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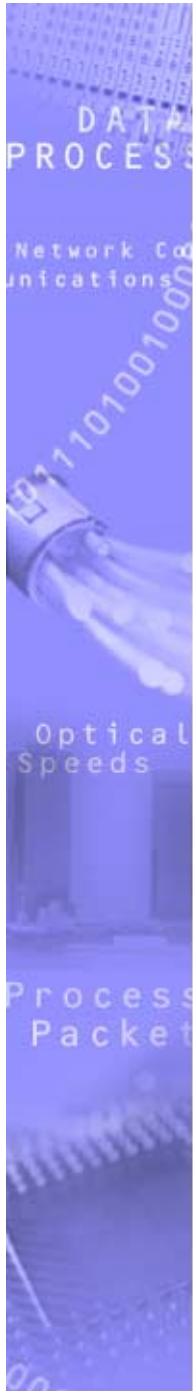
Phase I Simulation Results

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AuroraNetics, Inc.

July 8-13, 2001

Portland, Oregon

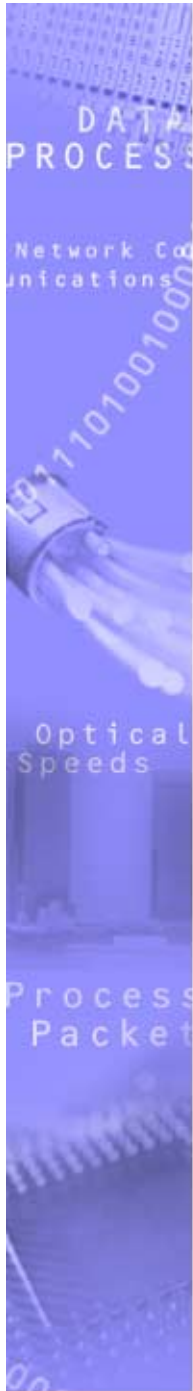


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- Single/dual priority transit buffer ring contention resolution algorithms
- Simulation results
- Conclusion



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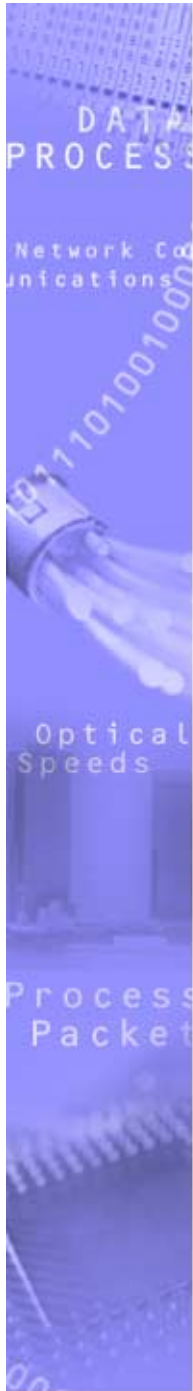


Objectives



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- Guaranteed **END-TO-END** delay and jitter bound for high priority traffic
- Priority discrimination and separation
 - LP traffic does not affect performance of HP traffic
- No packet loss on the ring
- Maximum available ring throughput
 - Delay/jitter performance of HP traffic is not affected by over provisioning of LP traffic
- Best possible delay and jitter for low priority traffic

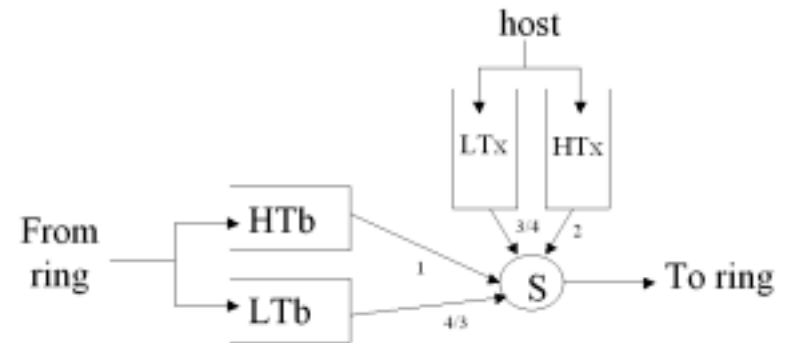
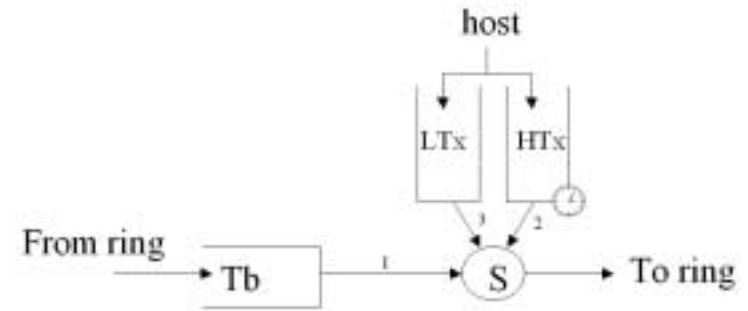


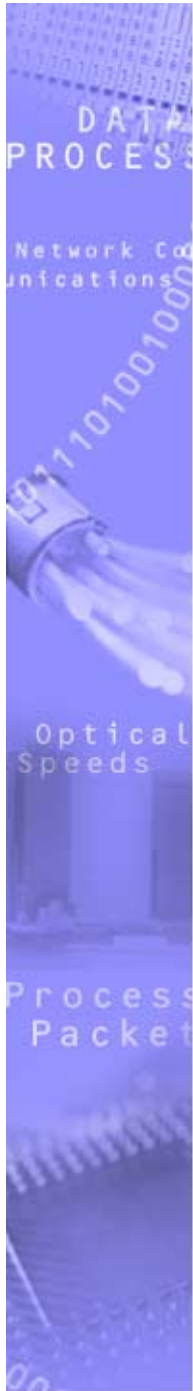
Simulation Models



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- **Single Transit Buffer**
 - $Tb = 4KB$ (Cut-Through)
 - Transit packets have priority over transmit packets
- **Two Transit Buffers**
 - $HTb = 4KB$ (Store-and-Forward)
 - $LTb = 256KB$ (Store-and-Forward)
 - Only high-priority transit traffic cuts through the transmit traffic
 - Transit packets are fully stored before they are forwarded to the ring (SF)



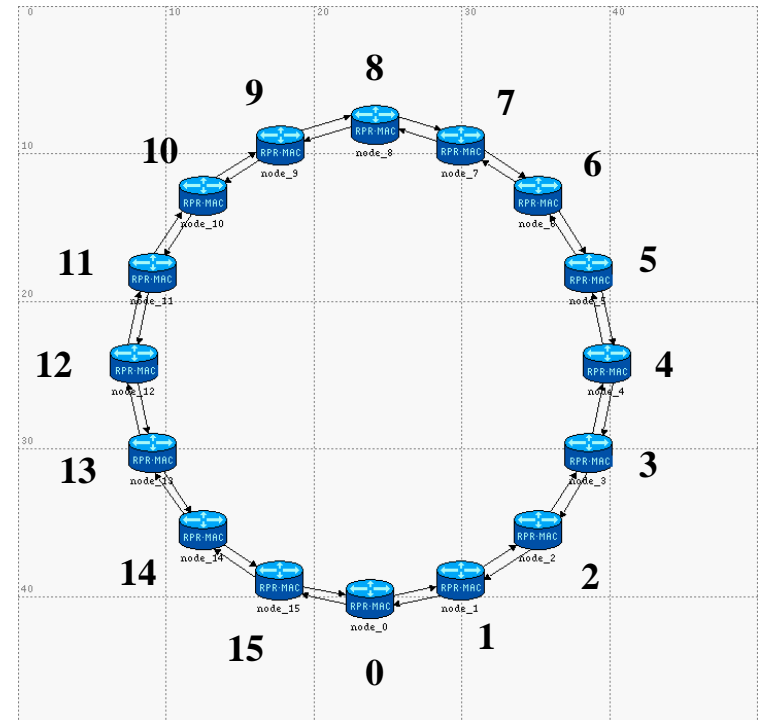


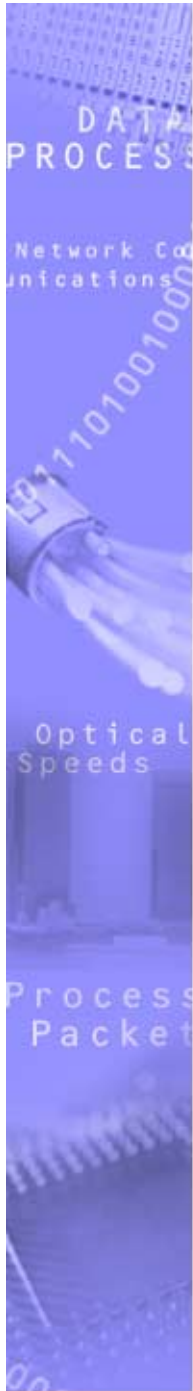
Scenarios

- 16 node, OC192 dual ring
- 100 km:
 - Segment Delay = 31.25μsec
- 1000km:
 - Segment Delay = 312.5μsec
- Packet size:
 - 64B(%60), 512B(%20), 1518B(%20)



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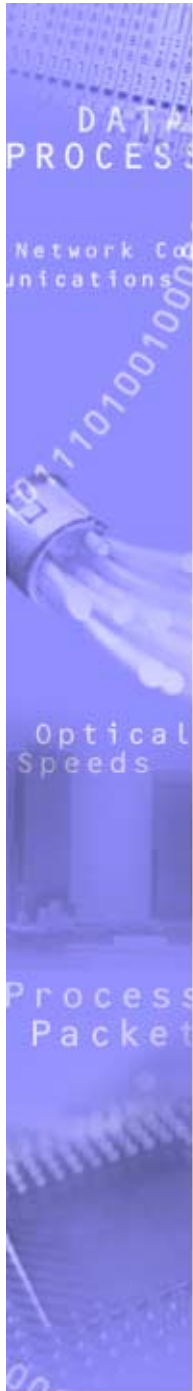


Traffic scenarios: Mesh (Any-to-Any)

- HTx: 370Mbps CBR
 - 1 tri-modal source per node
- LTx: 2.1Gbps bursts
 - 16 tri-modal sources per node
 - on 1msec, off 9msec, exponential distribution
 - total of ~3.4Gbps LTx per node
- Total traffic injected: ~60Gbps
 - Total HP traffic is ~6Gbps



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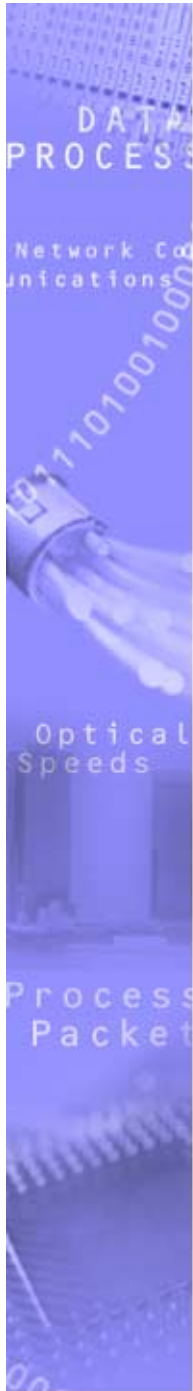


Traffic scenarios: Hub (Any-to-Hub, Hub-to-Any)



