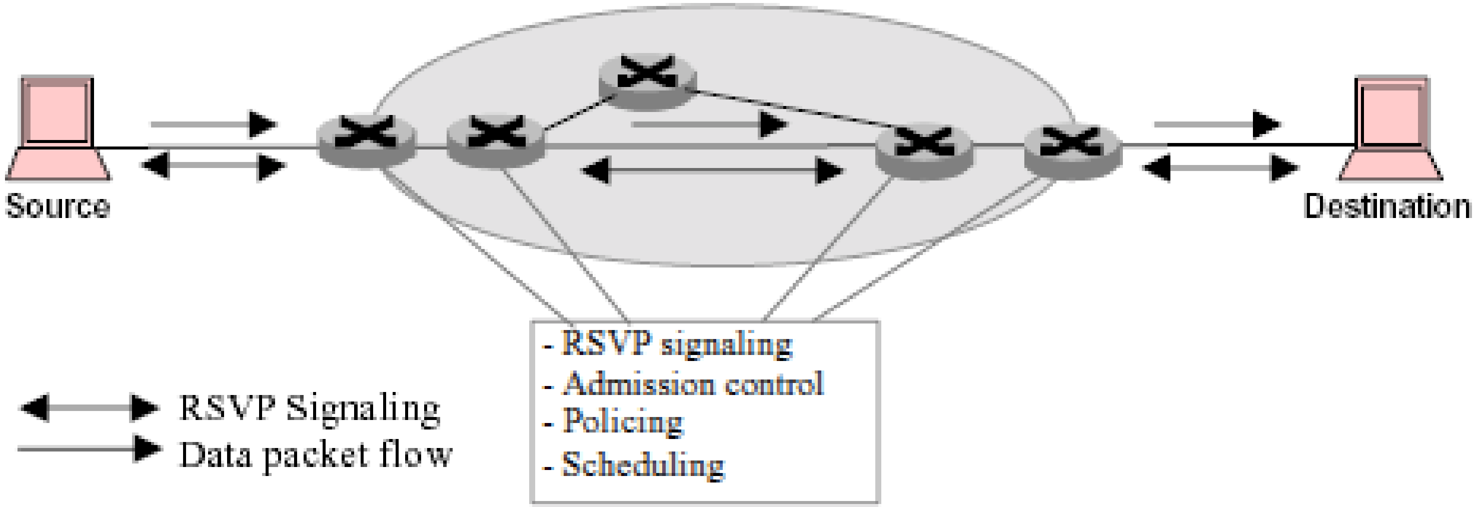
- IntServ is one of models proposed by IETF to meet the demand for end-to-end QoS over heterogeneous networks.
- IntServ implementation requires RSVP (Resource Reservation Protocol) signaling and resource allocations at every network element along the path.
- All the network elements must be RSVP-enable, giving rise to the **scalability problem** on its implementation for the entire Internet.



IntServ Services

- The *Guaranteed Service*: to achieve a bounded delay, which means it does not control the minimal or average delay of datagram, merely the maximal delay.

- The *Controlled-load Service:* to achieve little or no delay as that provided to best-effort traffic under lightly loaded conditions.

- Delay: fixed delay (such as transmission delay) & queuing delay.
  - Fixed delay is a property of chosen path;
  - Queuing delay is primarily a function of token bucket and data rate.

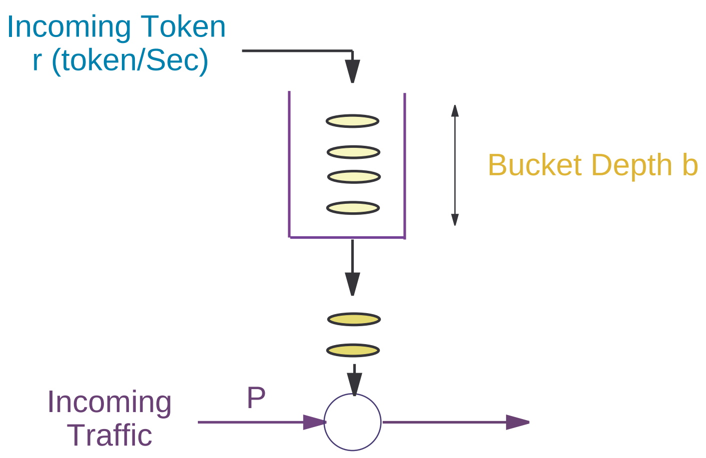
Resource Reservation

- In IntServ, resource reservation are made by requesting a service type specified by a set of quantitative parameters known as ***Tspec (Traffic Specification)***.

- Each set of parameters determines an appropriate priority level.

