QoS for Real Time Applications over Next Generation Data Networks

Final Project Presentation
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Progress of the tasks

- Progress to date:
  - Task 1: QoS in Integrated Services over DiffServ networks (UD)
  - Task 2: Interconnecting ATN with the next generation Internet (UD)
  - Task 3: QoS in DiffServ over ATM (UD)
  - Task 4: Improving Explicit Congestion Notification with the Mark-Front Strategy (OSU)
  - Task 5: Multiplexing VBR over VBR (OSU)
  - Task 6: Achieving QoS for TCP traffic in Satellite Networks with Differentiated Services (OSU)
- Conclusions

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Task 1

QoS in *Integrated Services* over *DiffServ networks*

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Integrated Services

- IntServ is one of models proposed by IETF to meet the demand for end-to-end QoS over heterogeneous networks.
- The IntServ model is characterized by resource reservation.
- 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.
- Scalability problem becomes a bound on its implementation for the entire Internet.

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Differentiated Services

- DiffServ is currently being standardized to overcome the scalability issue of IntServ.
- This model does not require significant changes to the existing infrastructure, and does not need many additional protocols.
- Because it is based on the processing of aggregated flows (classes), DiffServ does not consider the need of end applications.

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IntServ vs. DiffServ

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

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

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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 TCP/IP traffic meet the QoS demands?

- Can QoS be provided to end applications?

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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 SIMULATION RESULTS used to prove that QoS can be achieved by end IntServ applications when running over DiffServ backbone in the next generation Internet.

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Possibility of End-to-end QoS

- To support the end-to-end QoS model, the IntServ architecture must be supported over a wide variety of different types of network elements.
- In this context, a network that supports DiffServ may be viewed as a network backbone.
- 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.

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Possibility of End-to-end QoS (Continued)

- Obviously, a mapping function from IntServ flows to DiffServ classes has to be developed.

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Requirements of IntServ Services

- The objective of *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 objective of *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.

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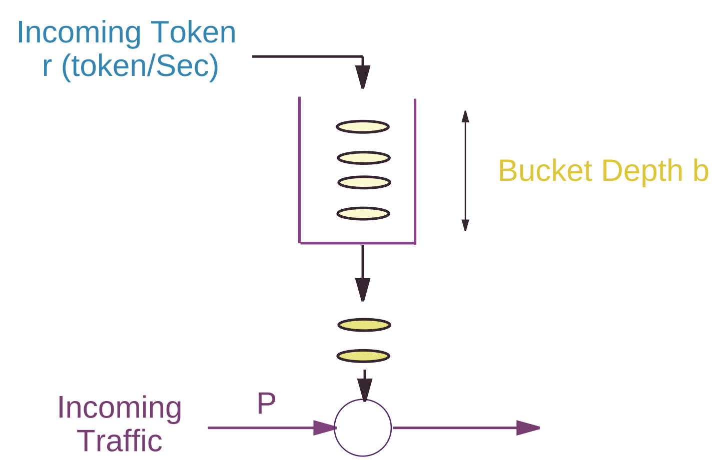
Tspec

- ***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*).



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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.

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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.

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Proposed IntServ to DiffServ Mapping

- In this study, we propose to map
  - **Guaranteed service** to **EF** PHB and
  - **Controlled-load** service to **AF** PHBs.

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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.

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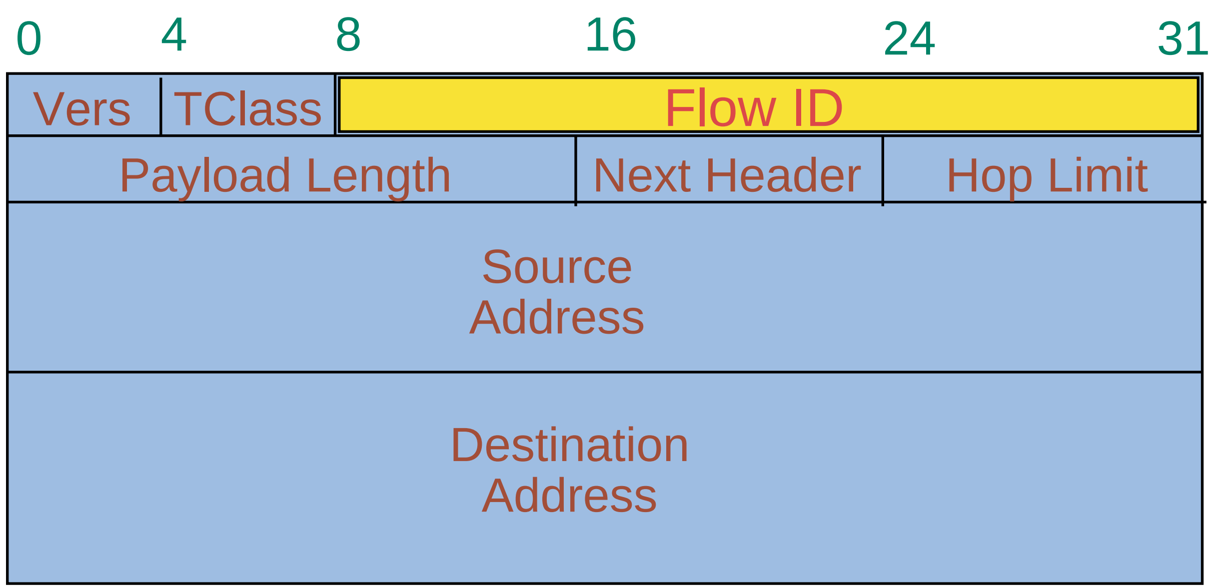
Mapping Function (Continued)

- 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

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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.

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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

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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.

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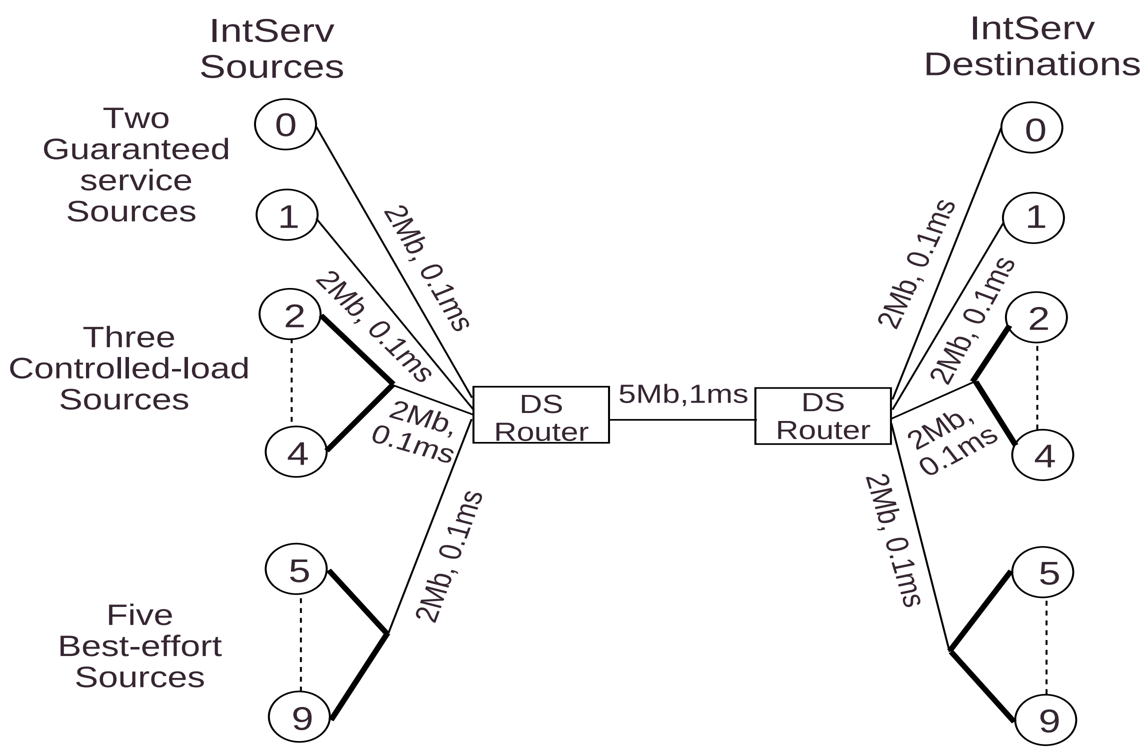
Simulation Configurations

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



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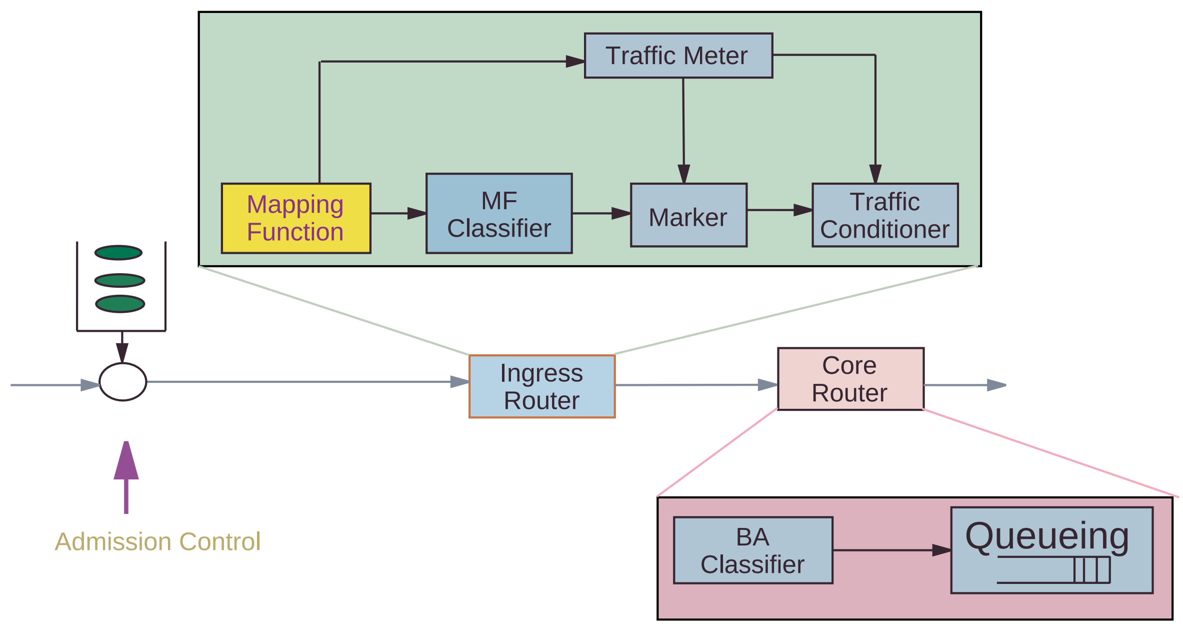
Simulation Configuration (Continued)

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



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Simulation Configurations (Continued)

- 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

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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.