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- Node 1,2,3,4,5,6,7 to Hub (Node 0):
 - HTx: 430Mbps CBR
 - 1 tri-modal source per node
 - LTx: 2Gbps bursts
 - 1 tri-modal source per node
 - on 1msec, off 1msec, exponential distribution
 - total of ~1Gbps LTx per node
- Total traffic injected: ~10Gbps
- Total HP traffic is ~3Gbps

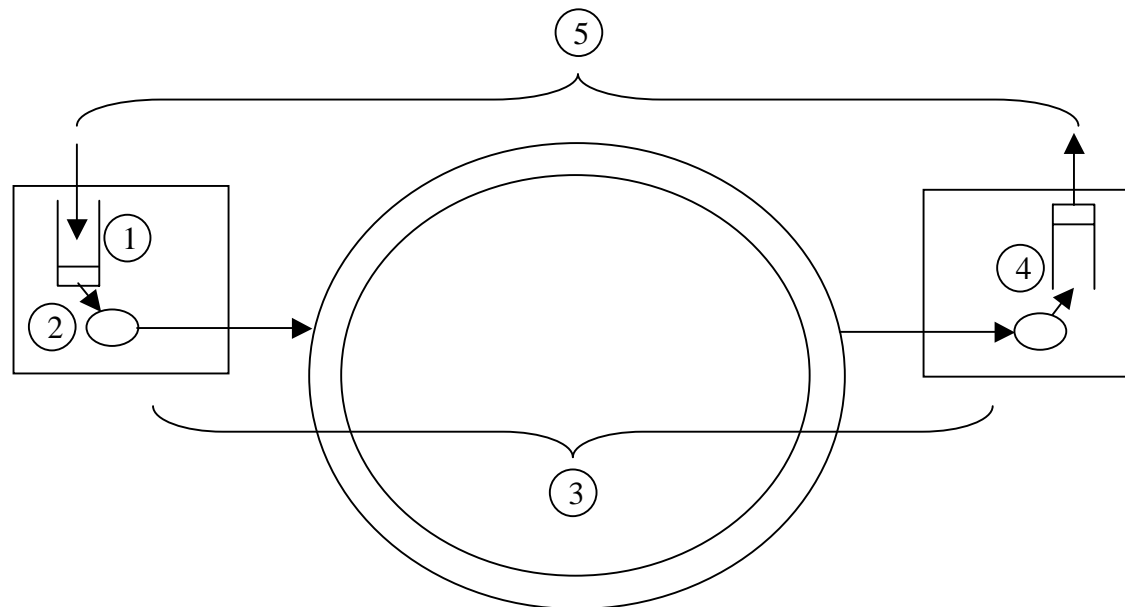


Important Statistics

$$\text{MAC ETE} = \overset{\textcircled{5}}{\text{Queuing Delay}} + \overset{\textcircled{1}}{\text{Medium Access Delay}} + \overset{\textcircled{2}}{\text{Ring ETE Delay (+Receive Buffer Delay)}}$$

$$\text{Ring ETE} = \overset{\textcircled{3}}{\text{Pkt Tx}} + \overset{\textcircled{4}}{\text{PropDelay}} + \text{Transit Node Delay}$$

$$\text{Transit Node Delay} = \text{Pkt Handling Time} + \text{(Insertion/Tb) Buffer Delay}$$





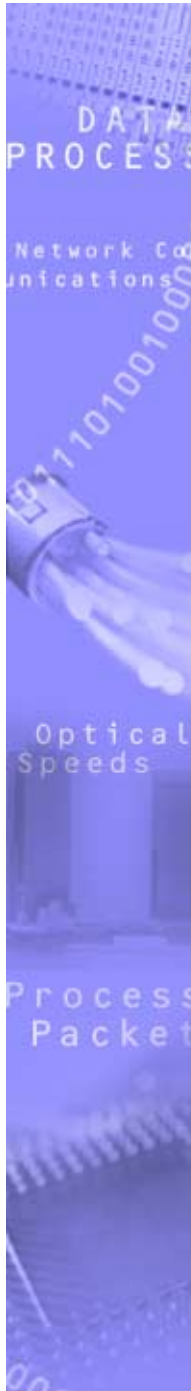
High Priority Ring ETE Delay Jitter Calculation

- Node 7 to Node 0, 100 km ring
 - 64B Transmission Delay = 0.07 μ sec
 - 1500B Transmission Delay = 1.24 μ sec
 - Propagation Delay = 31.25 μ sec (on each segment)
- Best Case: 64B pkt never waits
- Worst Case: 1500B pkt waits for a 1500B pkt at every node
- **Single Transit Buffer (Cut-Through)**
 - Best Case: $7 * \text{PropDelay} + \text{TransDelay} = 218.82 \mu\text{sec}$
 - Worst Case: $7 * \text{PropDelay} + 6 * \text{TransDelay} = 226.19 \mu\text{sec}$
 - Ring ETE Jitter: $226.19 - 218.82 = 7.37 \mu\text{sec}$
- **Two Transit Buffers (Store-and Forward)**
 - Best Case: $7 * (\text{PropDelay} + \text{TransDelay}) = 219.24 \mu\text{sec}$
 - Worst Case:
 $7 * (\text{PropDelay} + \text{TransDelay}) + 6 * \text{TransDelay} = 234.87 \mu\text{sec}$
 - Ring ETE Jitter: $234.87 - 219.24 = 15.63 \mu\text{sec}$



High Priority Medium Access Delay Jitter Calculation

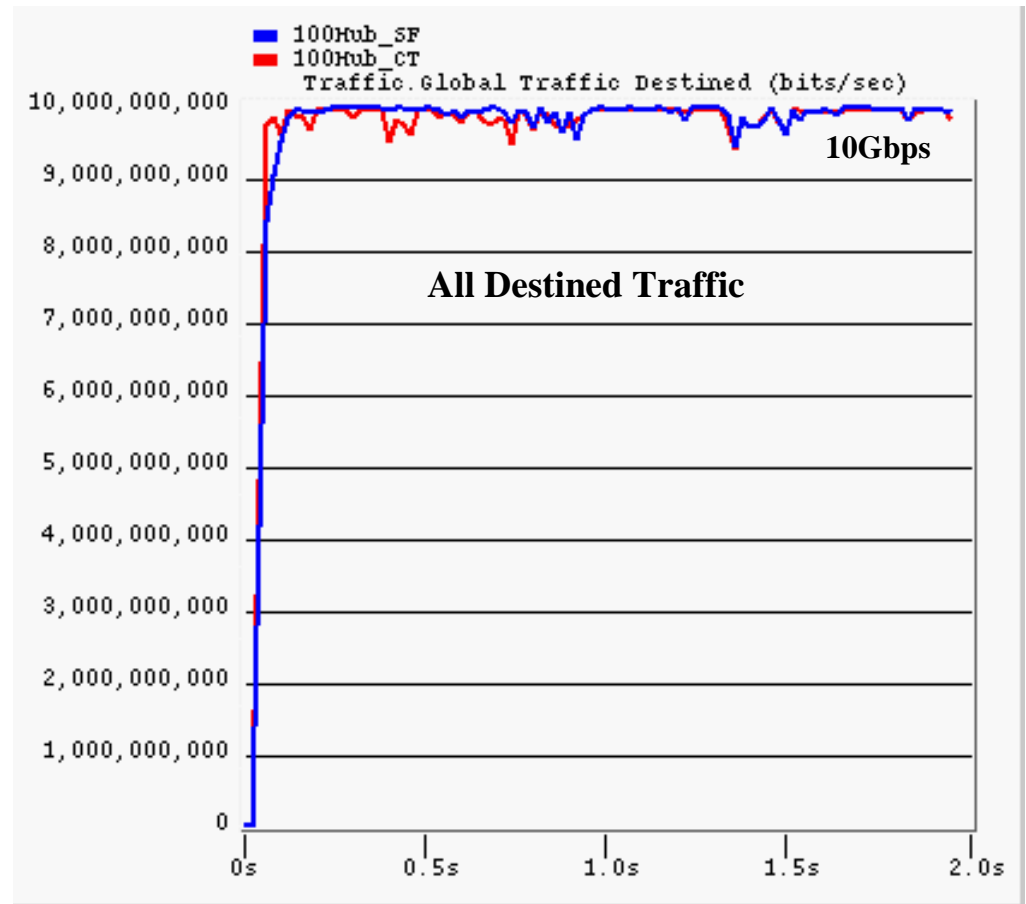
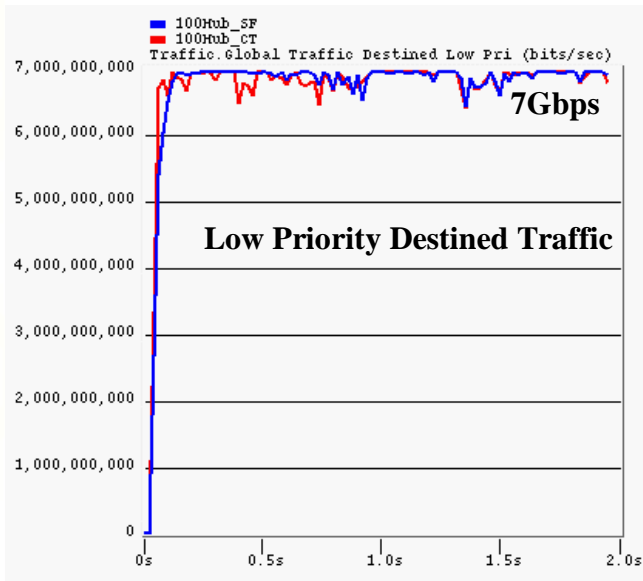
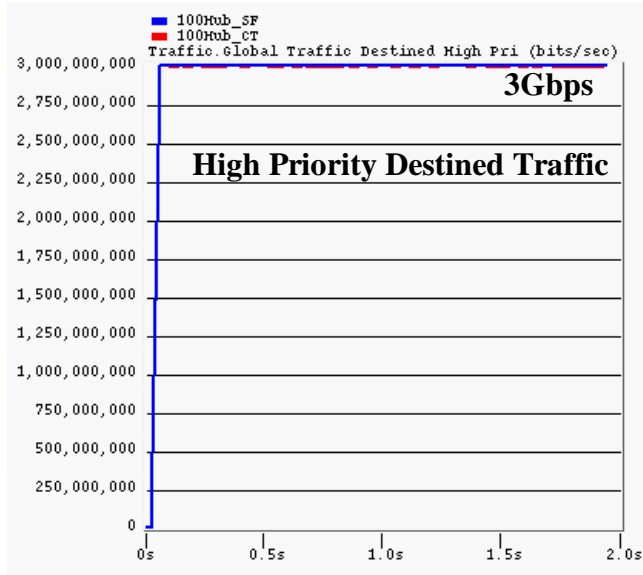
- Worst Case: Node 1 wants to send to Node 0
- **Single Transit Buffer (Cut-Through)**
 - Congestion message is sent to upstream and is relayed all the way up to Node 7 and Node 7 decreases its LP add rate.
 - $(6 * \text{PropDelay}) * 2 = 375 \mu\text{sec}$ (DEPENDS ON RING SIZE)
- **Two Transit Buffers (Store-and Forward)**
 - All the prior nodes (7,6,5,4,3,2) have sent 1500B HP pkts back to back and transmission starts immediately after pkt from Node 2 is completely received.
 - $6 * \text{TransDelay} = 7.44 \mu\text{sec}$