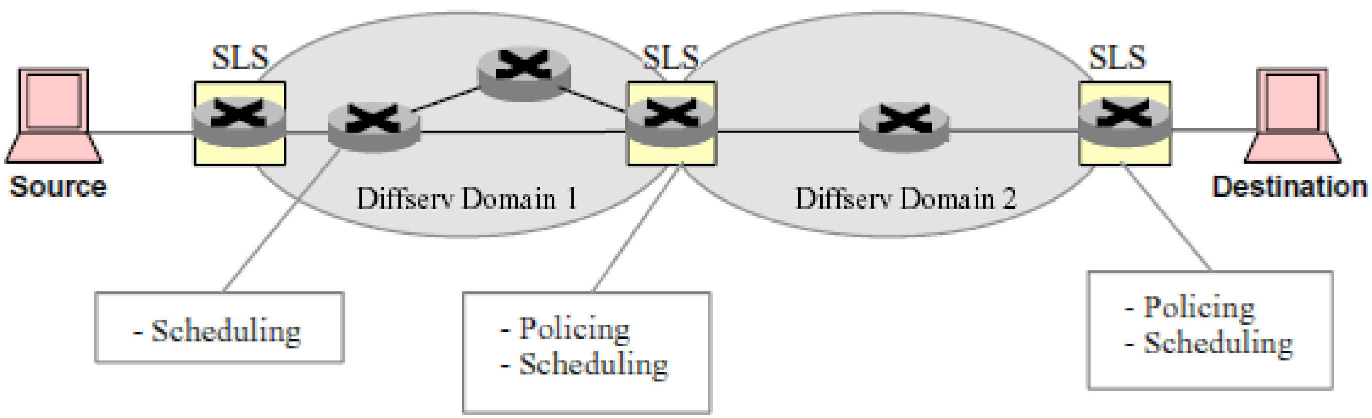
Tspec

- ***Tspec***: according to RFC 2212 (Guaranteed service) and RFC 2211 (Controlled-load service), ***Tspec*** takes the form of:
  - a token bucket specification, i.e., bucket rate (*r*) and bucket depth (*b*), and
  - a peak rate (*p*), a minimum policed unit (*m*) and a maximum datagram size (*M*).



Differentiated Services

- DiffServ is currently being standardized to overcome the scalability issue of IntServ.
- Scalability is achieved by offering services on aggregate basis, and by forcing as much as possible the per-flow states to the edges of the network.
- Because it is based on the processing of aggregated flows (classes), DiffServ **does not consider the need of end applications**.



SLS: Service Level Spec, the technical part of SLA (Service Level Agreement)

DiffServ Service Differentiation

- The service differentiation in DiffServ is achieved by means of Differentiated Services (DS) field in the IP header and the Per-Hop Behavior (PHB).
  - **DS field: Six bits in the TOS** (Type of Service) field of the IP header to mark a packet for being eligible for a particular forwarding behavior.
  - **PHBs:**
    - *Expedited* Forwarding;
    - *Assured* Forwarding;
    - *Best Effort.*

IntServ vs. DiffServ

- The Advantage of IntServ: application oriented.
- The Disadvantage of IntServ: scalability problem.

- The Advantage of DiffServ: enables scalability across large networks.
- The Disadvantage of DiffServ: does not consider the QoS requirements of end users.

Problem Statement

- With the implementation of IntServ for small WAN networks and DiffServ for the Internet backbone, combining the advantages of IntServ and DiffServ,

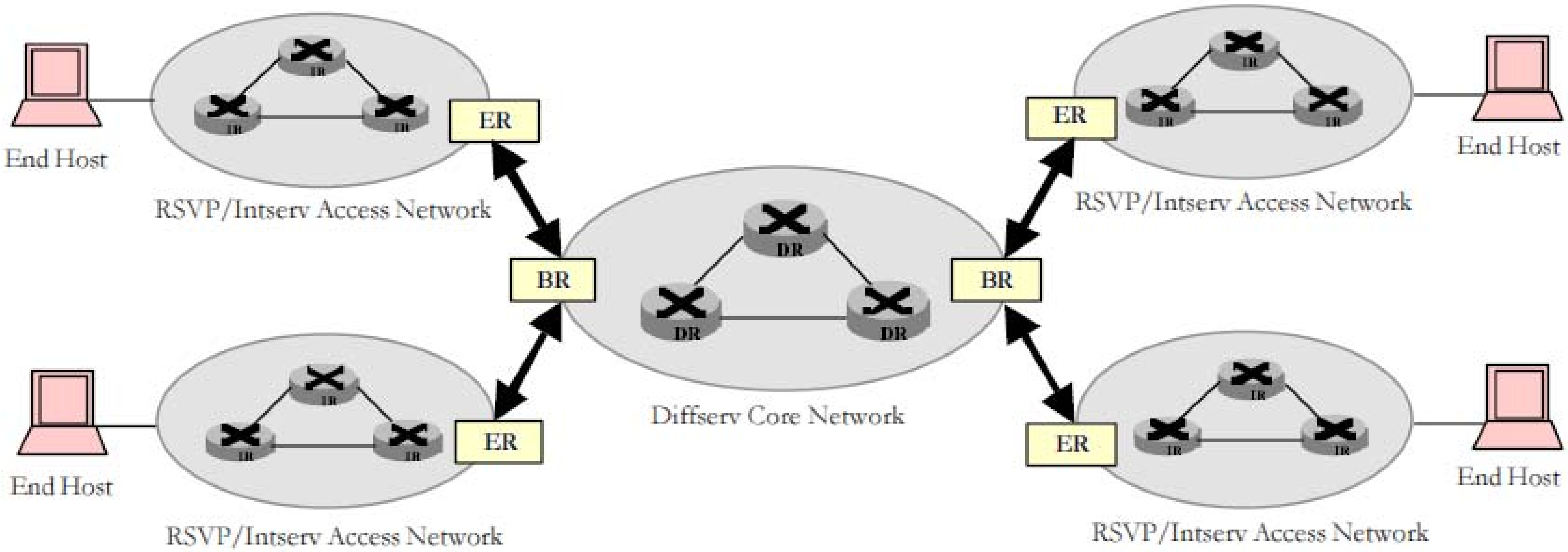
Can QoS be provided to end applications?

The Objective

- To investigate the POSSIBILITY of providing end-to-end QoS when IntServ runs over DiffServ backbone in the next generation Internet.
- To propose a MAPPING FUNCTION to run IntServ over the DiffServ backbone.
- To show the QUANTITATIVE RESULTS used to prove that QoS can be achieved by end IntServ applications when running over DiffServ backbone in the next generation Internet.

The Possibility of End-to-end QoS

- Combining IntServ and DiffServ has been proposed by IETF as one of the possible solutions to achieve end-to-end QoS in the next generation Internet.
- Obviously, a mapping function from IntServ flows to DiffServ classes has to be developed.