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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**.

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Goodput of Guaranteed Service: Case 1

- ***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.

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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.

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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.

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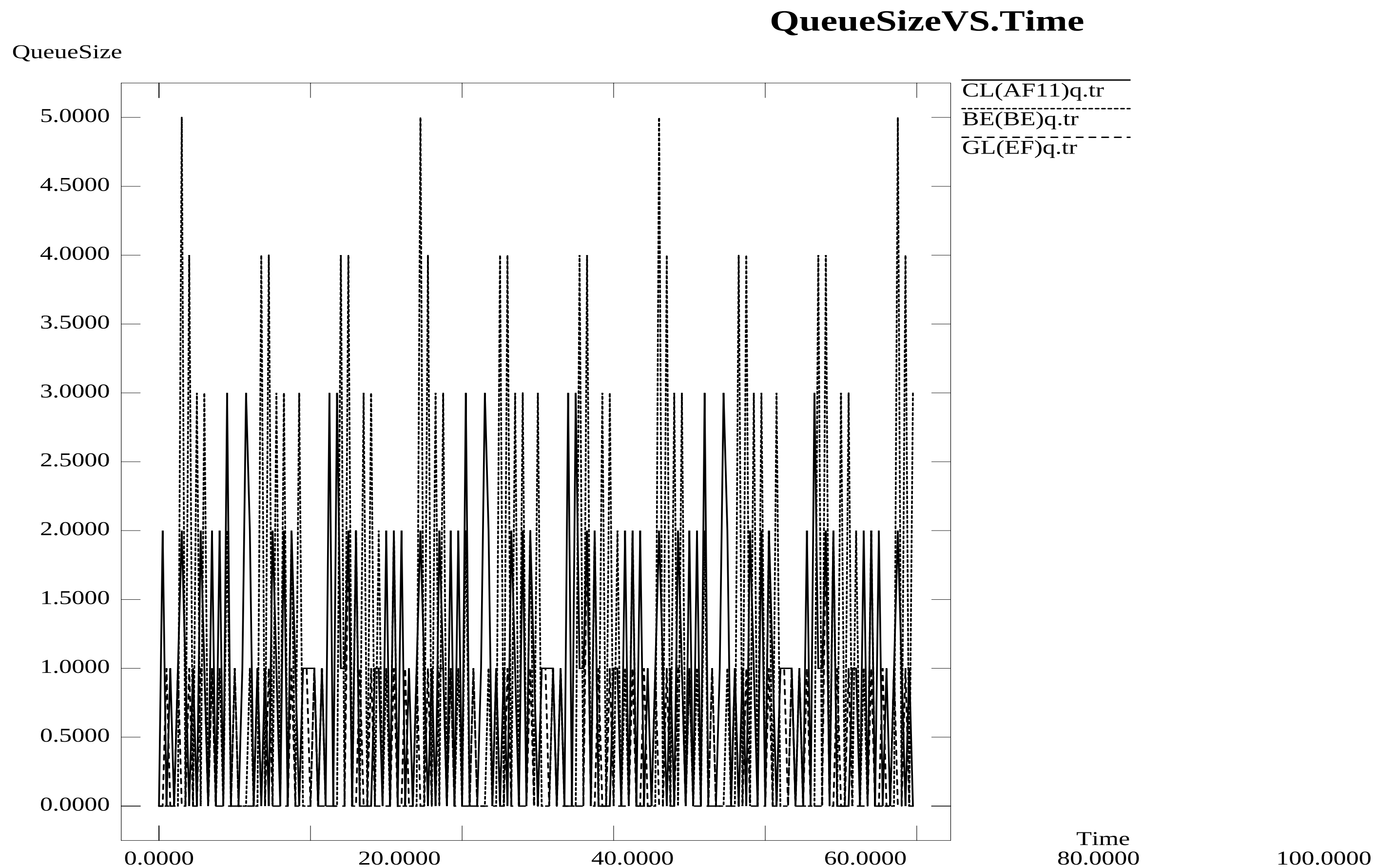
Queue Size Plot: Case 1



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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.

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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**.

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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.*

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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.

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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.

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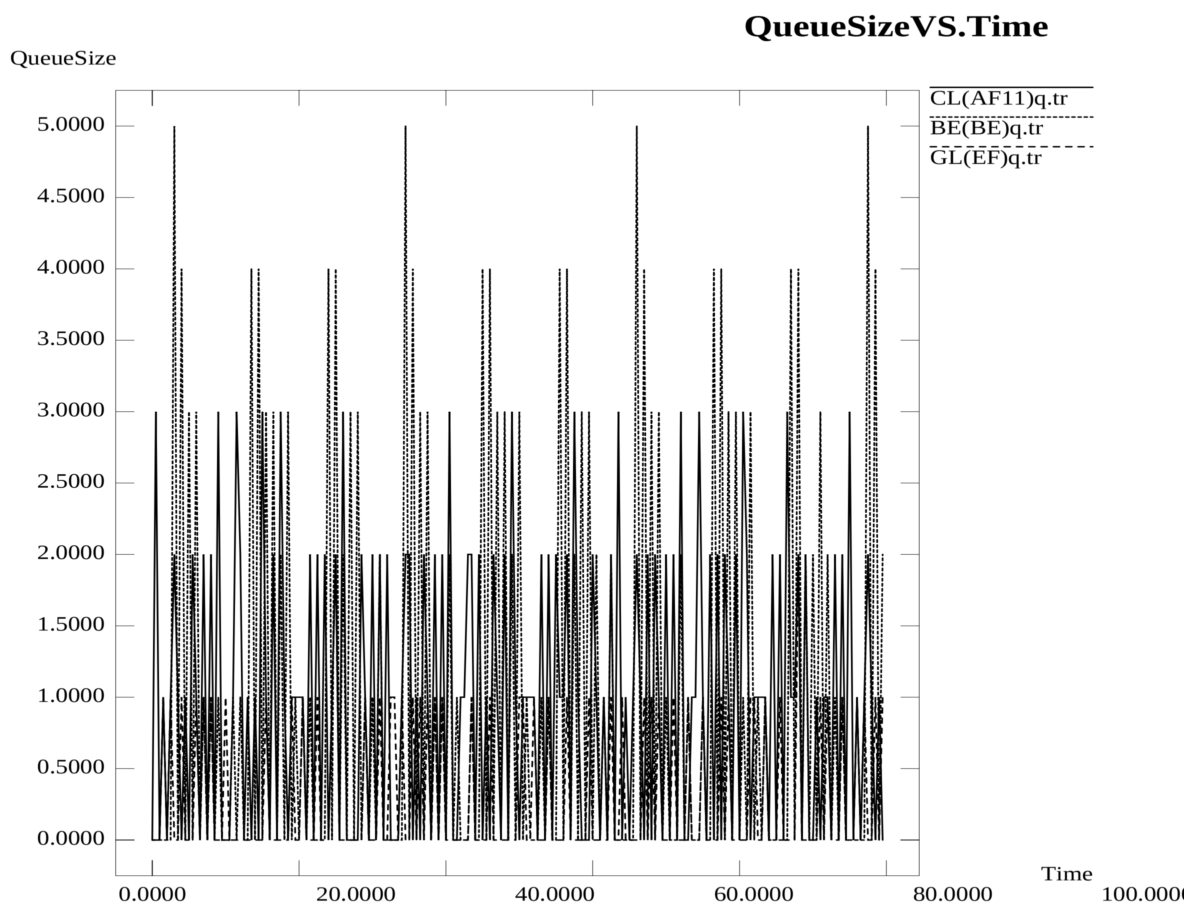
Queue Size Plot: Case 2



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Queue Size Plot: Case 2 (Continued)

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

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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**.

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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, instead of 2.7Mb.

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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.

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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.

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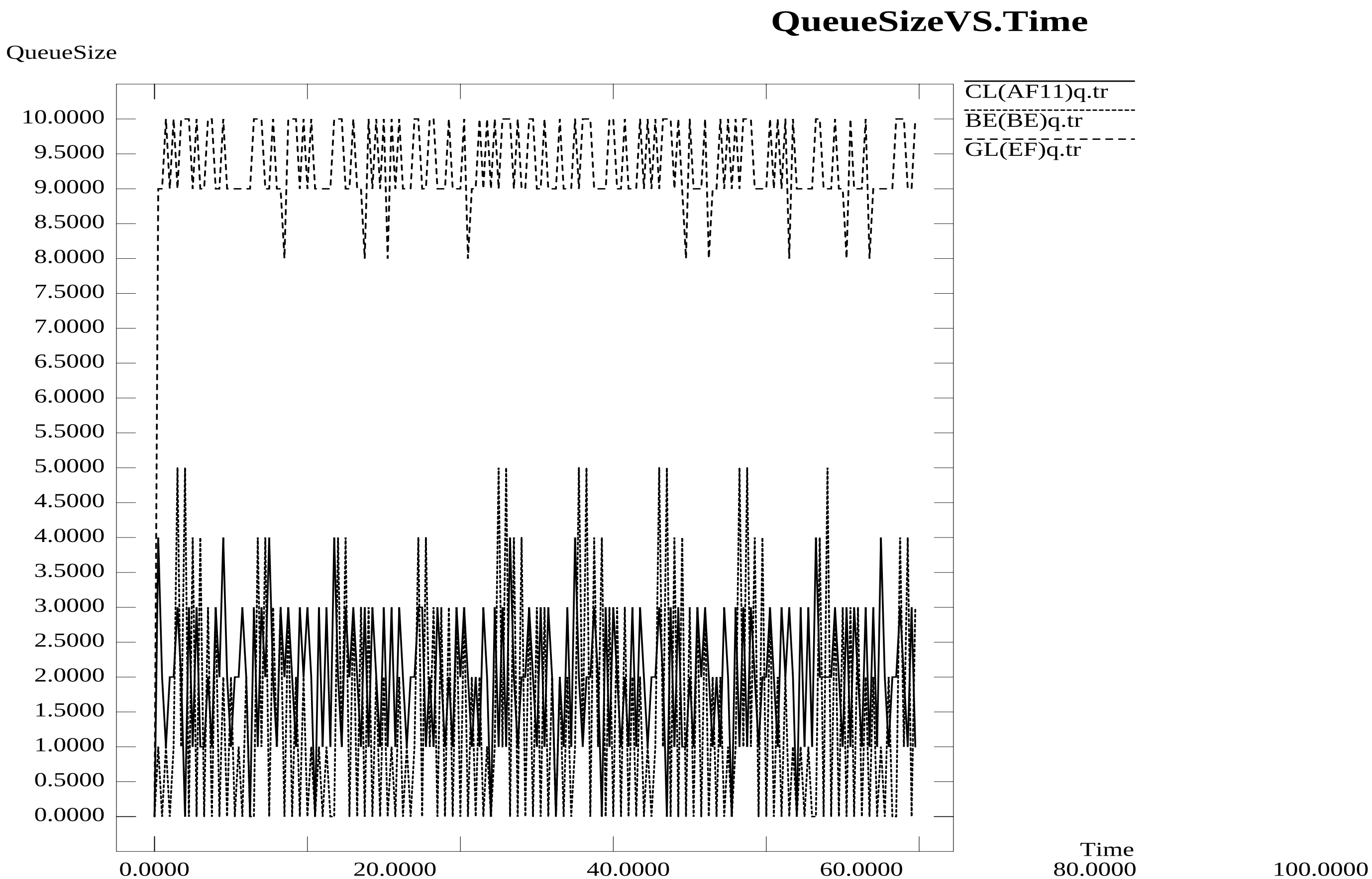
Queue Size Plot: Case 3



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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.