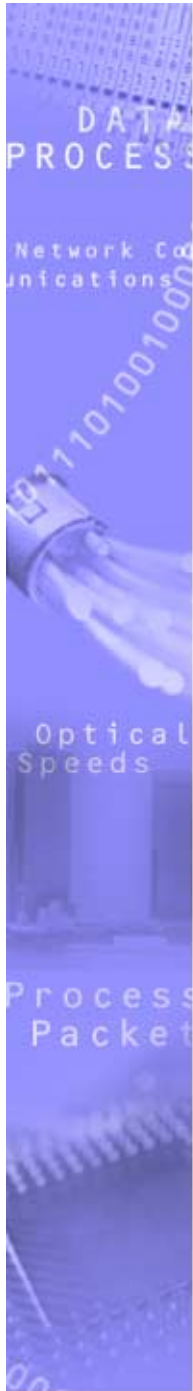
100 km Hub - Throughput



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- Single Transit Buffer
- Dual Transit Buffer

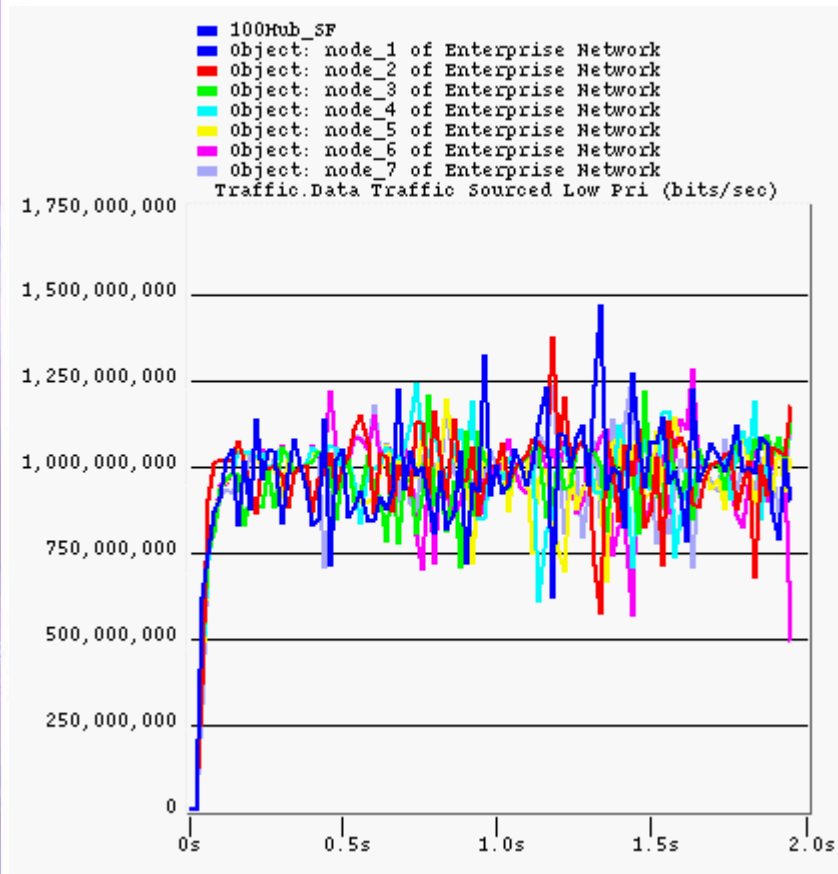


100 km Hub – Fairness Low Priority Traffic Sourced

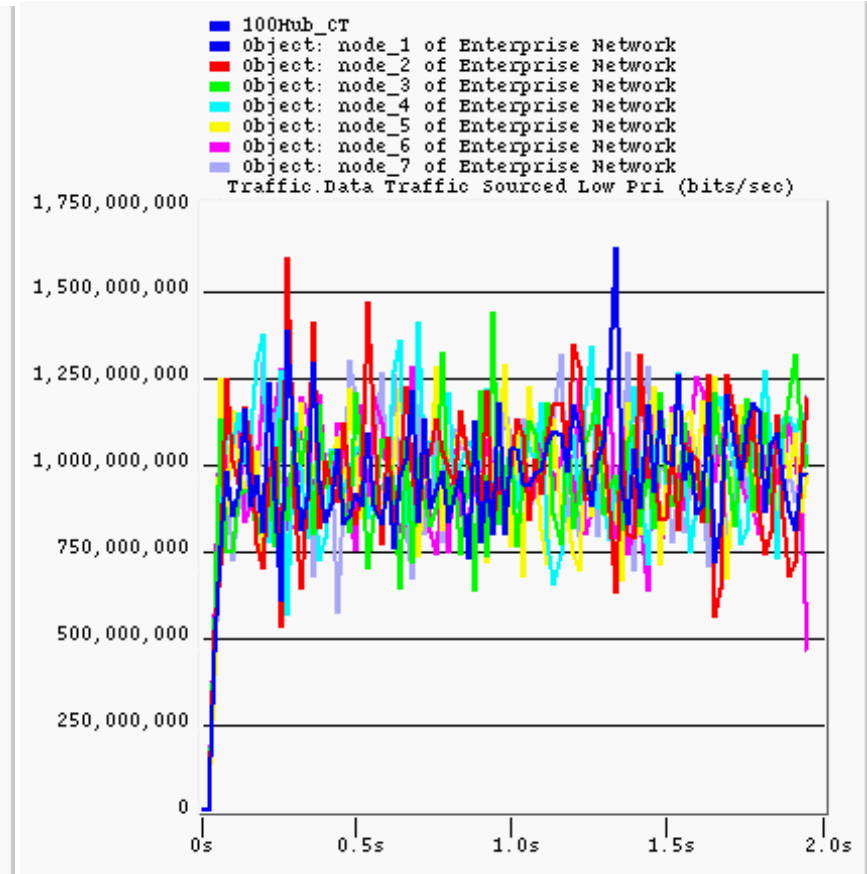


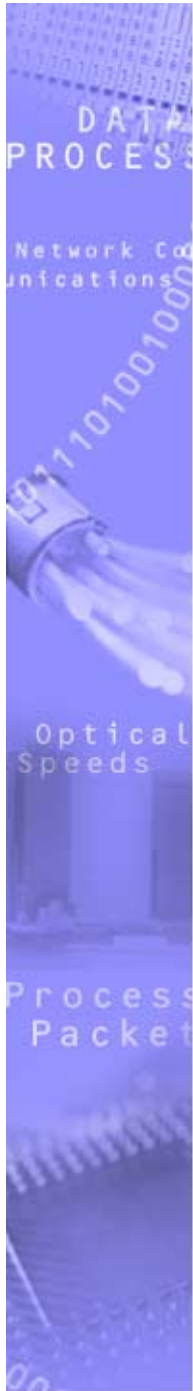
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Dual Transit Buffer