Mapping Considerations

- PHBs in DiffServ domain must be appropriately selected for each requested service in IntServ domain.
- The required policing, shaping and marking must be done at the edge router of the DiffServ domain.
- Taking into account the resource availability in DiffServ domain, admission control must be implemented for requested traffic in IntServ domain.

Proposed IntServ-to-DiffServ Mapping

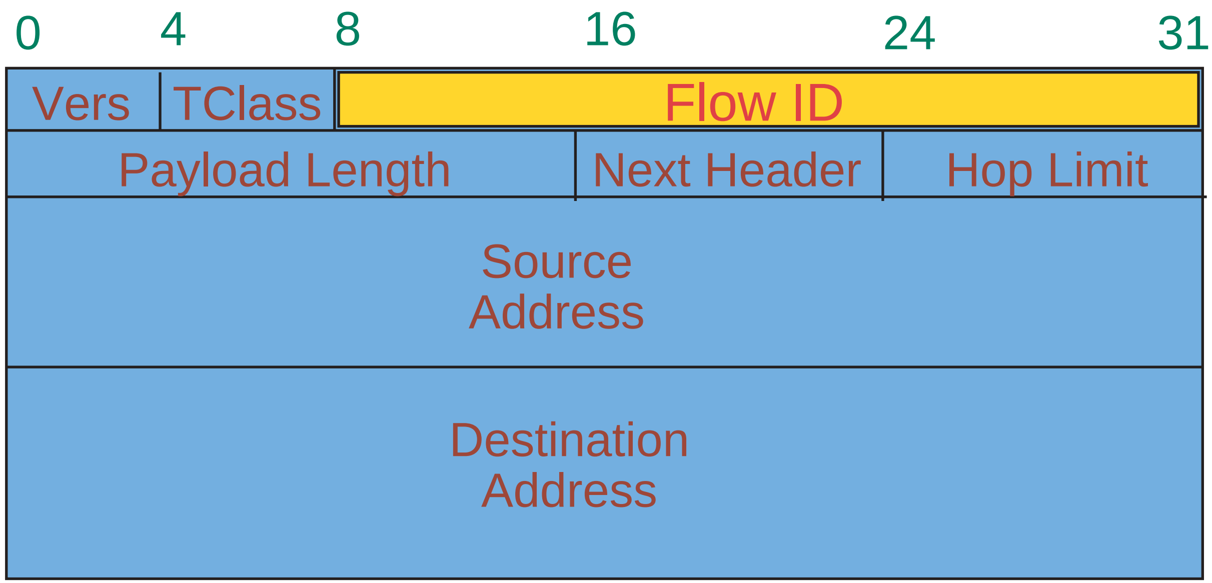
- In this study, we propose to map
  - **Guaranteed service** to **EF** PHB and
  - **Controlled-load** services to **AF** PHB different priority levels, depending on whether the controlled-load service is delay-tolerant or not.

Mapping Function

- **Mapping function:** a function which is used to assign an appropriate DSCP (DiffServ Codepoint) to a flow specified by *Tspec* parameters in IntServ domain.
- The Mapping function should ensure that the required QoS could be achieved for IntServ when running over DiffServ domain.

Mapping Function (Continued)

- Each packet in the flow from the IntServ domain has a **flow ID** indicated by the value of *flow-id* field in the IP header.



40-octet IPv6 base header

Mapping Function (Continued)

- The **flow ID** attributed with the *Tspec* parameters is used to determine which flow the packet belongs to.
- It is possible for different senders to use the same *Tspec* parameters to request service. However, they are differentiated by the **flow ID**. **Flow ID is unique.**
- It is also possible that different flows can be mapped to the same PHB in the DiffServ domain.

An Example Mapping Function

- An example mapping function used in our simulation

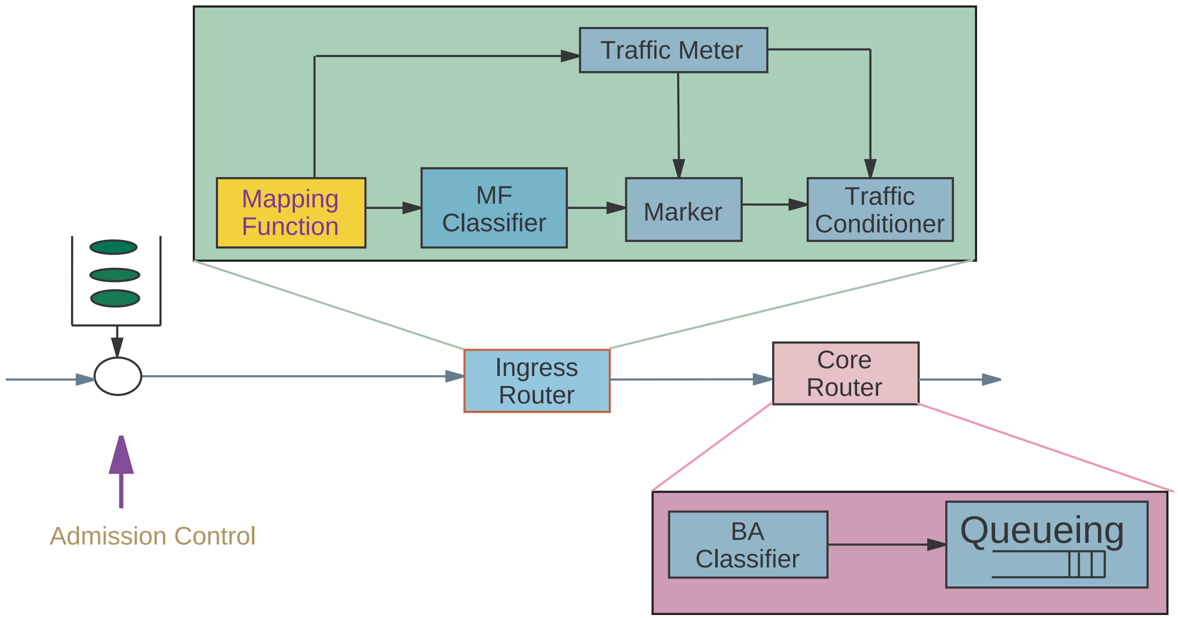
Tspec	***Flow ID***	***PHB***	***DSCP***
r=0.7 Mb, *b*=5000 bytes	0	EF	101110
r=0.7 Mb, *b*=5000 bytes	1	EF	101110
r=0.5 Mb, *b*=8000 bytes	2	AF11	001010
r=0.5 Mb, *b*=8000 bytes	3	AF11	001010
r=0.5 Mb, *b*=8000 bytes	4	AF11	001010