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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**.

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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)

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Drop Ratio of Controlled-load Service

- ***Simulation results:*** **Drop ratio of Guaranteed 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.

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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.

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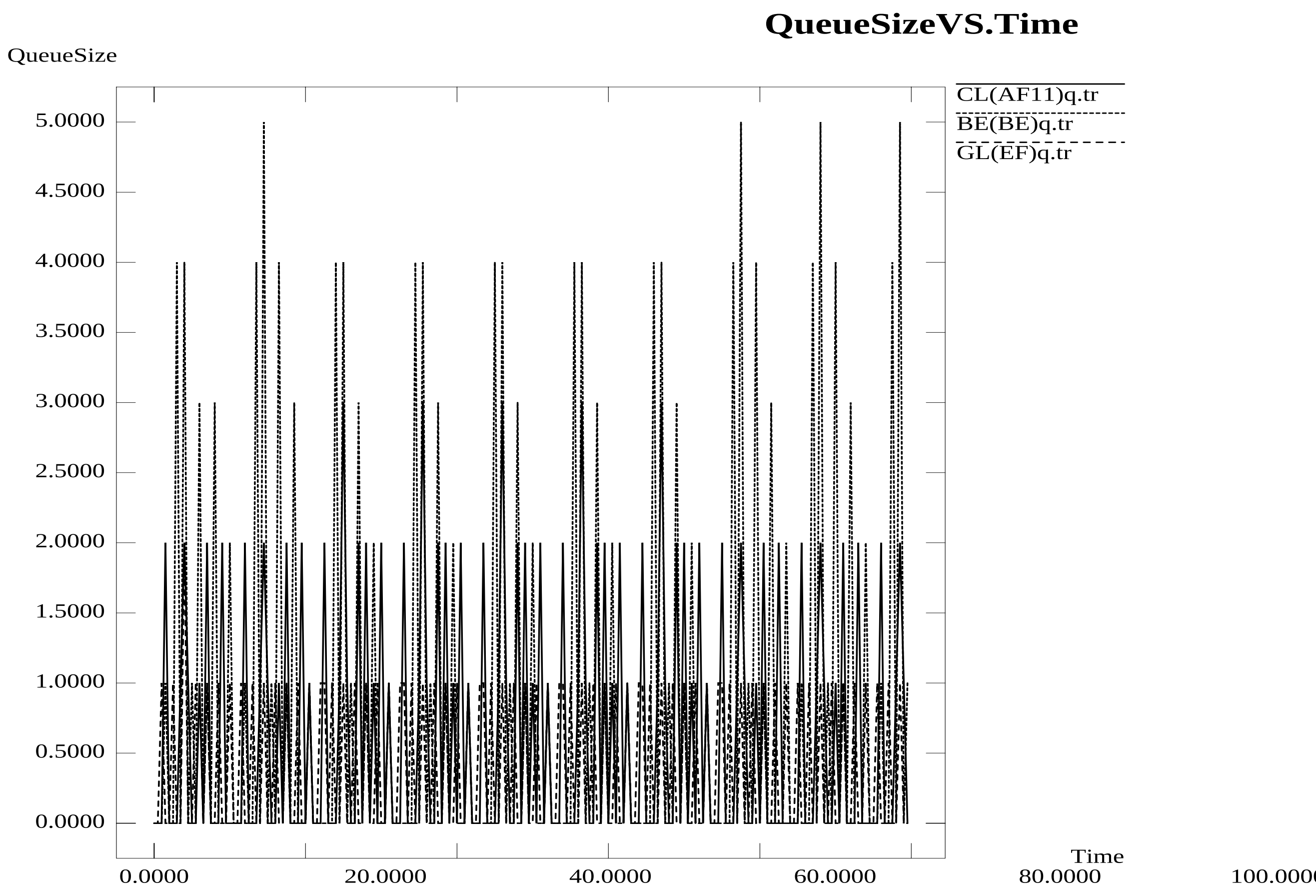
Queue Size Plot



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Observations

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

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Conclusion

- **We have shown that the end-to-end QoS requirements of IntServ applications can be successfully achieved when IntServ traffic is mapped to the DiffServ domain in the next generation Internet.**

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Task 2

Interconnecting *ATN* with *Next Generation Internet*

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QoS Requirements of ATN

- To carry time critical information required for aeronautical applications, ATN provides different QoS to applications.
- In the ATN, priority has the essential role of ensuring that high priority safety related and time critical data are not delayed by low priority non-safety data, especially when the network is overloaded with low priority data.
- The time critical information carried by ATN and the QoS required by ATN applications has led to the development of the ATN as an expensive independent network.

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ATN & DiffServ

- The largest public network, Internet, only offers best-effort service to users and hence is not suitable for carrying time critical ATN traffic.

- The rapid commercialization of the Internet has given rise to demands for QoS over the Internet.

- DiffServ has been proposed by IETF as one of models to meet the demand for QoS.

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Objective

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

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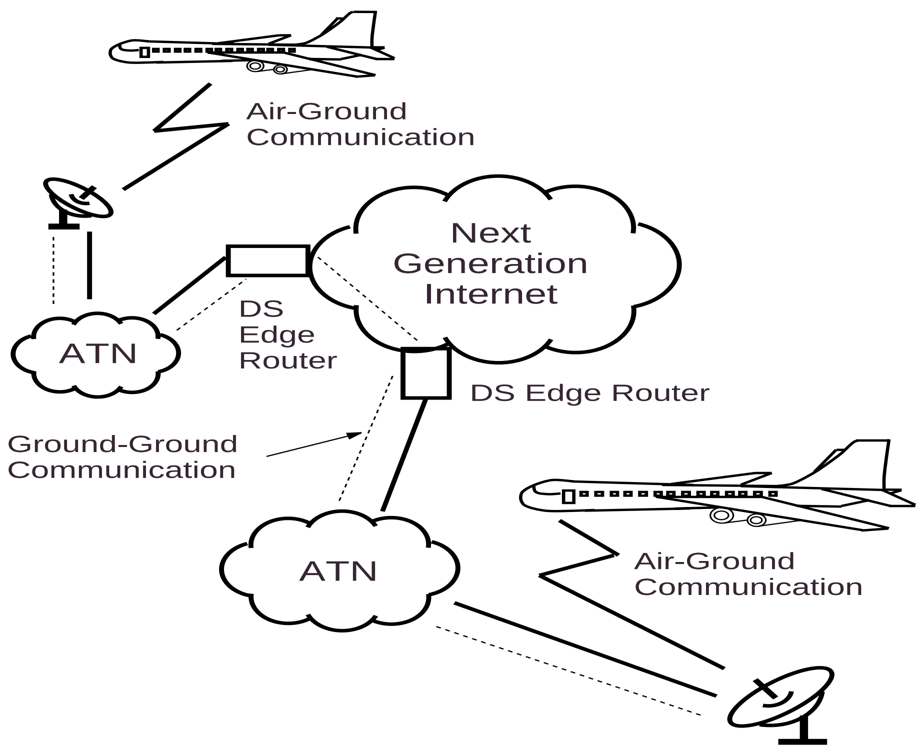
Significance

- Considerable cost savings could be possible if the next generation Internet backbone can be used to connect ATN subnetworks.



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Possibility of ATN over DiffServ

- The DiffServ model utilizes **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.

- The NPDU (Network Protocol Data Unit) header of an ATN packet contains an option part including **an 8-bit field named *Priority*** which indicates the relative priority of the NPDU.

- The value ***0000 0000*** indicates ***normal priority***; the values ***0000 0001* through *0000 1110*** indicate *the* ***priority in an increasing order.***

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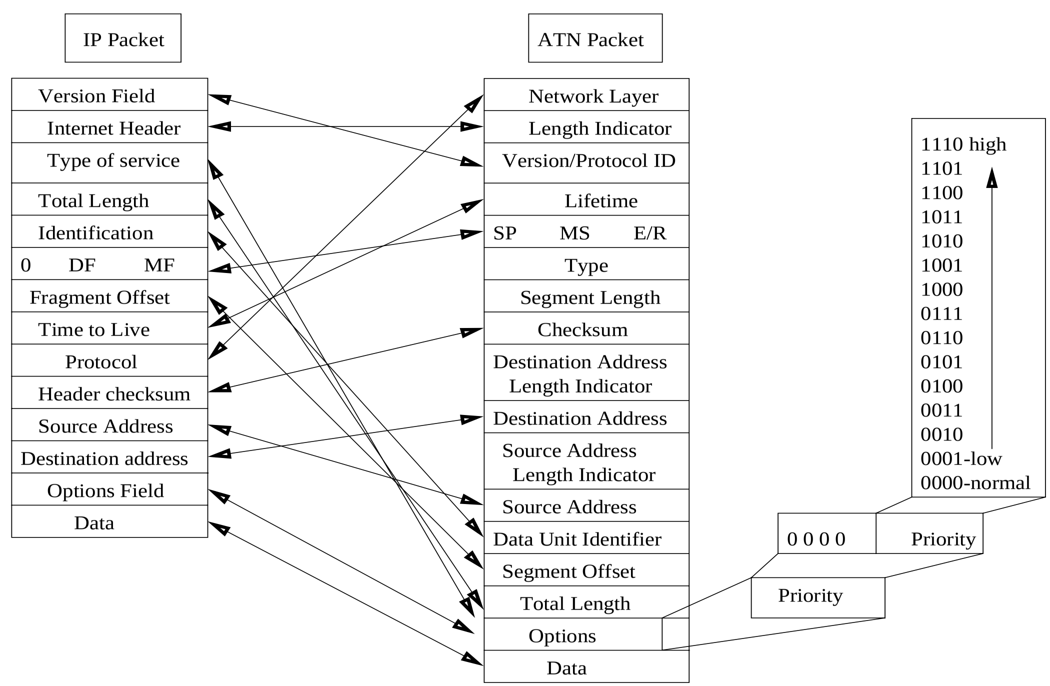
Possibility of ATN over DiffServ (Continued)

- The similarity between an ATN packet and an IP packet, shown below, provides the **possibility** for mapping ATN to DiffServ to achieve the required QoS when they are interconnected.