Single Transit Buffer



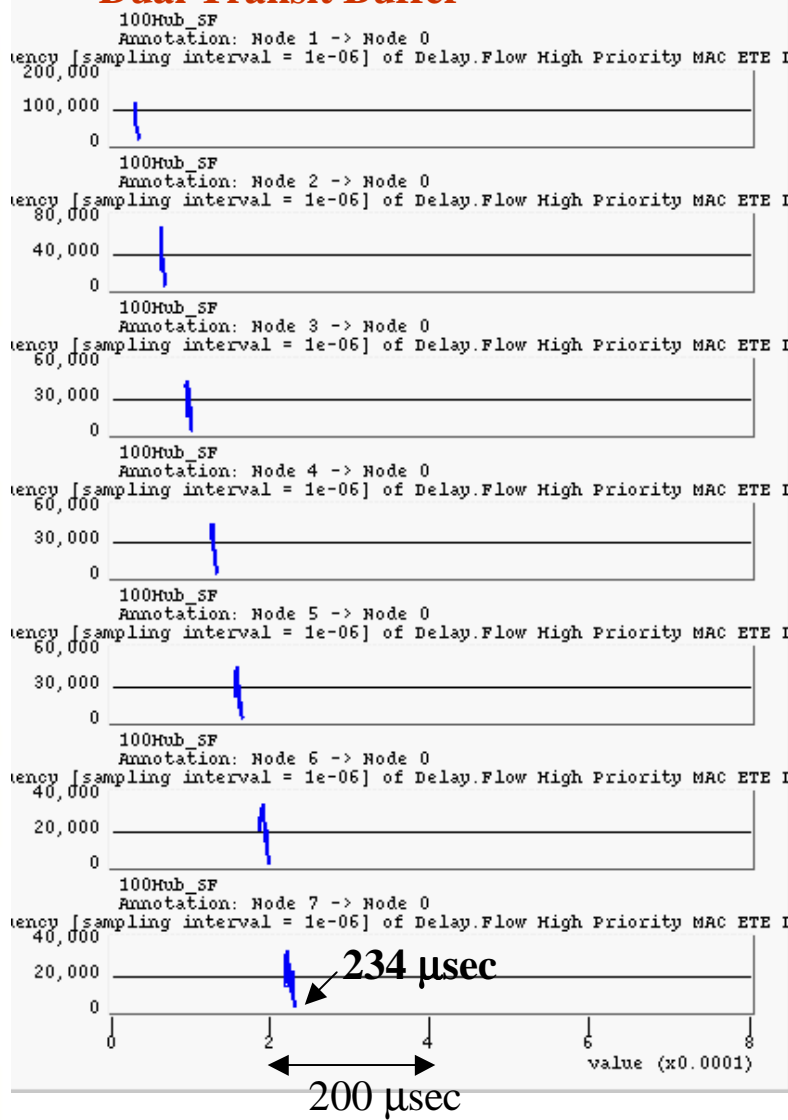


100 km Hub High Priority MAC ETE Delay Histogram

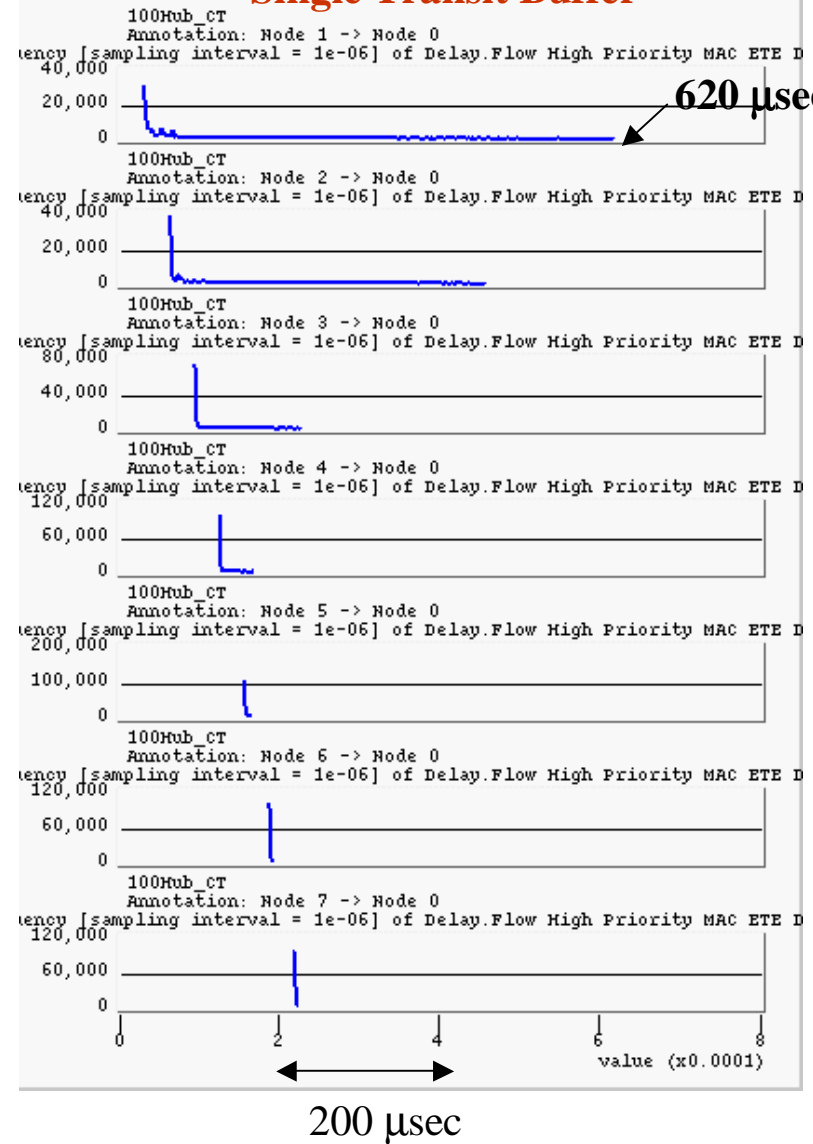


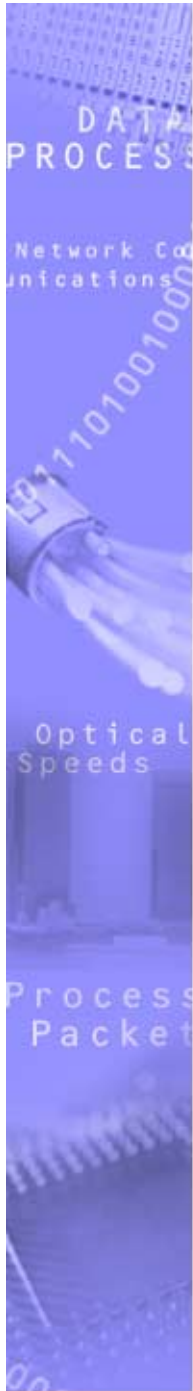
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Dual Transit Buffer



Single Transit Buffer



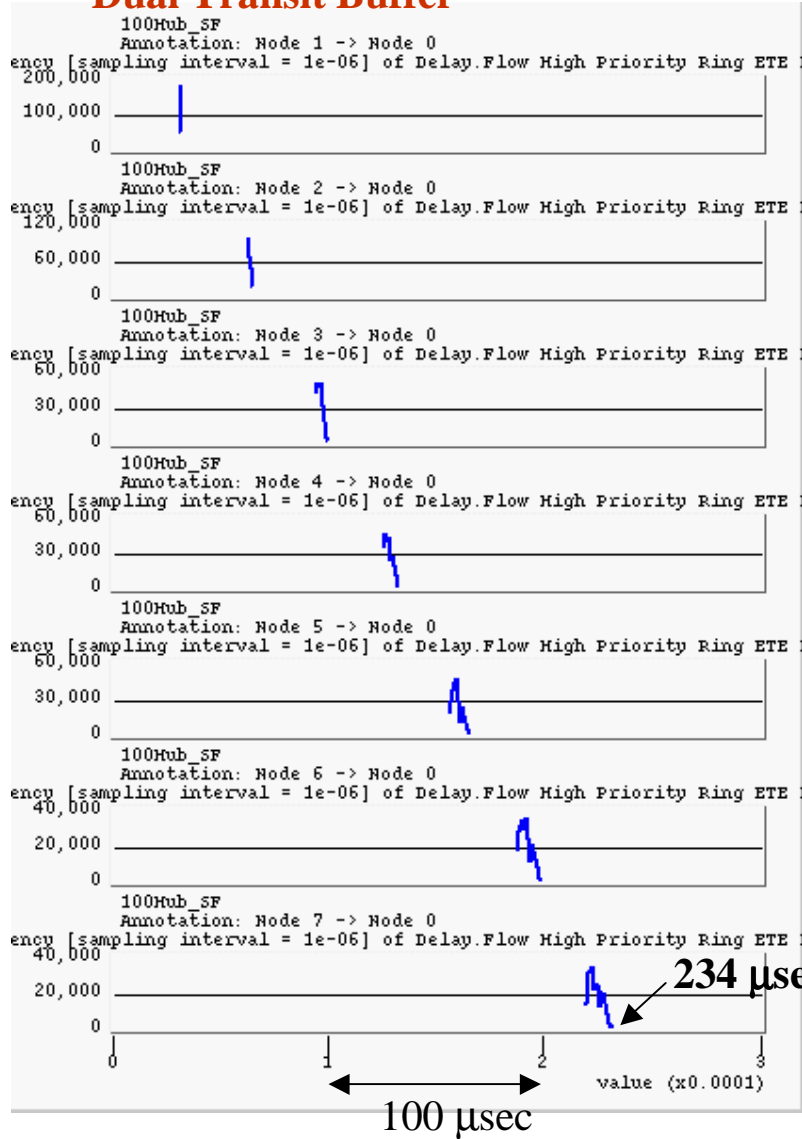


100 km Hub High Priority Ring ETE Delay Histogram

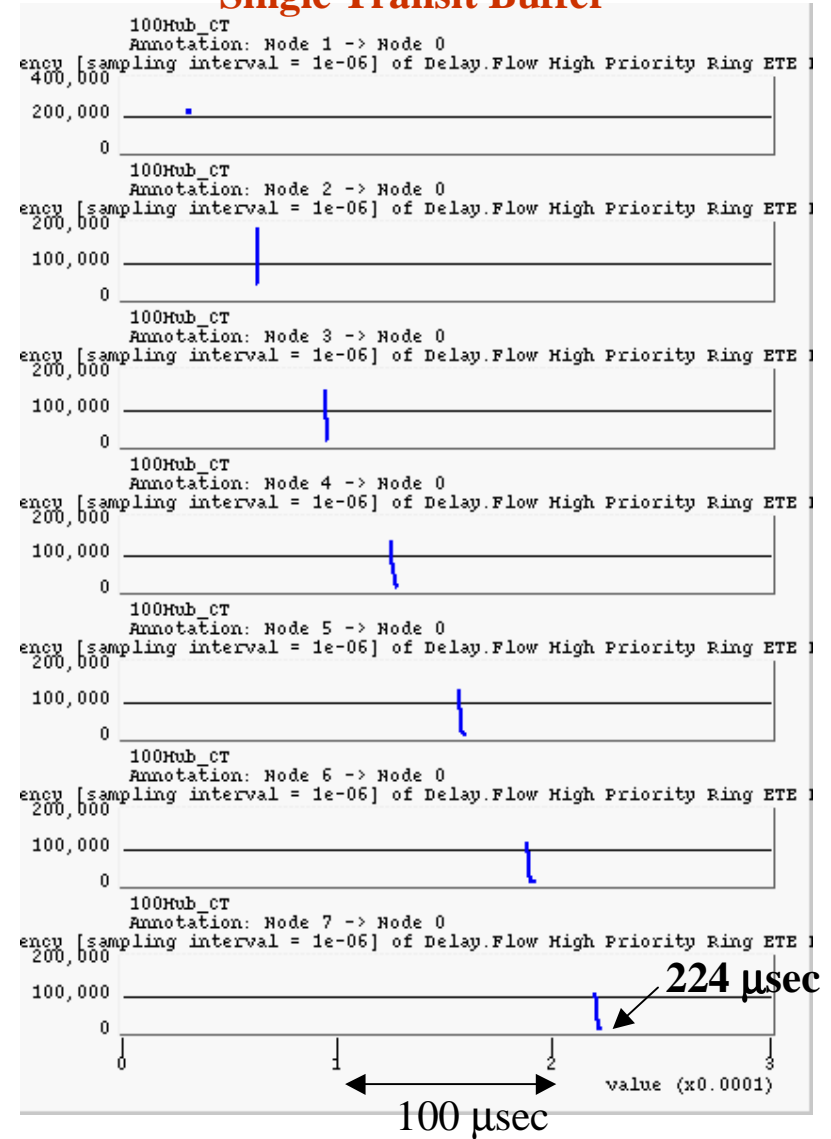


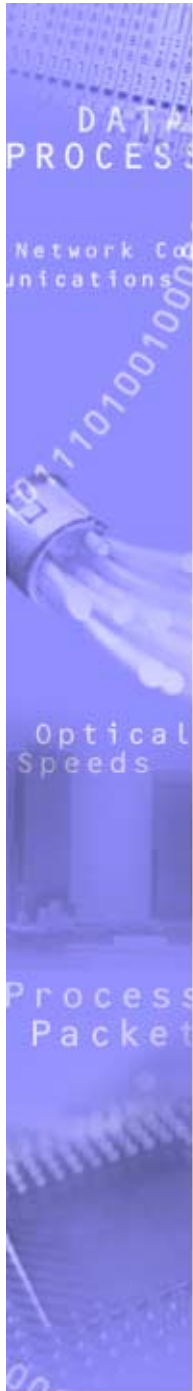
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Dual Transit Buffer