How Does the Mapping Function Work?

- Packets specified by *Tspec* parameters and *Flow ID* are first mapped to the corresponding PHBs in the DiffServ domain by appropriately assigning a DSCP according to the mapping function.
- Packets are then routed in the DiffServ domain where they receive treatments based on their DSCP code.

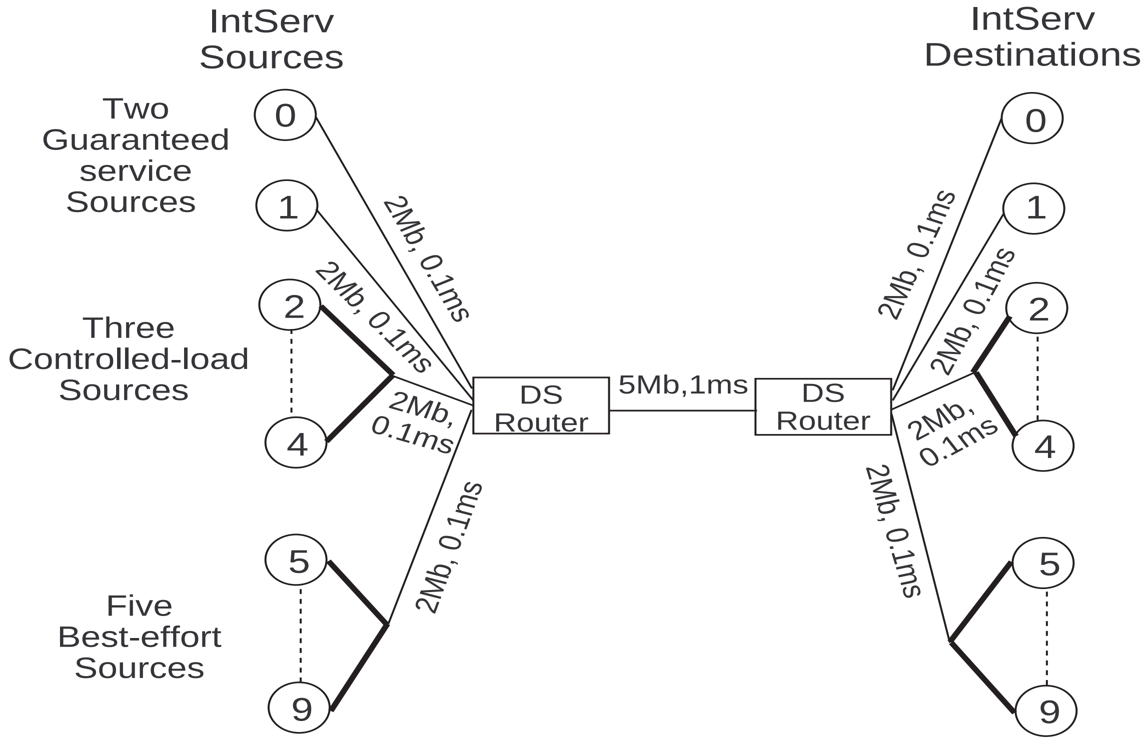
Mapping Function Implementation

- We integrated the mapping function into the edge DiffServ router.



Simulation Configurations

- Simulation tool: Berkeley *ns* V2.1b6
- Simulation configuration.



Simulation Parameters

- Configuration of queues inside the core DiffServ router.

	Queue Type	Scheduler weight
EF Queue	*PQ-Tail drop*	*0.4*
AF Queue	*RIO*	*0.4*
BE Queue	*RED*	*0.2*

- Since the bandwidth of bottleneck link is 5Mb, the above scheduling weight implies bandwidth of
  - EF: 2Mb
  - AF: 2Mb
  - BE: 1Mb

Performance Criteria

- **Goodput of each IntServ source**.
- **Queue size of each queue in the DiffServ core router**.
- **Drop ratio at scheduler**.
- **Non-conformant ratio**: the ratio of non-conformant packets as compared to in-profile packets.

QoS Obtained by Guaranteed Service: Case 1

- ***Case 1:*** **No congestion; no excessive traffic.**

Source NO.	Source Type	Source Rate	Resource Reservation	
			Token Rate	Bucket Depth
0	*Guaranteed Service*	*0.7Mb*	*0.7Mb*	*5000bytes*
1	*Guaranteed Service*	*0.7Mb*	*0.7Mb*	*5000bytes*

- Two Guaranteed service sources generate 1.4Mb traffic which is less than the scheduled bandwidth (2Mb) → **No congestion**.
- Source rate is equal to the bucket rate → **No excessive traffic**.

Goodput of Guaranteed Service: Case 1

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- *Simulation results of Case 1:* **Goodput of each Guaranteed Service source.**

Source No.	Flow ID	Case 1 (Kb/S)
0	*0*	*699.82*
1	*1*	*699.80*

- **Observation:** the goodput of each source is almost equal to the corresponding source rate.