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Mapping Consideration

- The PHB treatment of packets along the path in the DiffServ domain must approximate the QoS offered in the ATN network.

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Mapping Function

- We map the ***normal priority*** (indicated by *Priority* field in NPDU) in ATN domain to ***BE*** PHB in DiffServ domain;
- Map the ***high priority*** in ATN domain to ***EF*** PHB in DiffServ domain;
- Map the ***medium priorities*** in ATN domain to the corresponding classes of ***AF*** PHBs in DiffServ domain.

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An Example Mapping Function

- An example mapping function used in our simulation

ATN Priority Code	Priority	PHB	DSCP
0000 0000	Normal	BE	000000
0000 0111	Medium	AF11	001010
00001110	High	EF	101110

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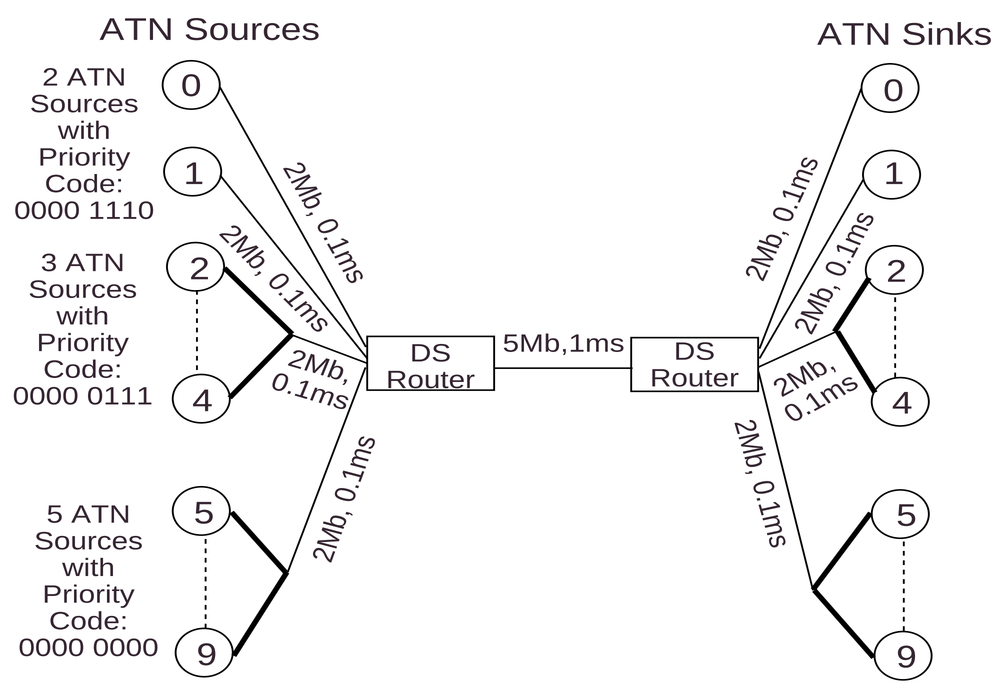
Simulation Configurations

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



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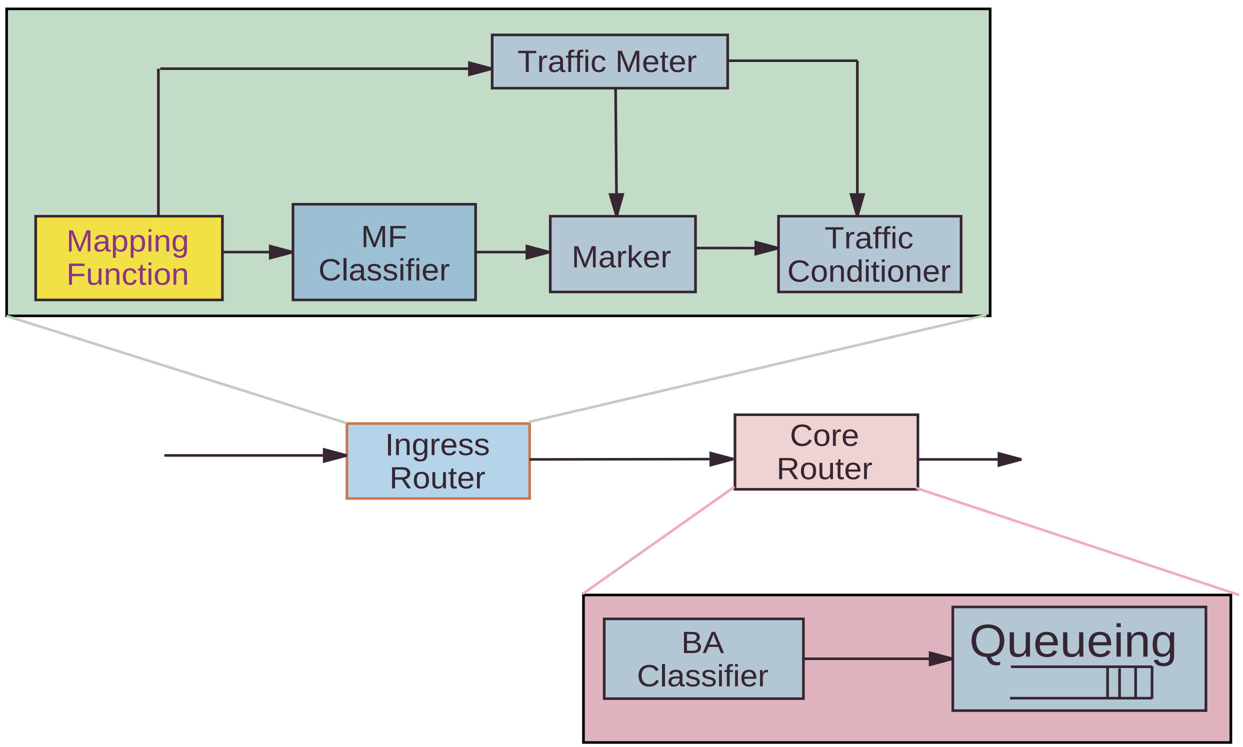
Simulation Configurations (Continued)

- We integrated the mapping function into the edge DiffServ router. (***Recall***)



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Simulation Configurations (Continued)

- Table below shows the configuration of queues inside the core DiffServ router.

	Queue Type	Queue 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

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Performance Criteria

- Goodput of each ATN source.
- Queue size of each queue.
- Drop ratio at scheduler.

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QoS Obtained by ATN Applications: Case 1

- ***Case 1:*** **No congestion.**

Source NO.	Source Type	Source Rate
0, 1	*High Priority*	*1Mb*
2, 3, 4	*Medium Priority*	*0.666Mb*
5,6,7,8,9	*Normal Priority*	*0.2Mb*

- The amount of traffic with different priorities are equal to the corresponding scheduled link bandwidth → **No congestion**.

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Goodput of ATN Applications: Case 1

- ***Results of Case 1:*** **Goodput of each ATN source.**

Source Priority		Case 1 (Kb/S)	Case 2 (Kb/S)	Case 3 (Kb/S)	Case 4 (Kb/S)
High	*Src 0*	*999.99*	*999.99*	*999.99*	*999.99*
	Src 1	*999.99*	*999.99*	*999.99*	*999.99*
Medium	*Src 2*	*666.66*	*666.66*	*668.24*	*668.47*
	Src 3	*666.66*	*666.66*	*667.34*	*667.53*
	Src 4	*666.66*	*666.66*	*664.42*	*663.99*
Normal	*Src 5*	*200.00*	*199.65*	*200.00*	*199.48*
	Src 6	*200.00*	*201.85*	*200.00*	*201.98*
	Src 7	*200.00*	*202.42*	*200.00*	*201.68*
	Src 8	*199.98*	*199.88*	*199.98*	*200.467*
	Src 9	*200.00*	*196.20*	*200.00*	*196.39*

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Drop Ratio of ATN Applications: Case 1

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

Type of traffic	**Case 1**	**Case 2**	**Case 3**	**Case 4**
High Priority Traffic	*0.00*	*0.00*	*0.00*	*0.00*
Medium Priority Traffic	*0.00*	*0.00*	*0.49*	*0.49*
Normal Priority Traffic	*0.00*	*0.67*	*0.00*	*0.67*

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

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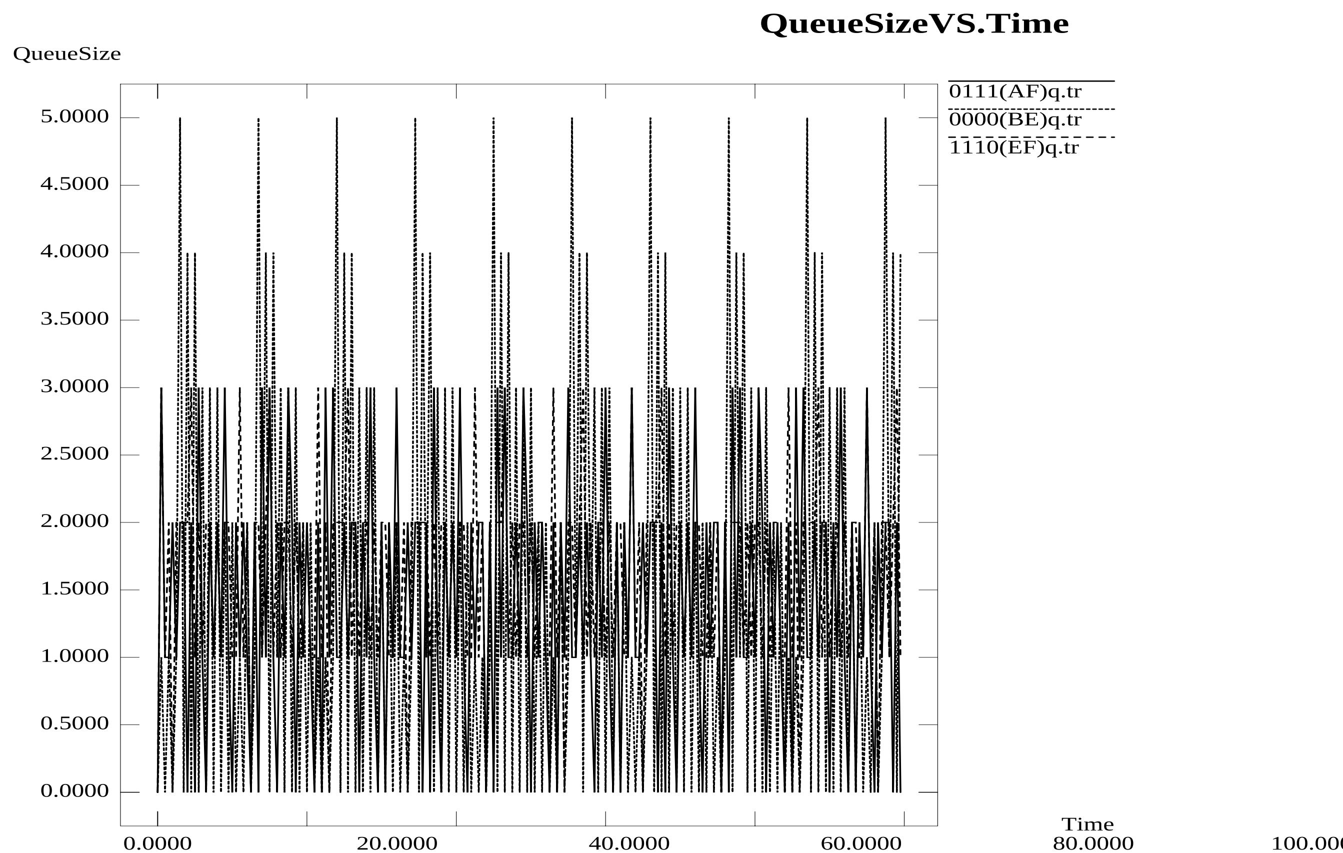
Queue Size Plot: Case 1