Single Transit Buffer



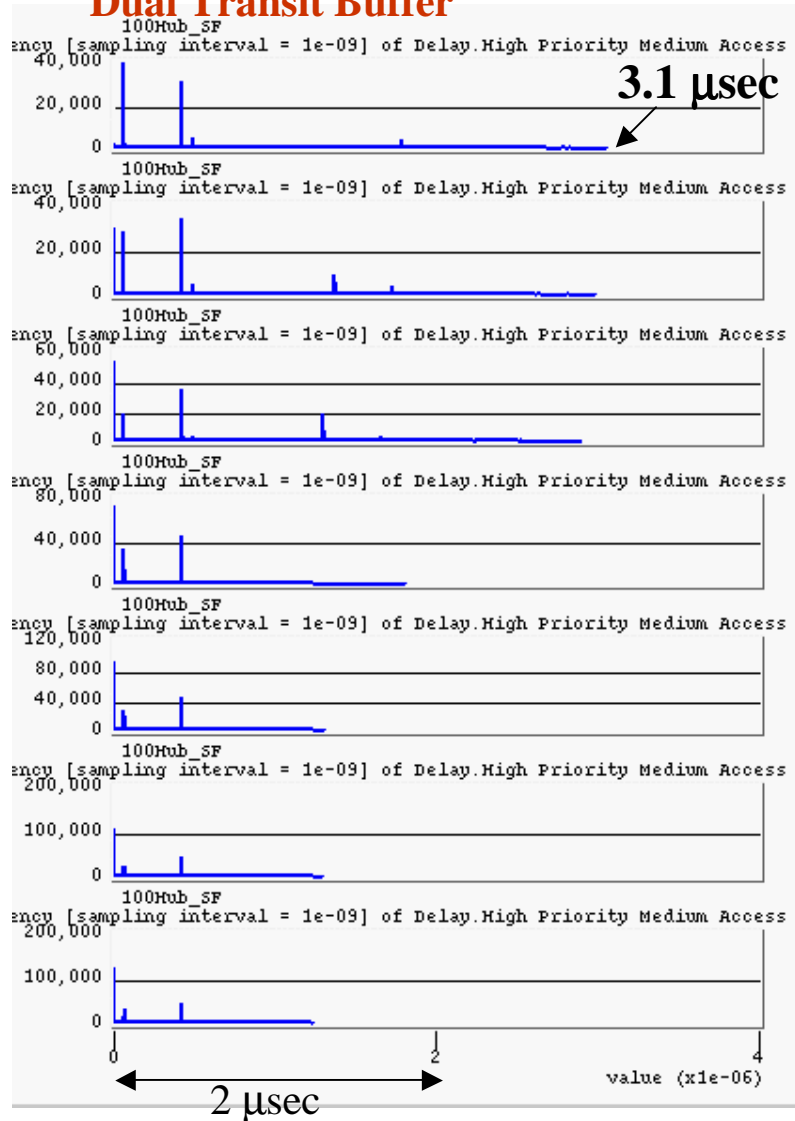


100 km Hub High Priority Medium Access Delay Histogram

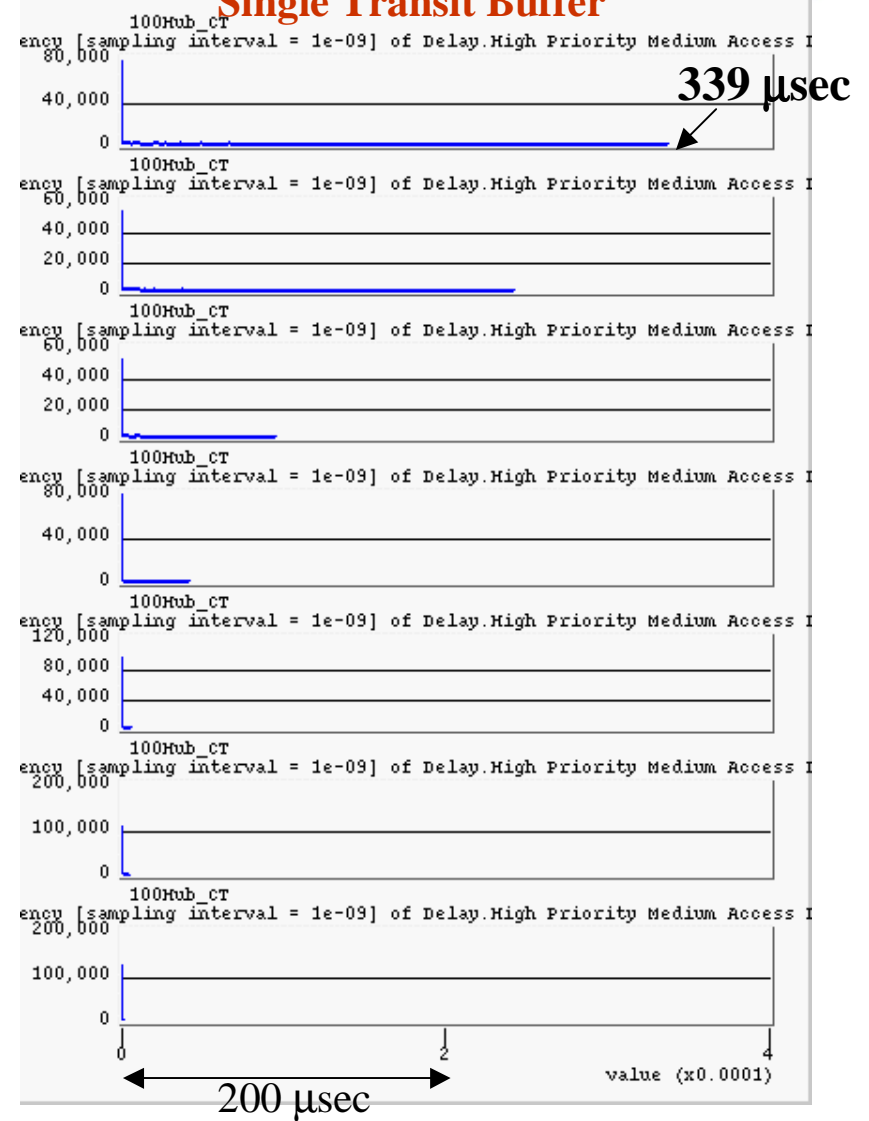


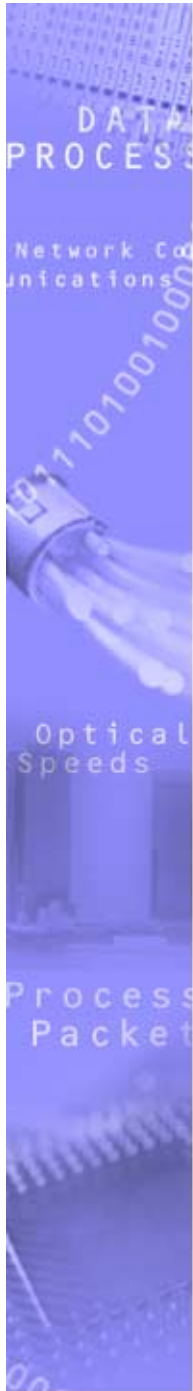
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Dual Transit Buffer



Single Transit Buffer

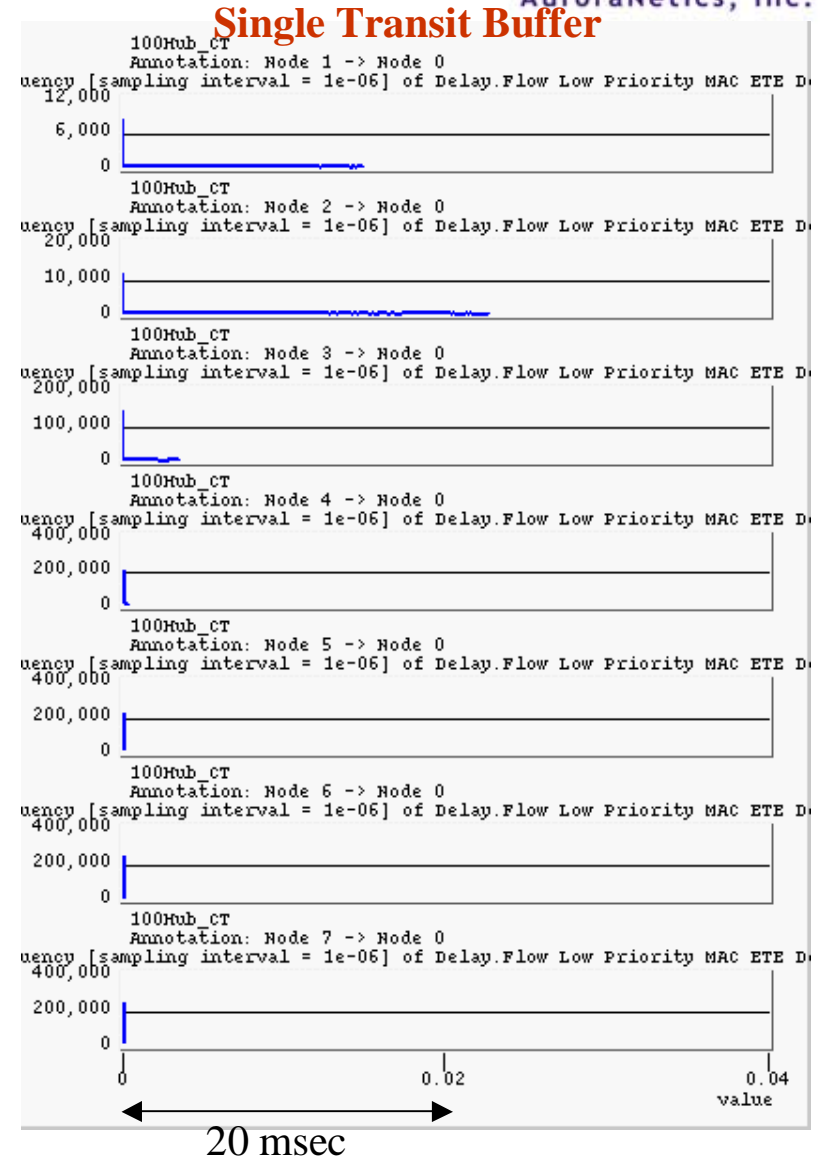
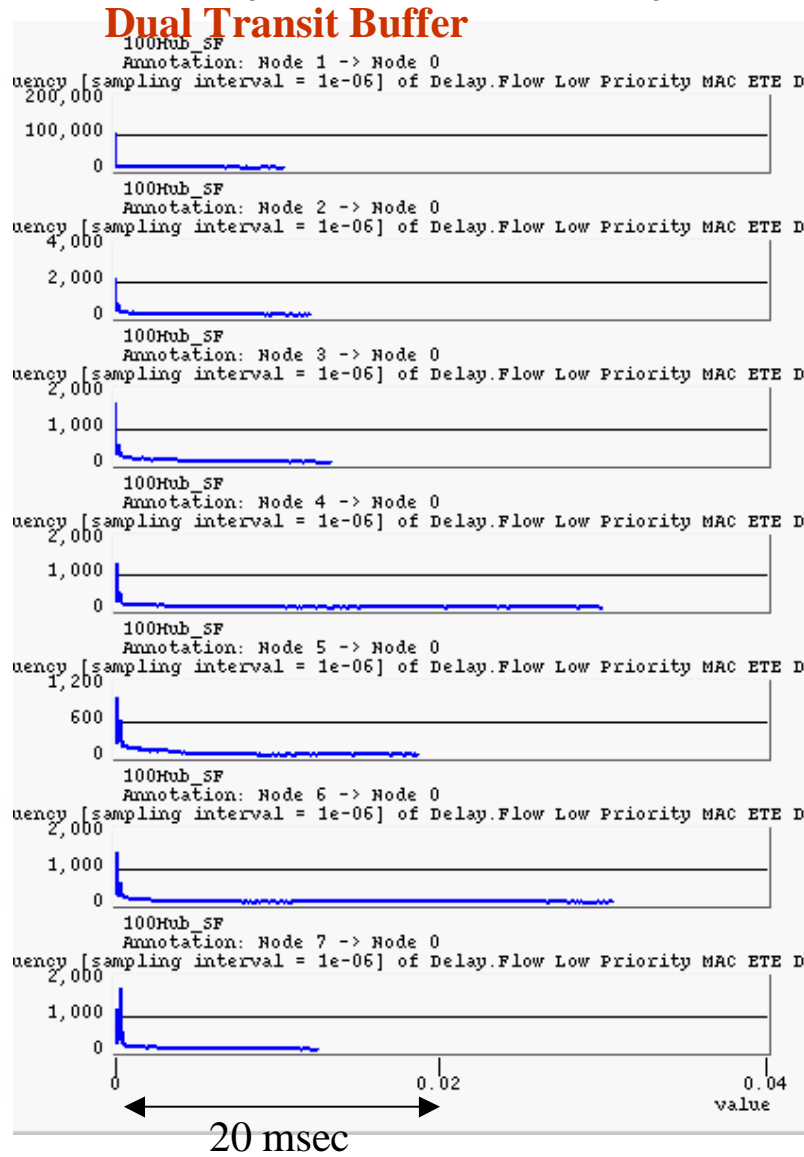