Drop Ratio of Guaranteed Service: Case 1

- ***Simulation results of Case 1:* Drop ratio of Guaranteed Service traffic (measured at scheduler).**

Type of traffic	Case 1
Guaranteed Service	*0.00*

- **Observation:** since there is no significant congestion, the drop ratio is zero.

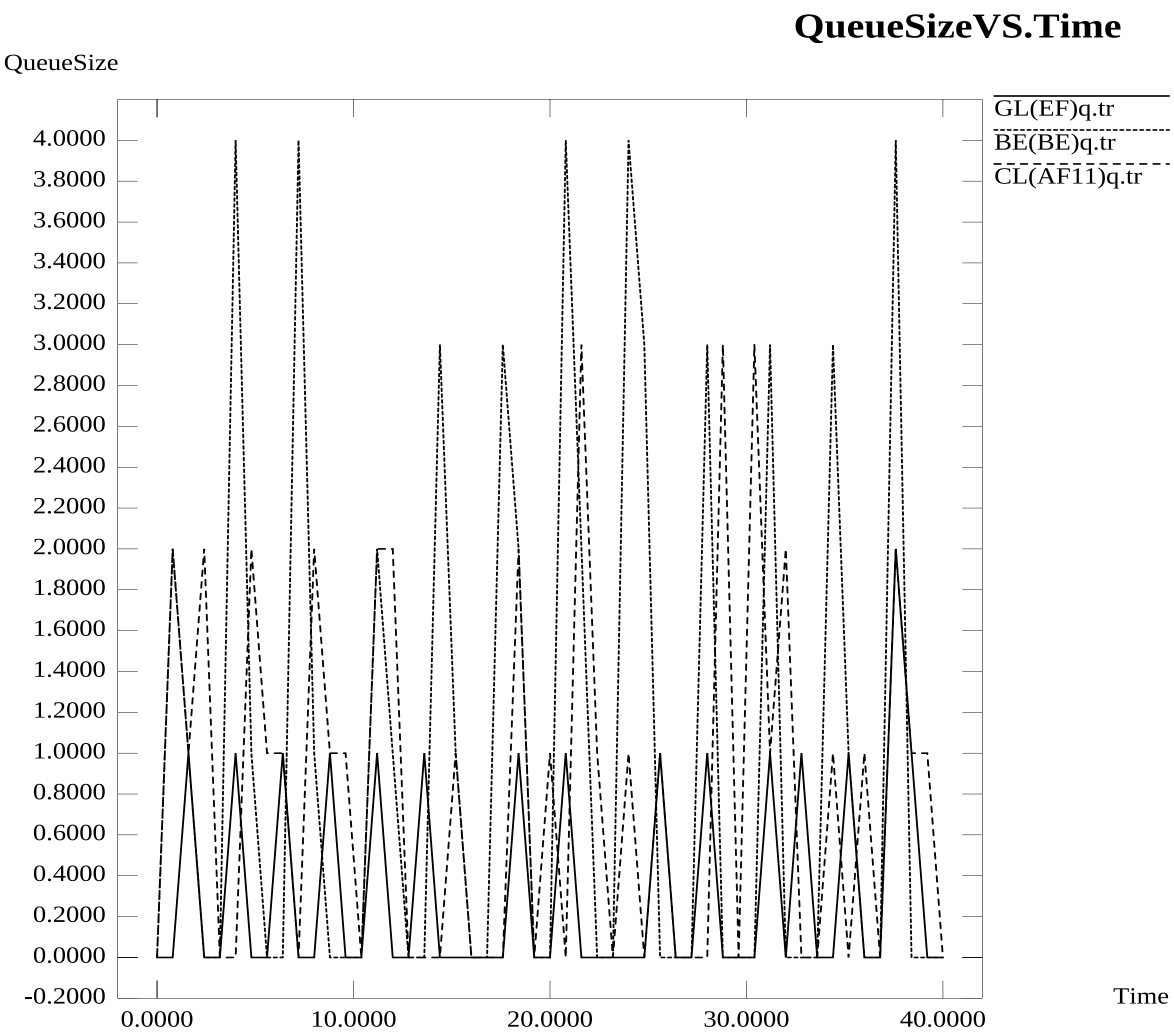
Non-conformant Ratio of Guaranteed Service: Case 1

- ***Simulation results of Case 1:*** **non-conformant ratio of each Guaranteed Service source.**

Source No.	Flow ID	Case 1
0	*0*	*0.00*
1	*1*	*0.00*

- **Observations:** since there is no excessive traffic, the non-conformant ratio is zero.

Queue Size Plot: Case 1



Queue Size Plot: Case 1 (Continued)

- **Observations:**
  - Since Case 1 is an ideal case, the size of each queue is very small.
  - BE queue has the largest jitter.

QoS Obtained by Guaranteed Service: Case 2

- ***Case 2:*** **No congestion; source 1 generates excessive traffic.**

Source NO.	Source Type	Source Rate	Resource Reservation	
			Token Rate	Bucket Depth
0	*Guaranteed Service*	*0.7Mb*	*0.7Mb*	*5000bytes*
1	*Guaranteed Service*	*0.9Mb*	*0.7Mb*	*5000bytes*

- Two Guaranteed service sources generate 1.6Mb traffic which is less than the scheduled bandwidth (2Mb) → **No congestion**.
- Source rate of source 1 (0.9 Mb) is greater than the bucket rate (0.7Mb) → **Source 1 generates excessive traffic**.