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Queue Size Plot: Case 1 (Continued)

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

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QoS Obtained by ATN Applications: Case 2

- ***Case 2: Normal Priority traffic gets into* congestion.**

Source NO.	**Source Type**	**Source Rate**
0, 1	*High Priority*	*1Mb*
2, 3, 4	*Medium Priority*	*0.666Mb*
5,6,7,8,9	*Normal Priority*	*0.6Mb*

- The amount of traffic with Normal Priority (3Mb) is greater than the corresponding scheduled link bandwidth (1 Mb) → **Normal Priority traffic gets into congestion**.

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Goodput of ATN Applications: Case 2

- ***Results of Case 2:*** **Goodput of each ATN source.**

Sources		Case 1 (Kb/S)	Case 2 (Kb/S)	Case 3 (Kb/S)	Case 4 (Kb/S)
High	Src 0	999.9990	999.9990	999.9990	999.9990
	Src 1	999.9990	999.9990	999.9990	999.9990
Medium	Src 2	666.6660	666.6660	668.2409	668.4719
	Src 3	666.6660	666.6660	667.3379	667.5270
	Src 4	666.6660	666.6660	664.4189	663.9990
Normal	Src 5	200.0039	199.6469	200.0039	199.4790
	Src 6	200.0039	201.8520	200.0039	201.9780
	Src 7	200.0039	202.4190	200.0039	201.6840
	Src 8	199.9830	199.8779	199.9830	200.4660
	Src 9	200.0039	196.2030	200.0039	196.3920

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Drop Ratio of ATN Applications: Case 2

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

Type of traffic	Case 1	Case 2	Case 3	Case 4
High Priority Traffic	*0.00000*	*0.00000*	*0.00000*	*0.00000*
Medium Priority Traffic	*0.00000*	*0.00000*	*0.49982*	*0.49982*
Normal Priority Traffic	*0.00000*	*0.66564*	*0.00000*	*0.66562*

- **Observations:** the drop ratio of Normal Priority traffic is increased.

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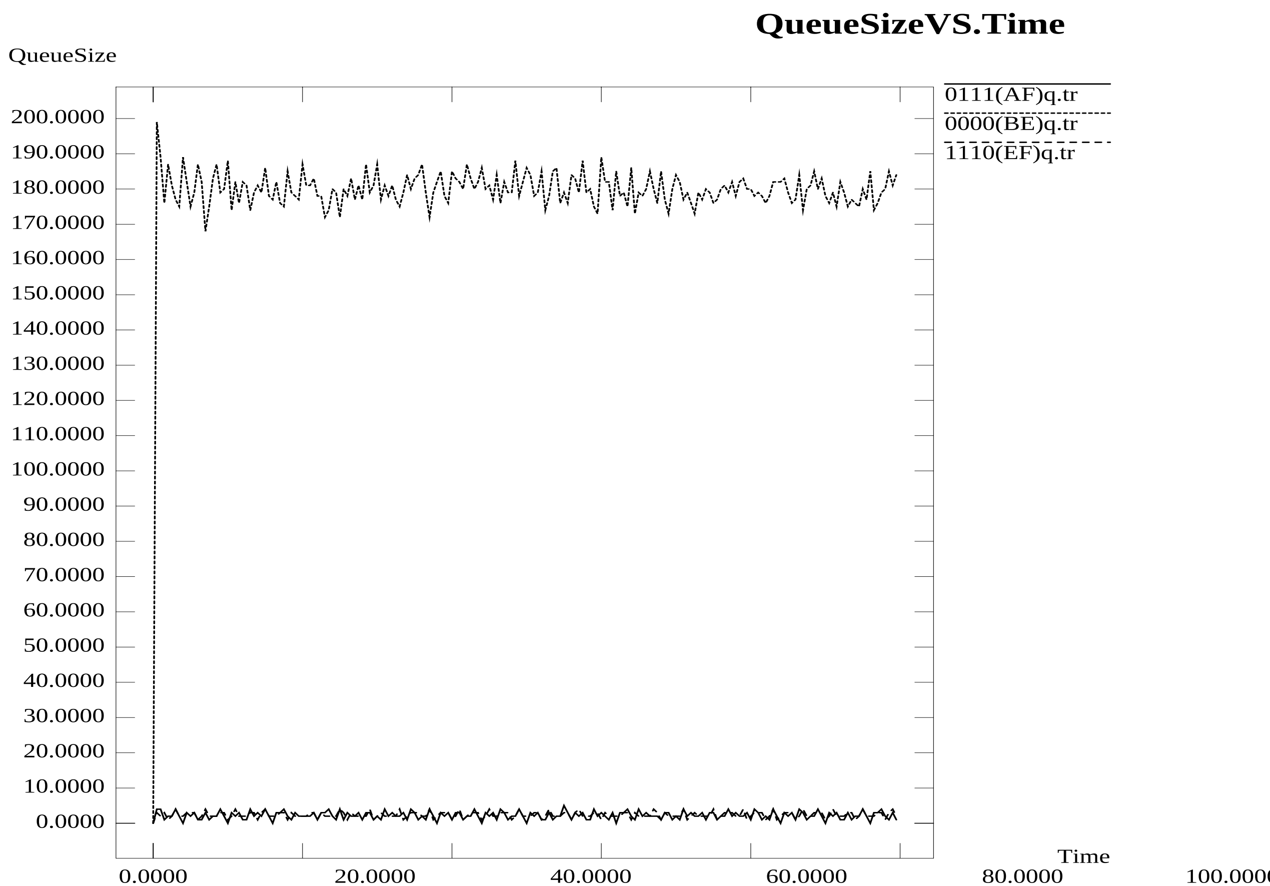
Queue Size Plot: Case 2



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Queue Size Plot: Case 2 (Continued)

- **Observations:**
  - In this case, the high priority traffic has the smallest average queue size and jitter;
  - The normal priority traffic has the biggest average queue size and jitter.

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QoS Obtained by ATN Applications: Case 3

- ***Case 3: Medium Priority traffic gets into* congestion.**

Source NO.	Source Type	Source Rate
0, 1	*High Priority*	*1Mb*
2, 3, 4	*Medium Priority*	*1.333Mb*
5,6,7,8,9	*Normal Priority*	*0.2Mb*

- The amount of traffic with Medium Priority (4Mb) is greater than the corresponding scheduled link bandwidth (2 Mb) → **Medium Priority traffic gets into congestion**.

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Goodput of ATN Applications: Case 3

- ***Results of Case 3:*** **Goodput of each ATN source.**

Sources		Case 1 (Kb/S)	Case 2 (Kb/S)	Case 3 (Kb/S)	Case 4 (Kb/S)
High	*Src 0*	*999.9990*	*999.9990*	*999.9990*	*999.9990*
	Src 1	*999.9990*	*999.9990*	*999.9990*	*999.9990*
Medium	*Src 2*	*666.6660*	*666.6660*	*668.2409*	*668.4719*
	Src 3	*666.6660*	*666.6660*	*667.3379*	*667.5270*
	Src 4	*666.6660*	*666.6660*	*664.4189*	*663.9990*
Normal	*Src 5*	*200.0039*	*199.6469*	*200.0039*	*199.4790*
	Src 6	*200.0039*	*201.8520*	*200.0039*	*201.9780*
	Src 7	*200.0039*	*202.4190*	*200.0039*	*201.6840*
	Src 8	*199.9830*	*199.8779*	*199.9830*	*200.4660*
	Src 9	*200.0039*	*196.2030*	*200.0039*	*196.3920*

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Drop Ratio of ATN Applications: Case 3

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

Type of traffic	**Case 1**	**Case 2**	**Case 3**	**Case 4**
High Priority Traffic	*0.00000*	*0.00000*	*0.00000*	*0.00000*
Medium Priority Traffic	*0.00000*	*0.00000*	*0.49982*	*0.49982*
Normal Priority Traffic	*0.00000*	*0.66564*	*0.00000*	*0.66562*

- **Observations:** the drop ratio of Medium Priority traffic is increased.