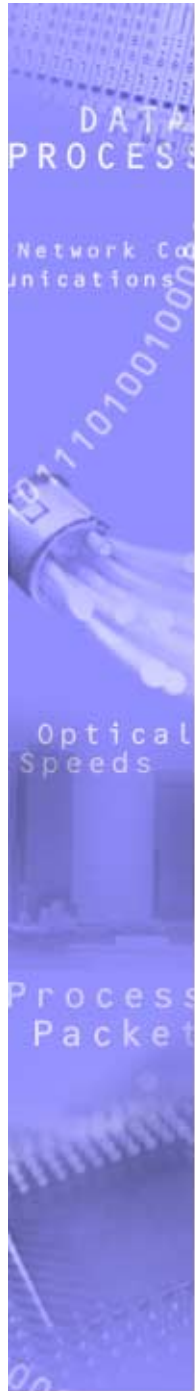


100 km Hub Low Priority MAC ETE Delay Histogram



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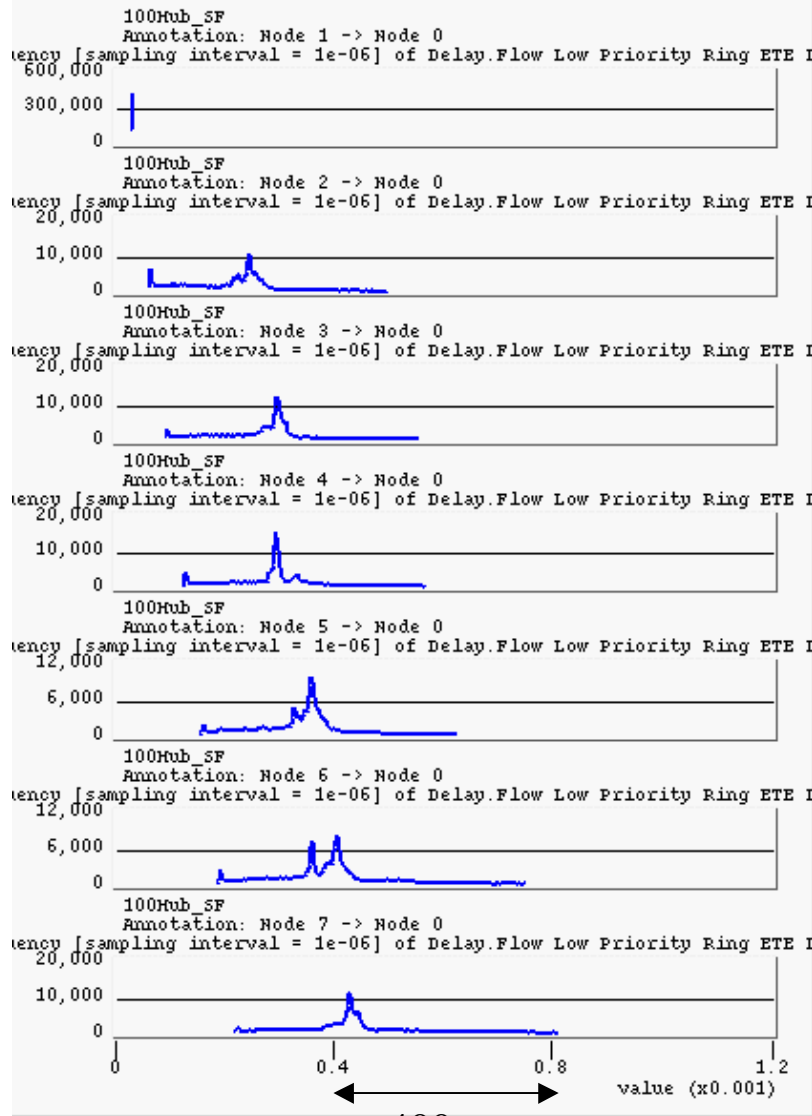


100 km Hub Low Priority Ring ETE Delay Histogram

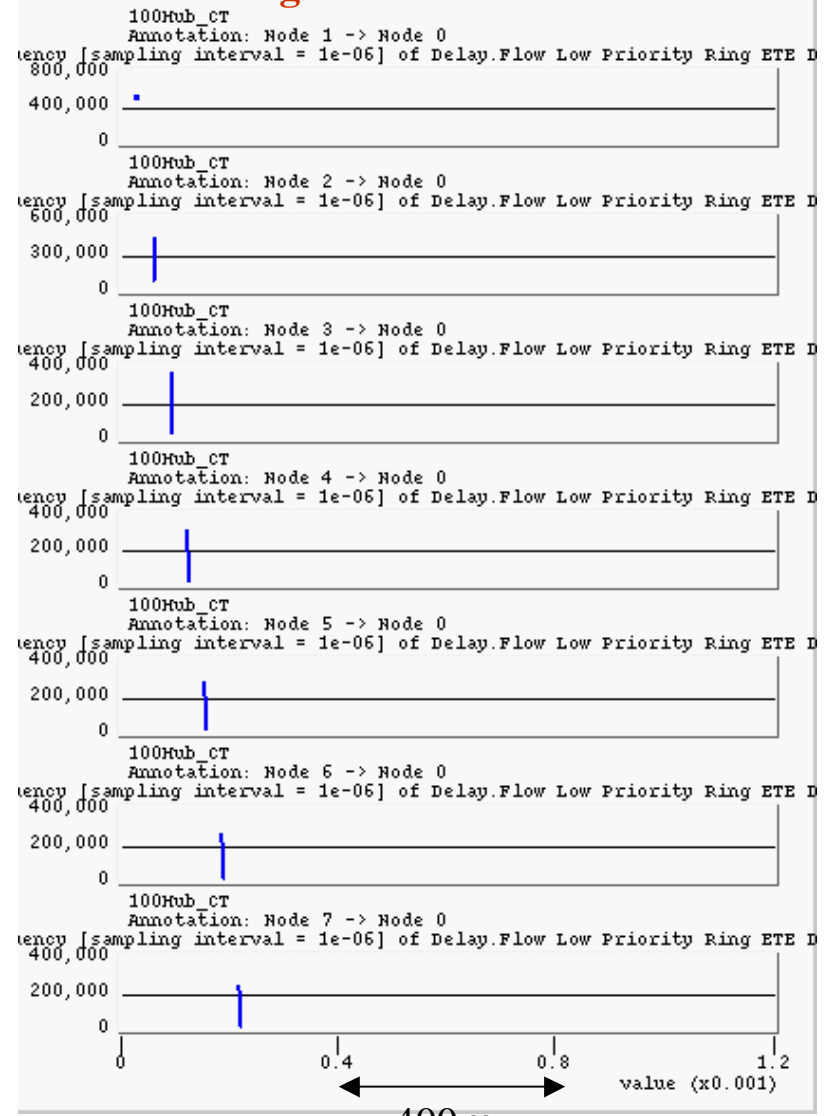


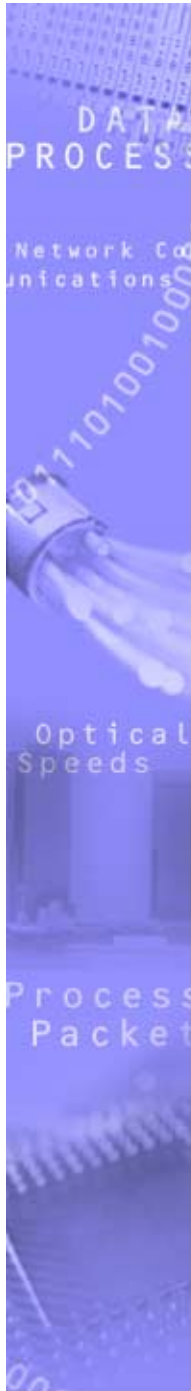
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Dual Transit Buffer