Goodput of Guaranteed Service: Case 2

- ***Simulation results of Case 2:*** **Goodput of each Guaranteed Service source.**

Source No.	Flow ID	Case 1 (Kb/S)	Case 2 (Kb/S)
0	*0*	*699.83*	*699.80*
1	*1*	*699.80*	*699.64*

- **Observations:** the goodput of source 0 is almost equal to the corresponding source rate; *however, the goodput of source 1 is equal to its token rate, 0.7Mb, instead of its source rate, 0.9Mb.*

Drop Ratio of Guaranteed Service: Case 2

- ***Simulation results of Case 2:*** **Drop ratio of Guaranteed Service traffic (measured at scheduler).**

Type of traffic	Case 1	Case 2
Guaranteed Service	*0.00*	*0.00*

- **Observation:** since there is no significant congestion, the drop ratio is zero.

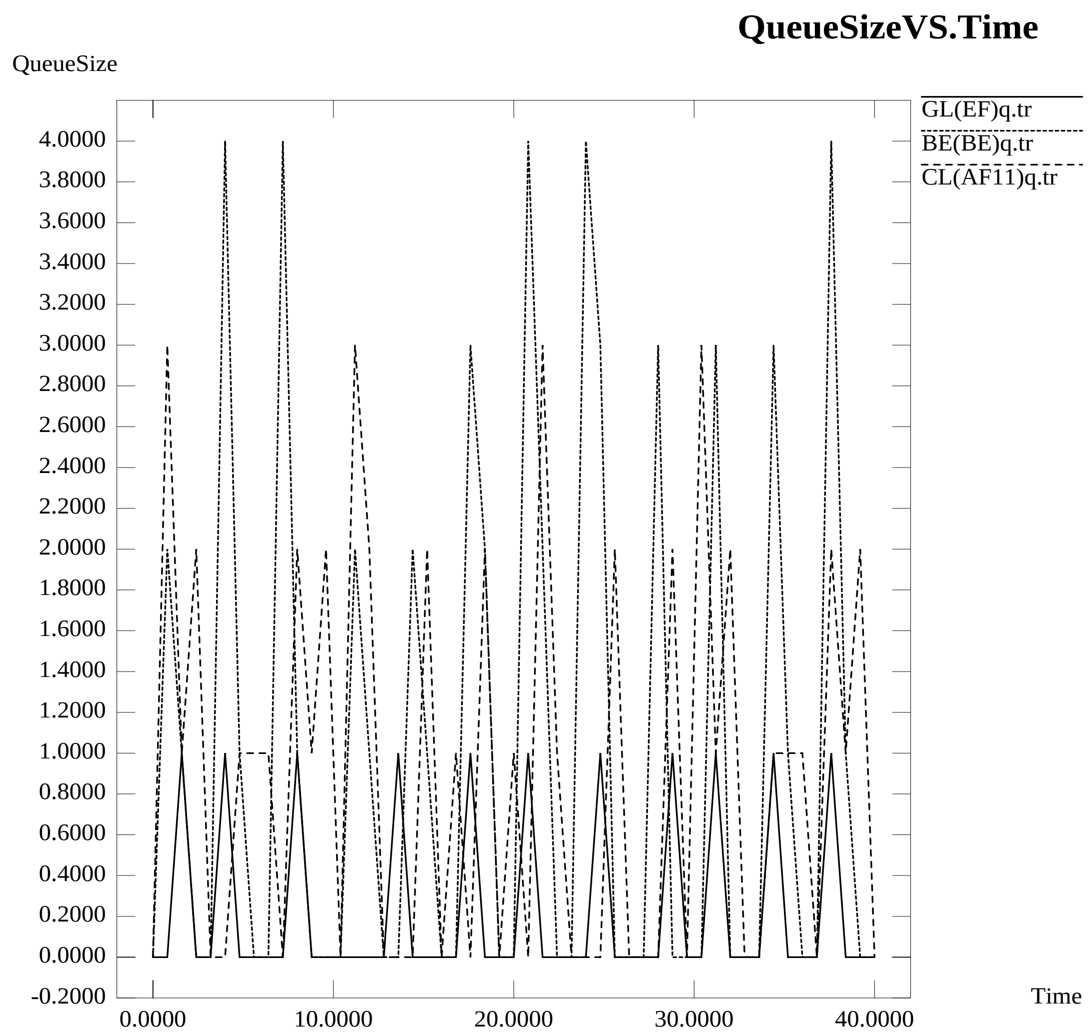
Non-conformant Ratio Guaranteed Service: Case 2

- ***Simulation results of Case 2:*** **non-conformant ratio of each Guaranteed Service source.**

Source No.	Flow ID	Case 1	Case 2
0	*0*	*0.00*	*0.00*
1	*1*	*0.00*	*0.22*

- **Observation:** since source 1 generates excessive traffic, its non-conformant ratio is increased, compared to Case 1.

Queue Size Plot: Case 2



Queue Size Plot: Case 2 (Continued)

- **Observations:**
  - In this case, BE queue has the largest size and jitter;
  - Guaranteed Load service queue has the smallest size and jitter.
  - In addition, compared with Case 1, the upper bound of Guaranteed Load queue size is guaranteed.

QoS Obtained by Guaranteed Service: Case 3

- ***Case 3:* Guaranteed service gets into congestion; no excessive traffic----evaluation under congestion.**

Source NO.	Source Type	Source Rate	Resource Reservation	
			Token Rate	Bucket Depth
0	*Guaranteed Service*	*0.7Mb*	*0.7Mb*	*5000bytes*
1	*Guaranteed Service*	*2Mb*	*2Mb*	*5000bytes*

- Two Guaranteed service sources generate 2.7Mb traffic which is greater than the scheduled bandwidth (2Mb) → **Guaranteed service gets into congestion**.
- Source rate is equal to the bucket rate → **No excessive traffic**.