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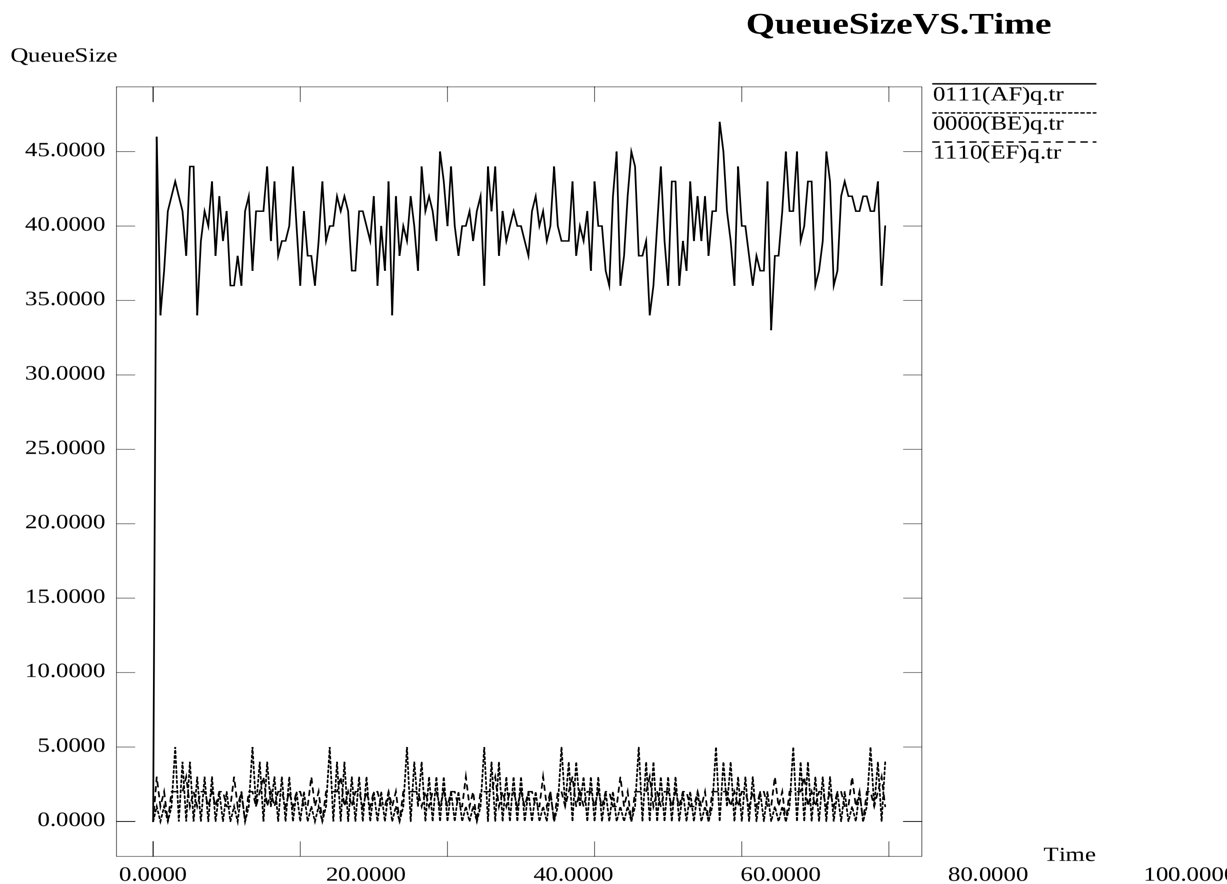
Queue Size Plot: Case 3



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Queue Size Plot: Case 3 (Continued)

- **Observations:**
  - The high priority traffic has the smallest average queue size and jitter.
  - Note that both the queue size and jitter of medium priority traffic are greater than the other two's.

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QoS Obtained by ATN Applications: Case 4

- ***Case 4: Both Medium and Normal Priority traffic gets into* congestion.**

Source NO.	Source Type	Source Rate
0, 1	*High Priority*	*1Mb*
2, 3, 4	*Medium Priority*	*1.333Mb*
5,6,7,8,9	*Normal Priority*	*0.6Mb*

- The amount of traffic with both Medium (4Mb) and Normal Priority (3Mb) is greater than the corresponding scheduled link bandwidth (2Mb, 1Mb) → **Both Medium and Normal Priority traffic gets into congestion**.

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Goodput of ATN Applications: Case 4

- ***Results of Case 4:*** **Goodput of each ATN source.**

Sources		Case 1 (Kb/S)	Case 2 (Kb/S)	Case 3 (Kb/S)	Case 4 (Kb/S)
High	*Src 0*	*999.9990*	*999.9990*	*999.9990*	*999.9990*
	Src 1	*999.9990*	*999.9990*	*999.9990*	*999.9990*
Medium	*Src 2*	*666.6660*	*666.6660*	*668.2409*	*668.4719*
	Src 3	*666.6660*	*666.6660*	*667.3379*	*667.5270*
	Src 4	*666.6660*	*666.6660*	*664.4189*	*663.9990*
Normal	*Src 5*	*200.0039*	*199.6469*	*200.0039*	*199.4790*
	Src 6	*200.0039*	*201.8520*	*200.0039*	*201.9780*
	Src 7	*200.0039*	*202.4190*	*200.0039*	*201.6840*
	Src 8	*199.9830*	*199.8779*	*199.9830*	*200.4660*
	Src 9	*200.0039*	*196.2030*	*200.0039*	*196.3920*

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Drop Ratio of ATN Applications: Case 4

- ***Simulation results of Case 4:*** **Drop ratio of ATN traffic (measured at scheduler).**

Type of traffic	Case 1	Case 2	Case 3	Case 4
High Priority Traffic	*0.00000*	*0.00000*	*0.00000*	*0.00000*
Medium Priority Traffic	*0.00000*	*0.00000*	*0.49982*	*0.49982*
Normal Priority Traffic	*0.00000*	*0.66564*	*0.00000*	*0.66562*

- **Observations:** the drop ratio of both Medium and Normal Priority traffic are increased.

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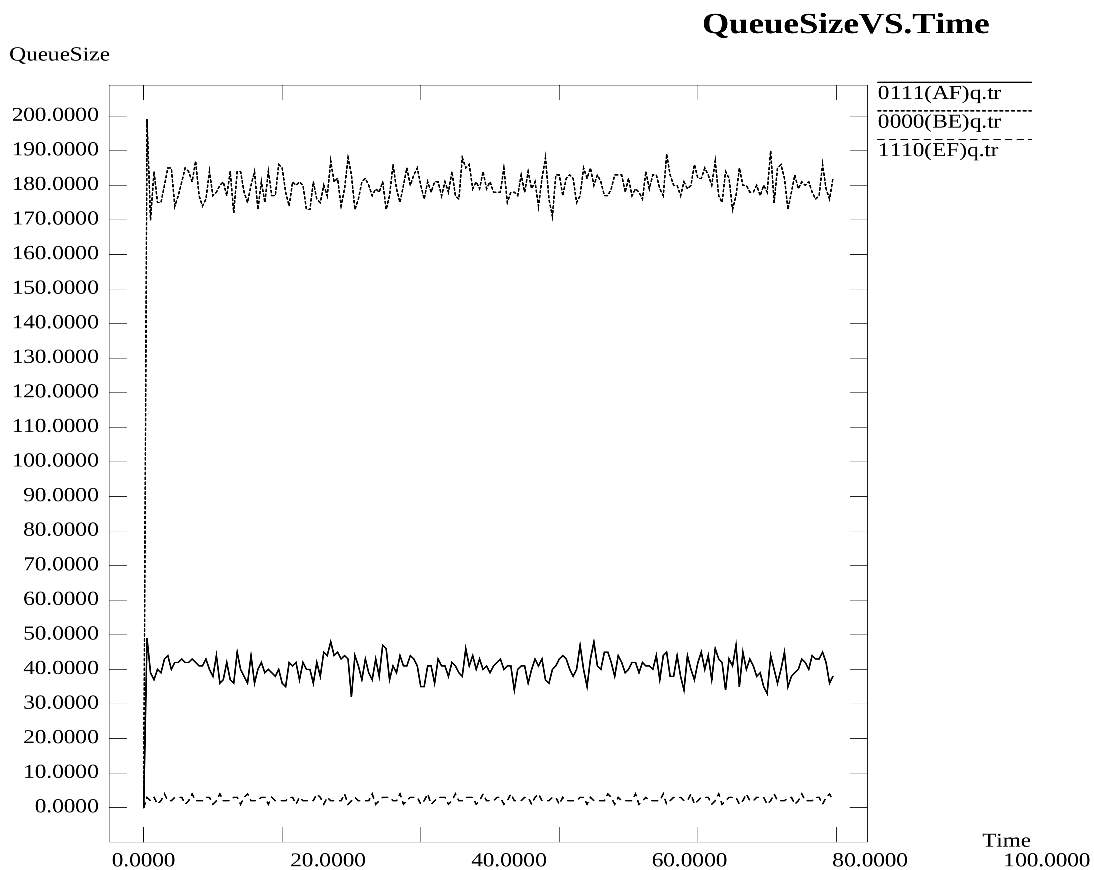
Queue Size Plot: Case 4



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Queue Size Plot: Case 4

- **Observations:**
  - In this case, the high priority traffic has the smallest average queue size and jitter;
  - The normal priority traffic has the biggest average queue size and jitter.

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Observations

- ***The high priority traffic*** always has the smallest jitter, the smallest average queue size and the smallest drop ratio without being affected by the performance of other traffic.

- ***The medium priority traffic*** has smaller drop ratio, jitter and average queue size than ***the normal priority traffic***.

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Conclusion

- The high priority traffic receives the highest priority; the medium priority traffic receives higher priority than normal priority traffic.
- According to our simulation, the QoS requirements of ATN applications can be successfully achieved when ATN traffic is mapped to the DiffServ domain in the next generation Internet.

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Task 3

QoS in *DiffServ* over *ATM*

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Prioritized EPD

- DS service classes can use the CLP bit of ATM cell header to provide service differentiation.
- EPD does not consider the priority of cells.
- Prioritized EPD can be used to provide service discrimination.
- Two thresholds are used to drop cells depending on the CLP bit.

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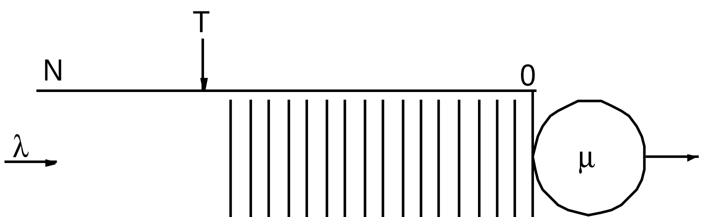
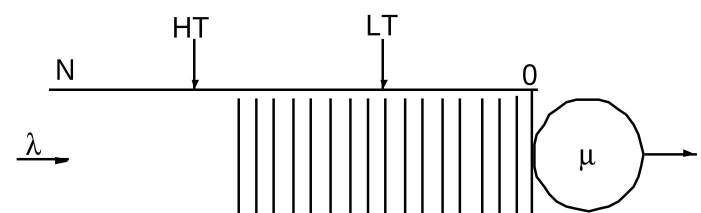
Buffer Management Schemes

EPD



- QL < T
  - Accept all packets.
- T ≤ QL < N
  - Discard all new incoming packets.
- QL ≥ N
  - Discard all.