Single Transit Buffer



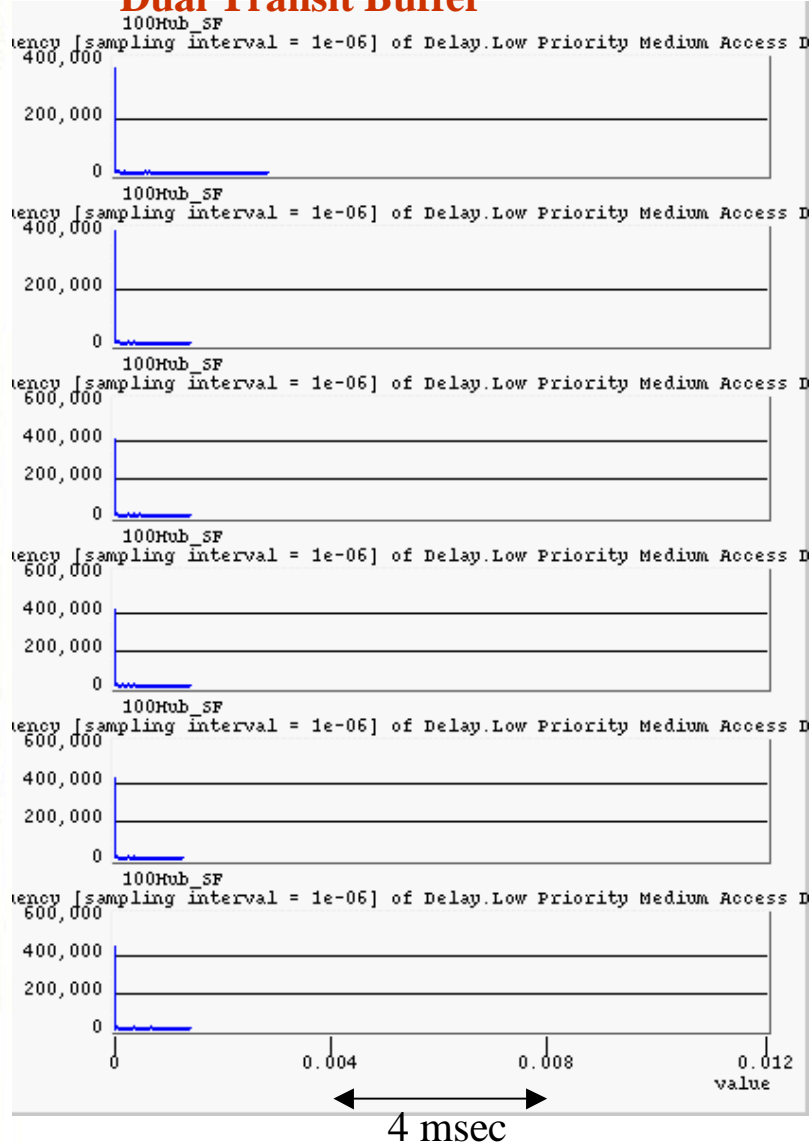


100 km Hub Low Priority Medium Access Delay Histogram

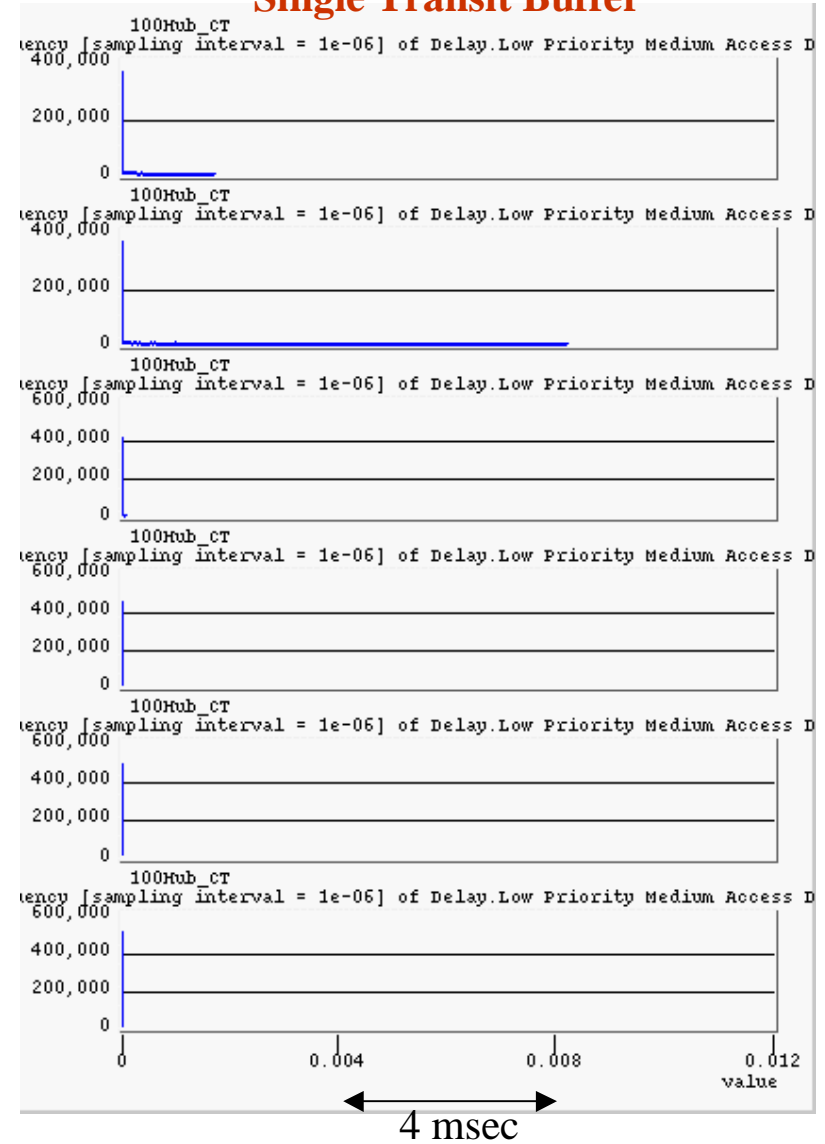


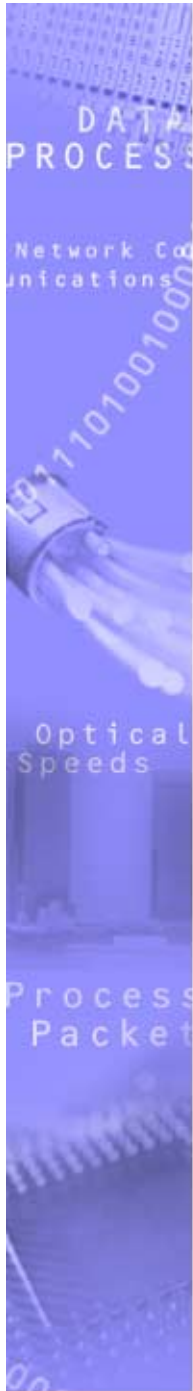
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Dual Transit Buffer



Single Transit Buffer

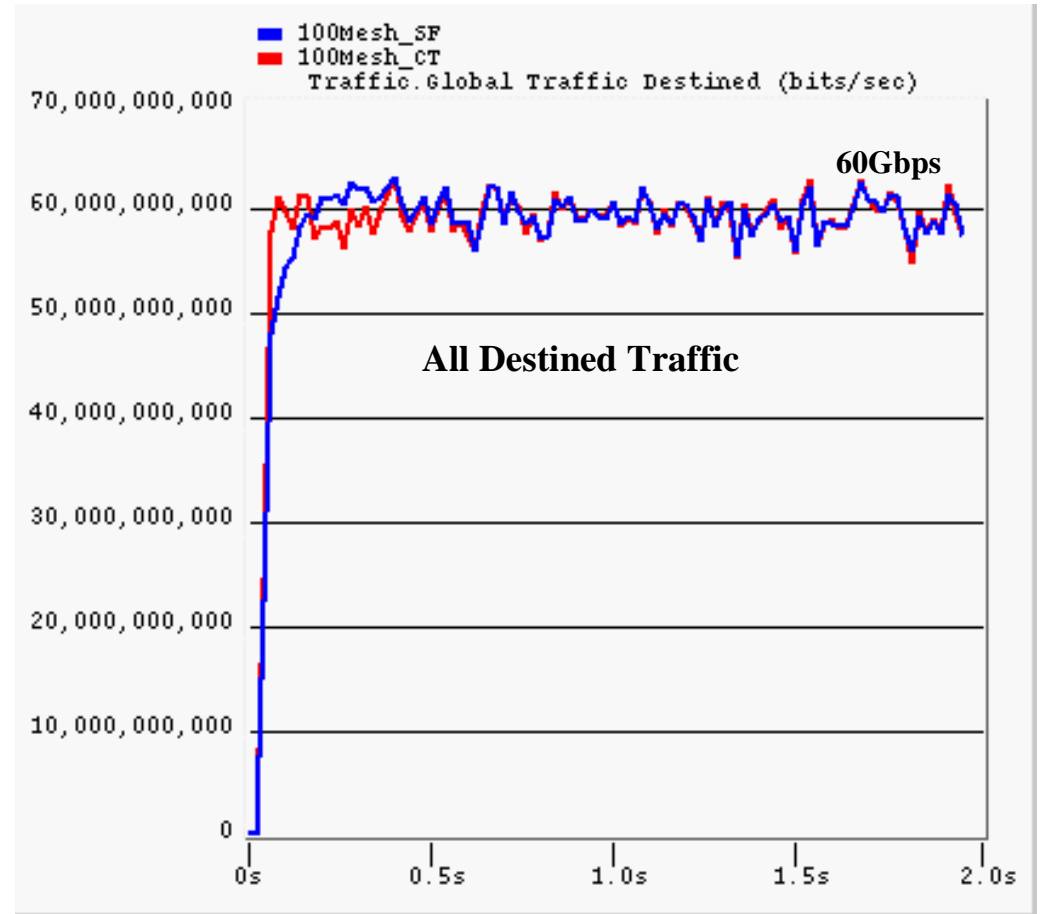
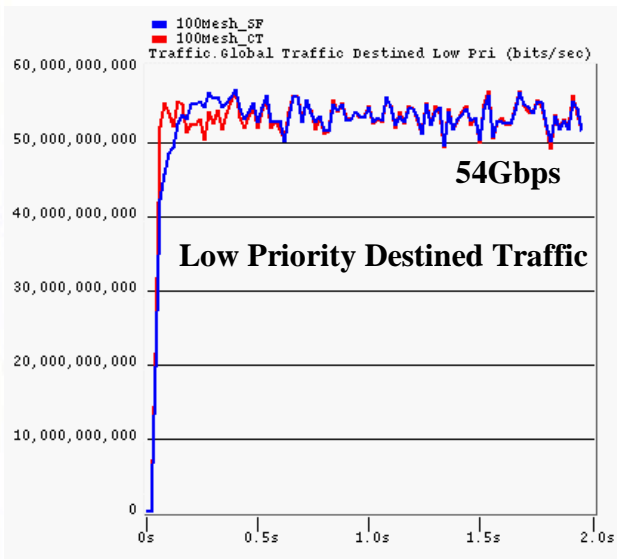
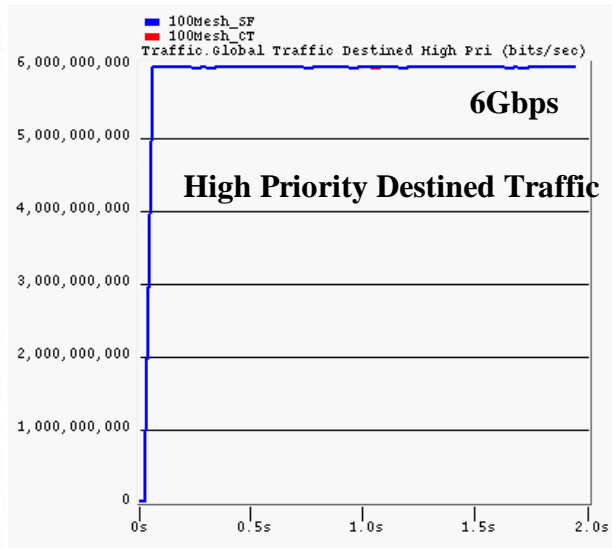




100 km Mesh - Throughput



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- Single Transit Buffer
- Dual Transit Buffer