Goodput of Guaranteed Service: Case 3

- ***Simulation results of Case 3:*** **Goodput of each Guaranteed Service source.**

Source No.	Flow ID	Case 1 (Kb/S)	Case 2 (Kb/S)	Case 3 (Kb/S)
0	*0*	*699.8250*	*699.8039*	*459.8790*
1	*1*	*699.8039*	*699.6359*	*1540.1400*

- **Observation:** the total goodput of two sources is limited by the scheduled bandwidth, 2Mb (although the source send 2.7Mb).

Drop Ratio of Guaranteed Service: Case 3

- ***Simulation results of Case 3:*** **Drop ratio of Guaranteed Service traffic (measured at scheduler).**

Type of traffic	Case 1	Case 2	Case 3
Guaranteed Service	*0.00*	*0.00*	*0.26*

- **Observation:** the drop ratio is increased.

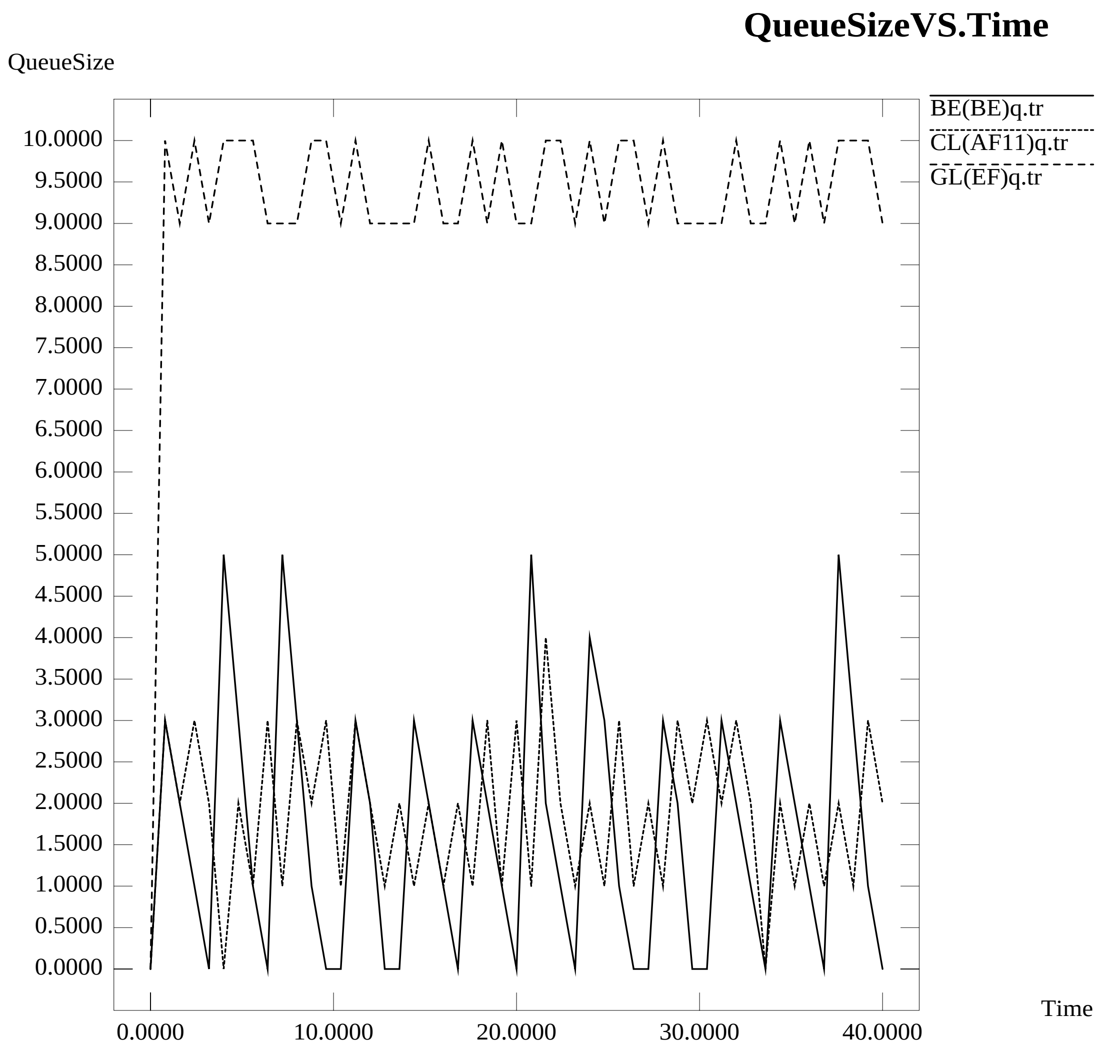
Non-conformant Ratio of Guaranteed Service: Case 3

- ***Simulation results of Case 3:*** **non-conformant ratio of each Guaranteed Service source.**

Source No.	Flow ID	Case 1	Case 2	Case 3
0	*0*	*0.00*	*0.00*	*0.00*
1	*1*	*0.00*	*0.22*	*0.00*

- **Observations:** since there is no excessive traffic, the non-conformant ratio is zero.

Queue Size Plot: Case 3



Queue Size Plot: Case 3 (Continued)

- **Observations:** since we increased the source rate and token rate of source 1 in order to make Guaranteed service congested, it is reasonable that the upper bound of Guaranteed service queue size is increased.

QoS Obtained by Controlled-load Service

- **No congestion; source 3 generates excessive traffic. (Similar to Case 2 of Guaranteed Service)**

Source NO.	Source Type	Source Rate	Resource Reservation	
			Token Rate	Bucket Depth
2	*Controlled-load Service*	*0.5Mb*	*0.5Mb*	*8000bytes*
3	*Controlled-load Service*	*0.7Mb*	*0.5Mb*	*8000bytes*
4	*Controlled-load Service*	*0.5Mb*	*0.5Mb*	*8000bytes*

- Total source rate is 1.7Mb, less than the scheduled bandwidth (2Mb) → **No congestion**.
- Source rate of source 3 (0.7 Mb) is greater than its bucket rate (0.5Mb) → **Source 3 generates excessive traffic**.