PEPD



- QL <LT
  - Accept all packets.
- LT ≤ QL < HT
  - Discard all new low priority packets.
- HT ≤ QL < N
  - Discard all new packets
- QL ≥ N
  - Discard all packets

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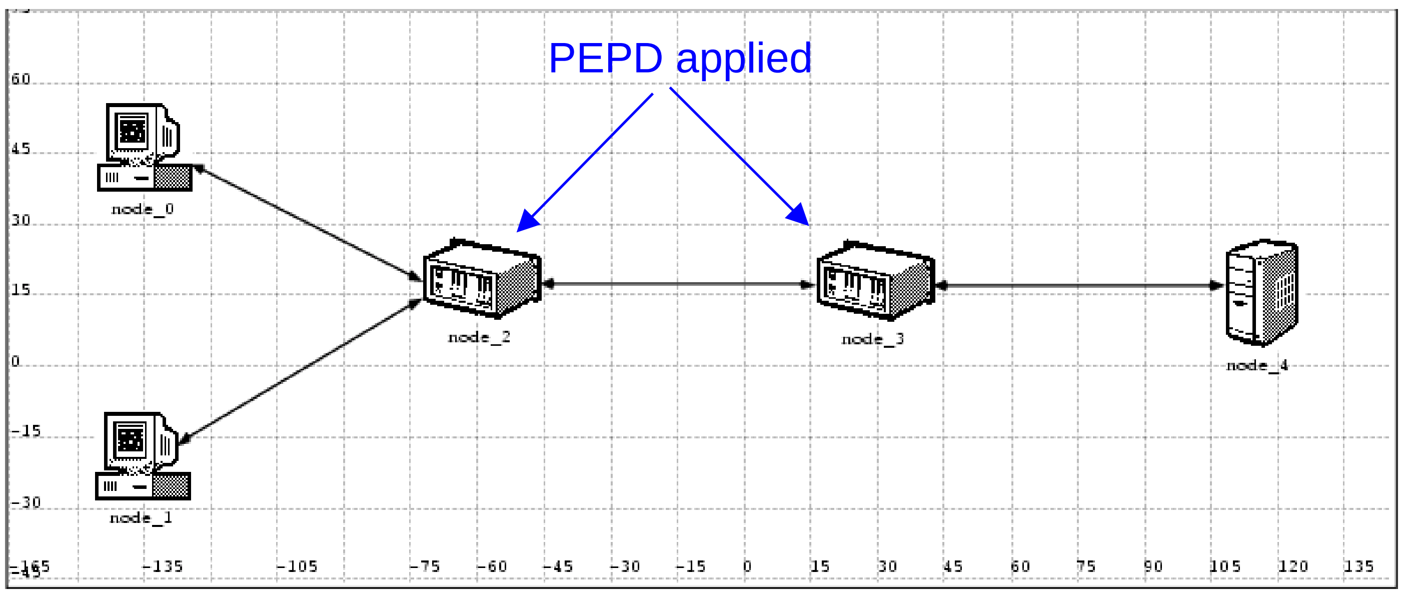
OPNET Simulation Configuration



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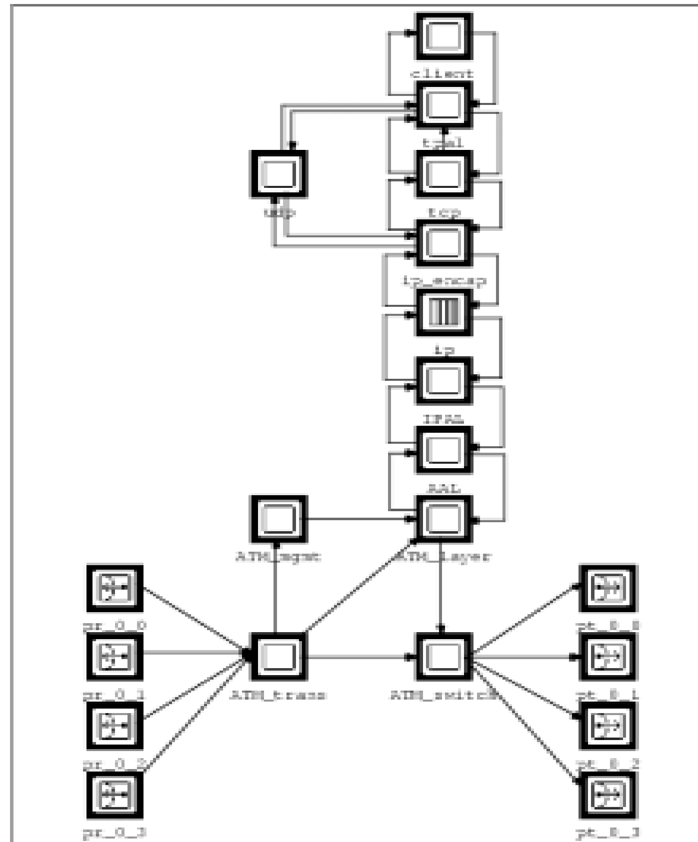
DS-ATM Protocol Stack

- AAL Layer marks the End of Packet.
- ATM_layer changes the CLP bit depending on the packet of the DS service.



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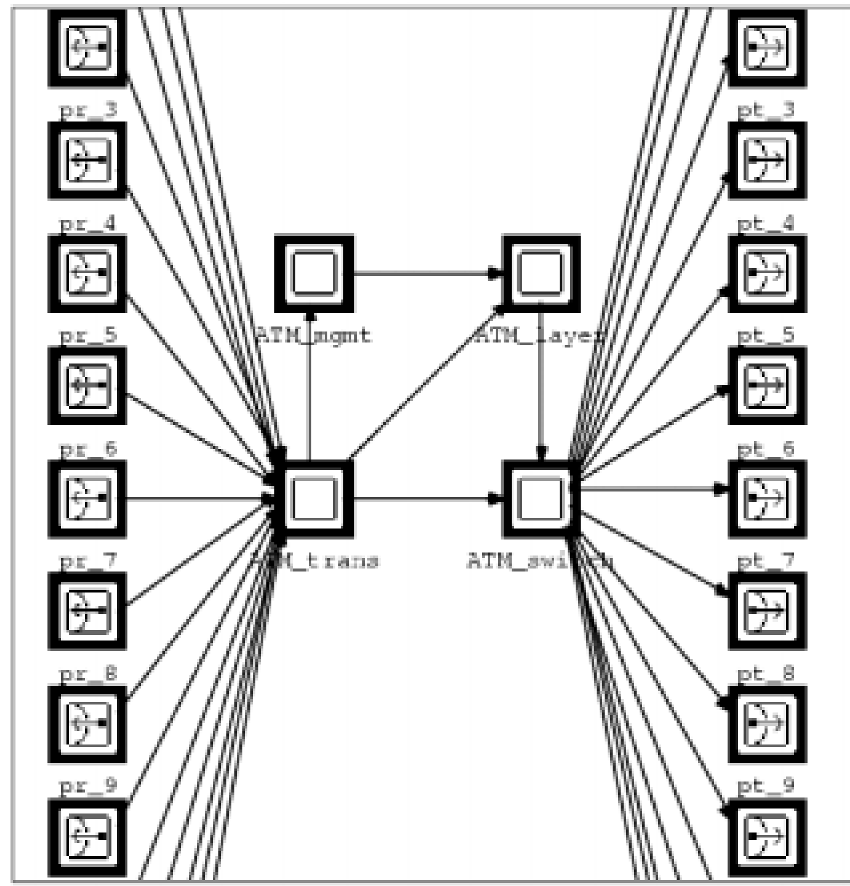
ATM Switch Node

- Support service differentiation in the ATM switch buffer.
- Change the buffer management scheme in the ATM_switch process to Prioritized EPD.



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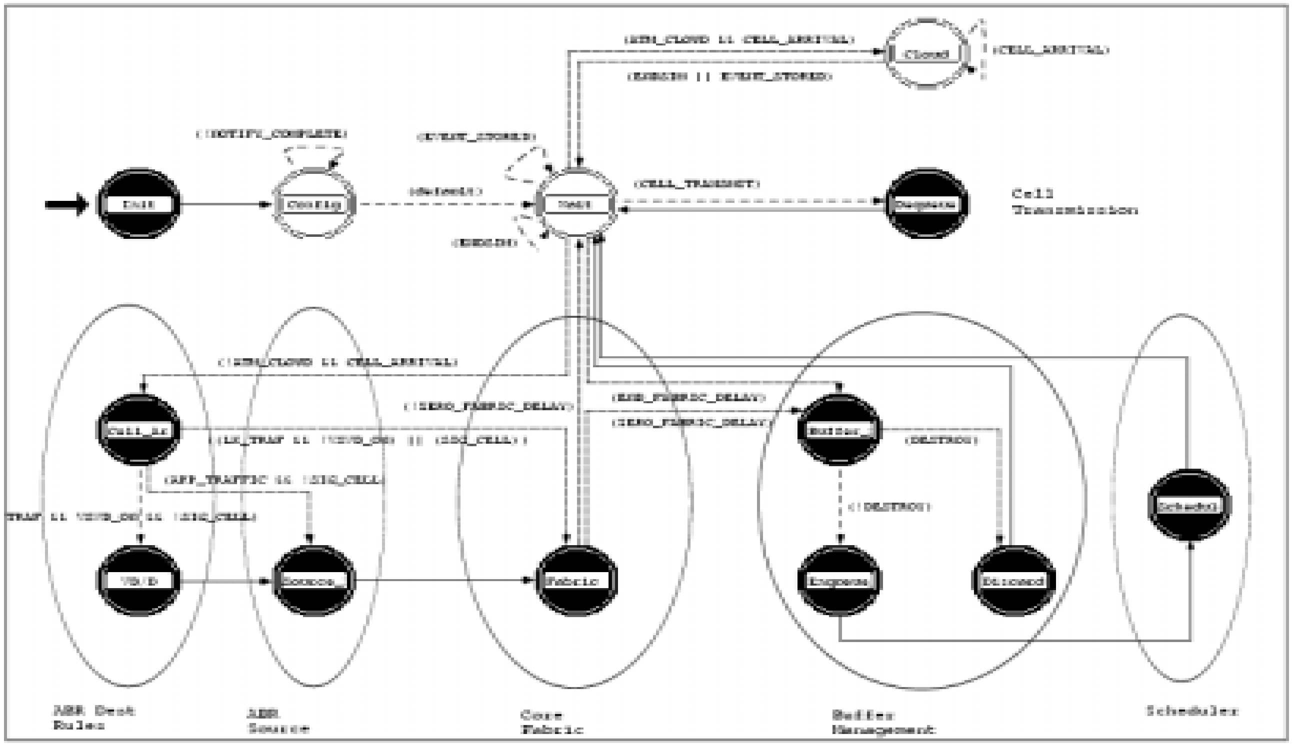
ATM_Switch Process



Implements the PEPD buffer management to support service differentiation.