Goodput of Controlled-load Service

- ***Simulation results:*** **Goodput of each Guaranteed Service source.**

Source No.	Flow ID	Goodput (Kb/S)
2	*2*	*499.9889*
3	*3*	*700.0140*
4	*4*	*499.9889*

- **Observations:** the goodput of each source is almost equal to the corresponding source rate, *which is different from Case 2 of Guaranteed service.*
- This is because the non-conformant packets are degraded and then forwarded. (Proposed as one of the forwarding scheme for non-conformant packets by RFC2211)

Drop Ratio of Controlled-load Service

- ***Simulation results:*** **Drop ratio of Controlled Service traffic (measured at scheduler).**

Type of traffic	Drop ratio
Controlled-load Service	*0.0000*

- **Observations:** since there is no significant congestion, the drop ratio is zero.

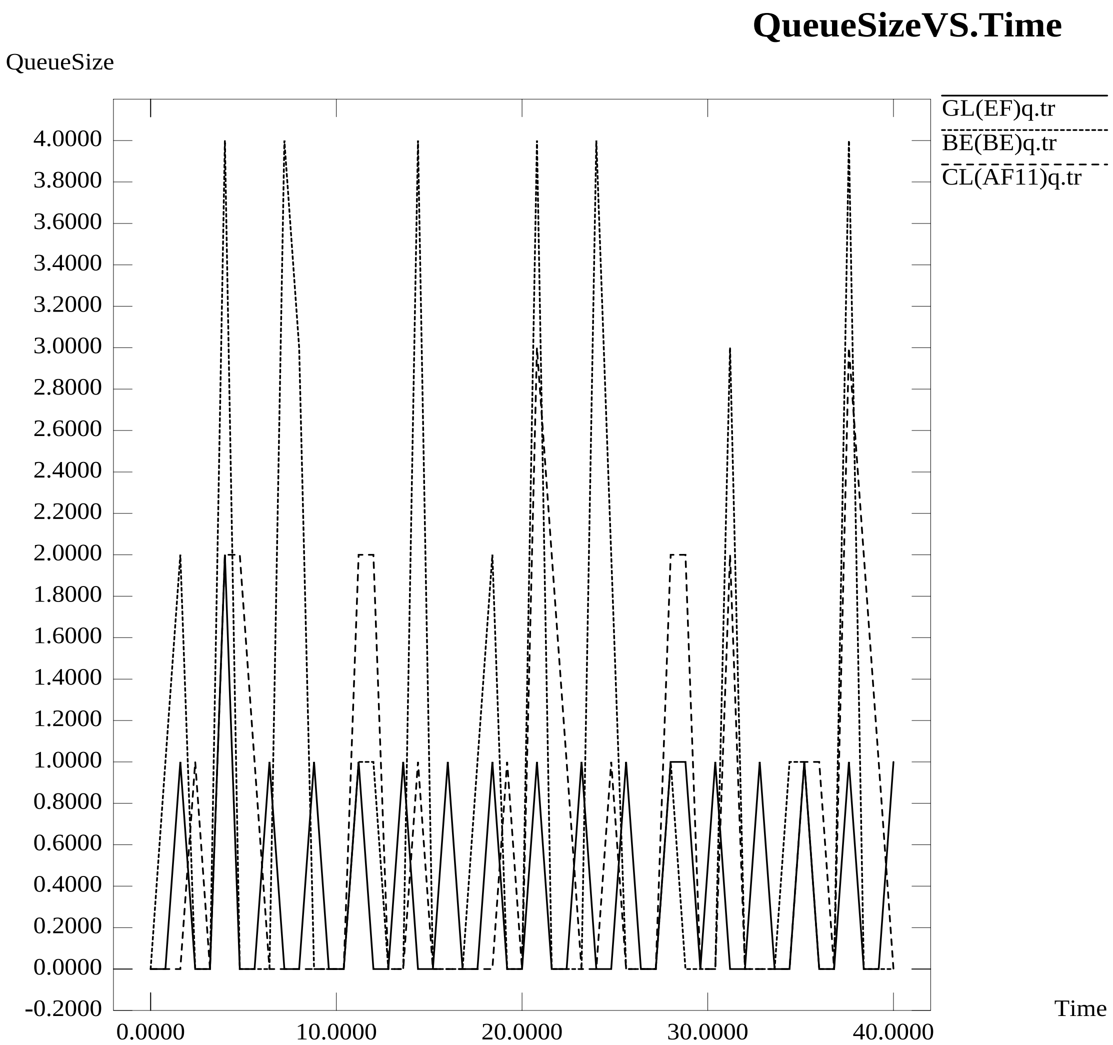
Non-conformant Ratio of Controlled-load Service

- ***Simulation results:*** **non-conformant ratio of each Guaranteed Service source.**

Source No.	**Flow ID**	**Non-conformant Ratio**
2	*2*	*0.00000*
3	*3*	*0.28593*
4	*4*	*0.00000*

- **Observations:** since source 3 generates excessive traffic, its non-conformant ratio is much higher than other two's.

Queue Size Plot



Conclusion

- The upper bound of queuing delay of ***Guaranteed Service*** is guaranteed. In addition, it always has the smallest jitter without being affected by other traffic flows.

- The ***controlled-load Service*** has smaller jitter and queue size than the best effort traffic. The non-conformant packets are degraded and then forwarded.

Acknowledgement

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