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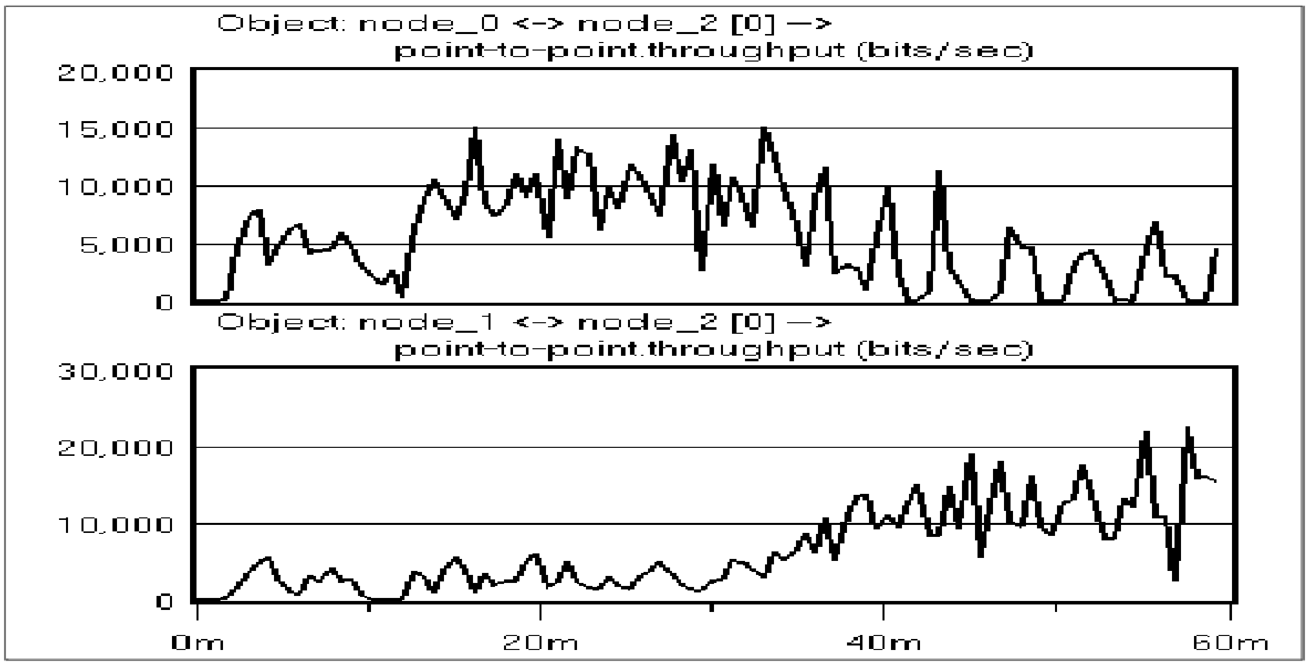
Source Rates



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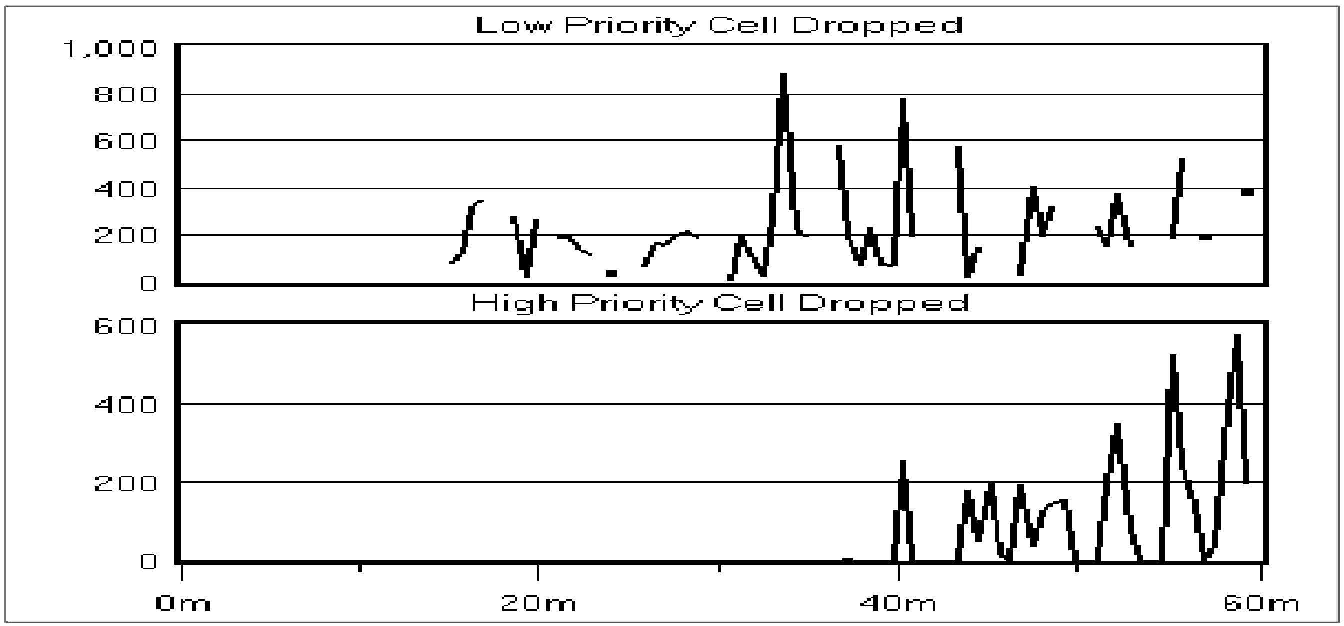
Cell Dropping



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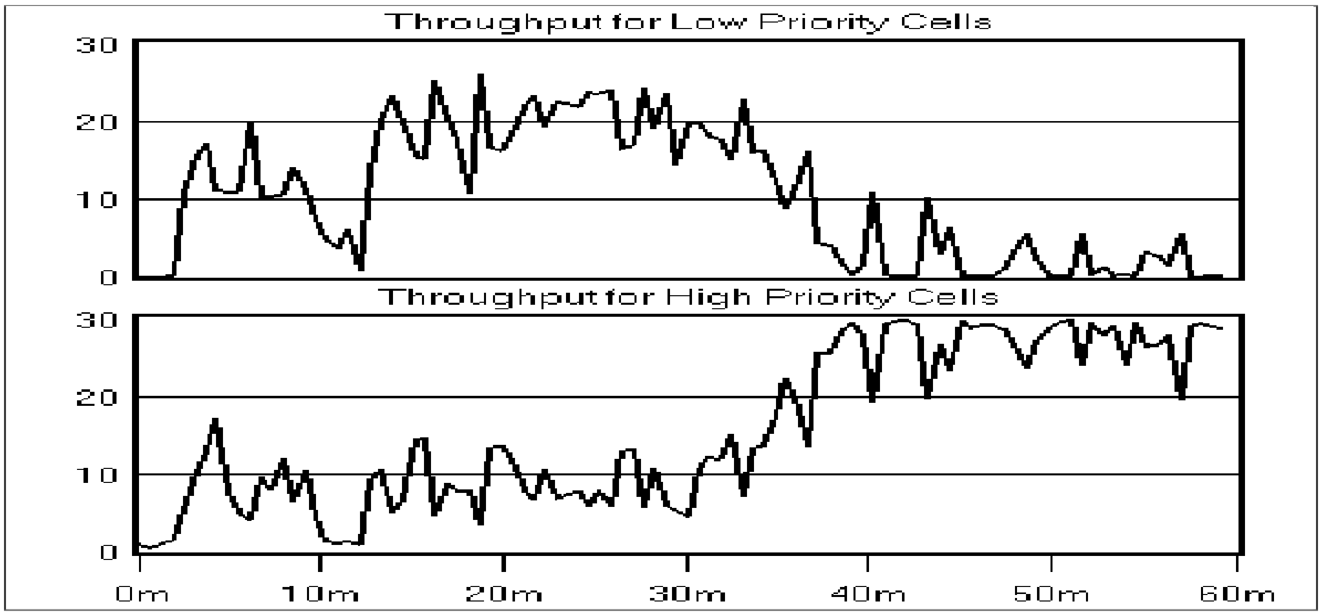
Throughput



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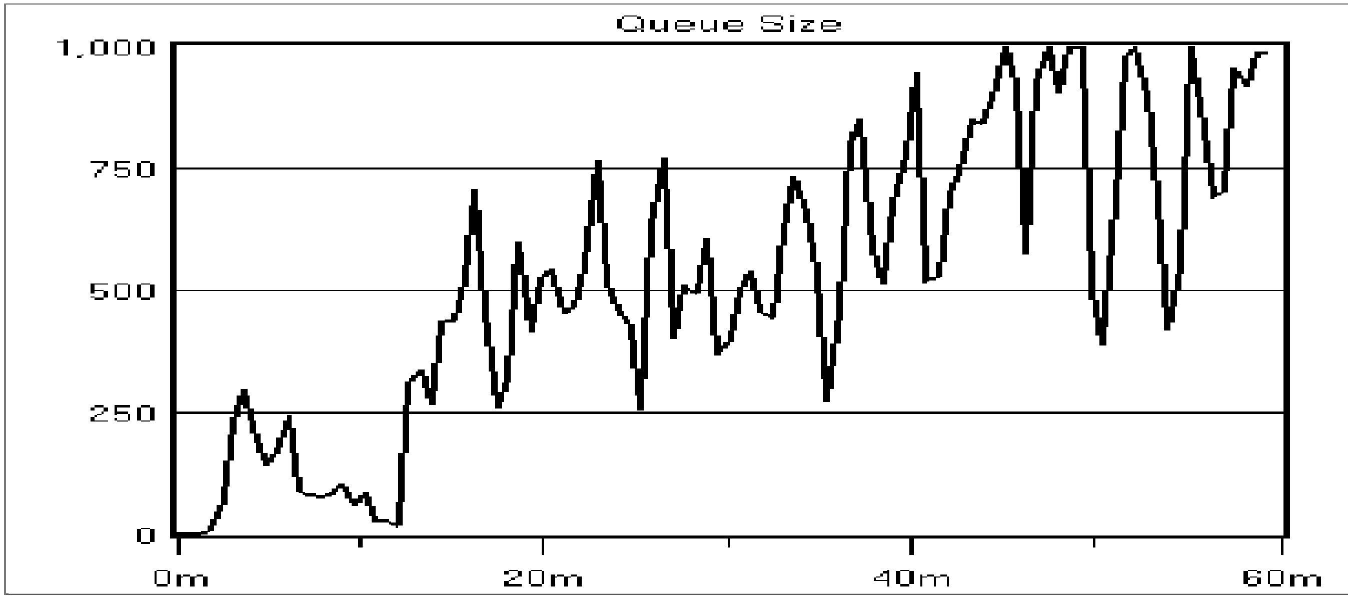
Queue Occupancy



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Conclusion

- Prioritized EPD can provide differential treatment to packets in an ATM core network.
- OVERALL: The tasks have been completed successfully.
- Thanks to NASA for the support of this project.

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