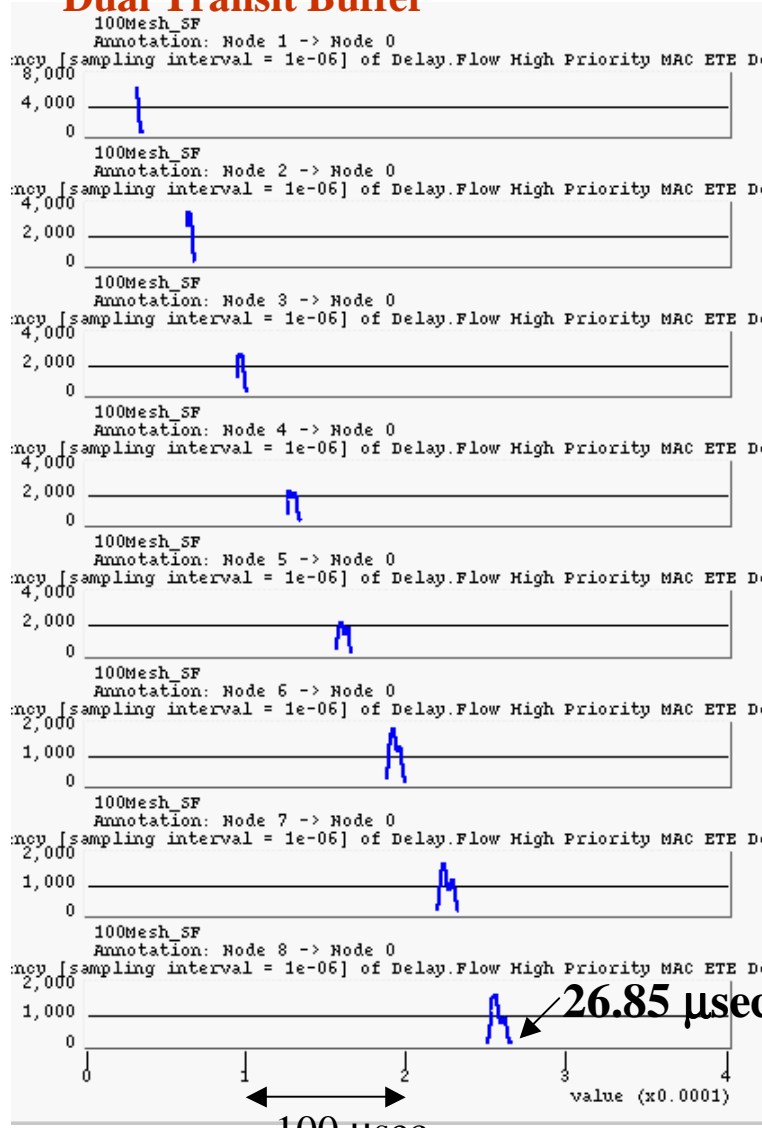


100 km Mesh High Priority MAC ETE Delay Histogram

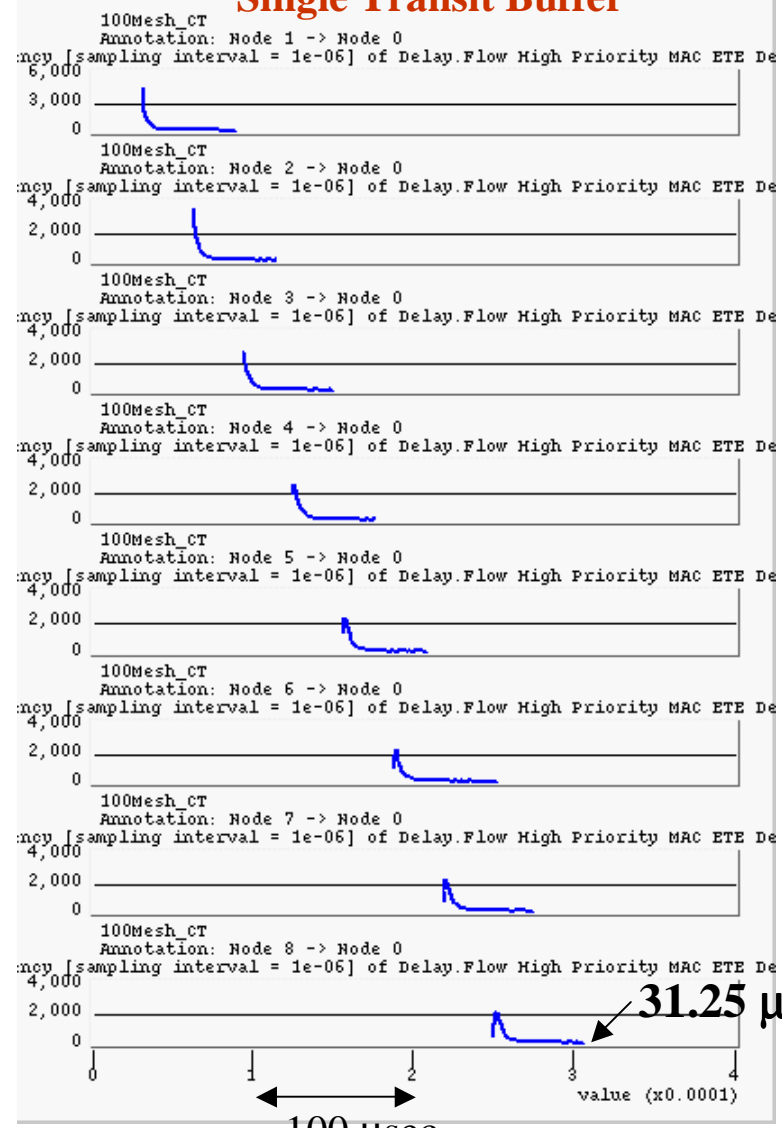


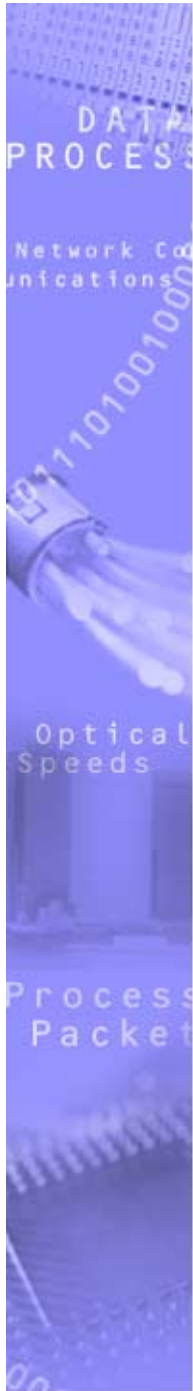
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Dual Transit Buffer



Single Transit Buffer



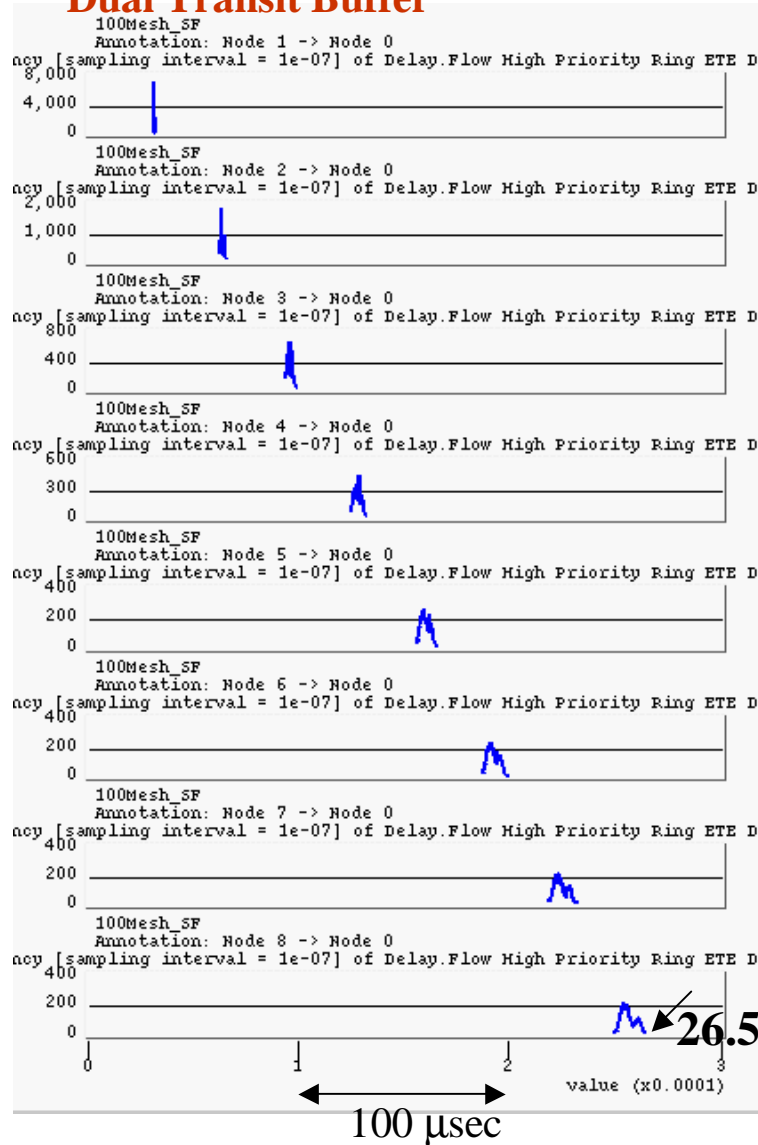


100 km Mesh High Priority Ring ETE Delay Histogram

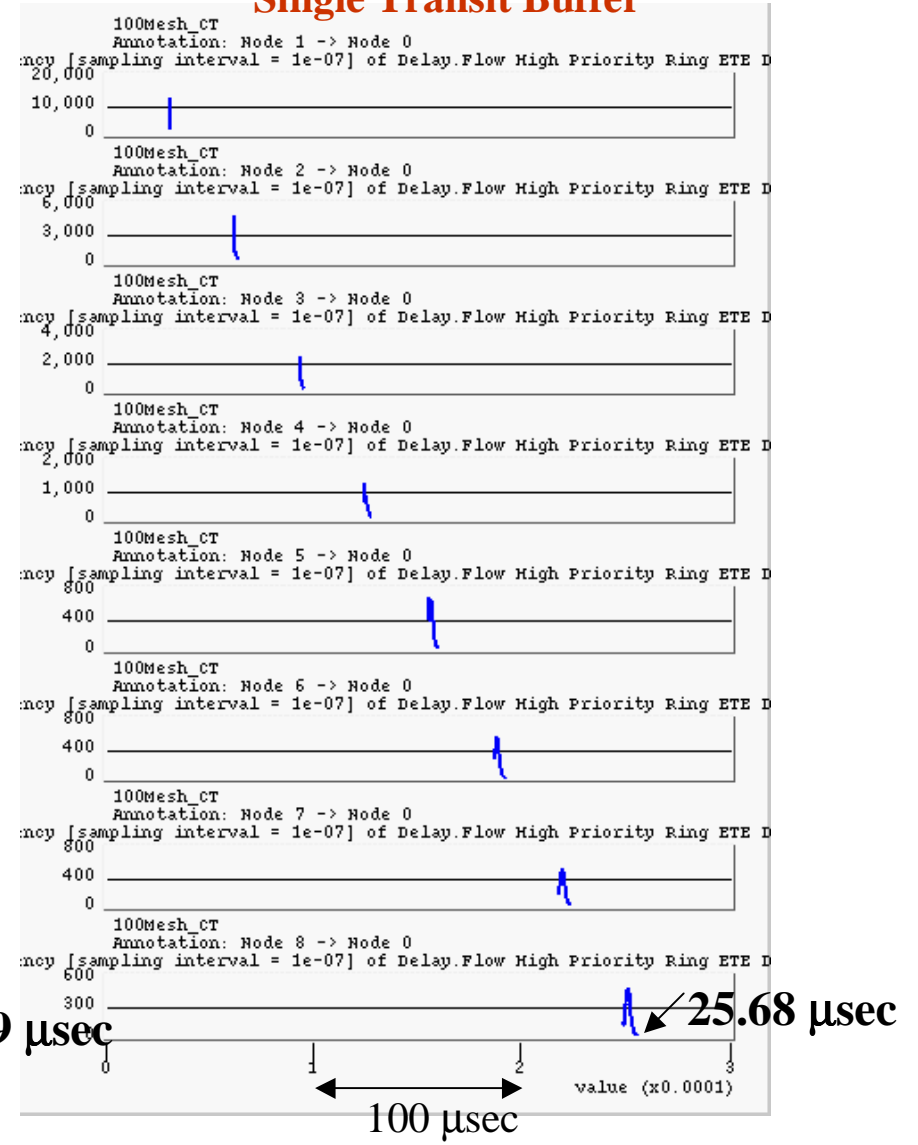


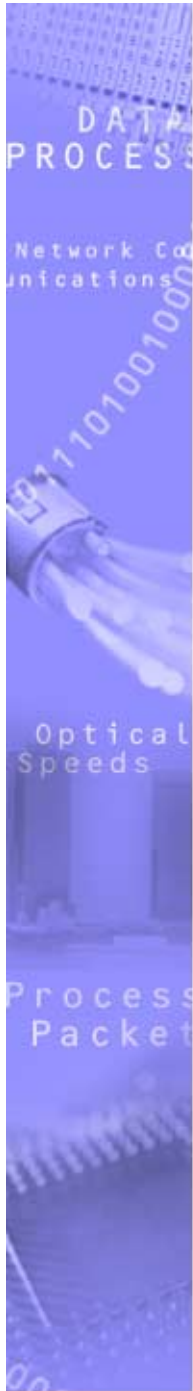
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Dual Transit Buffer



Single Transit Buffer



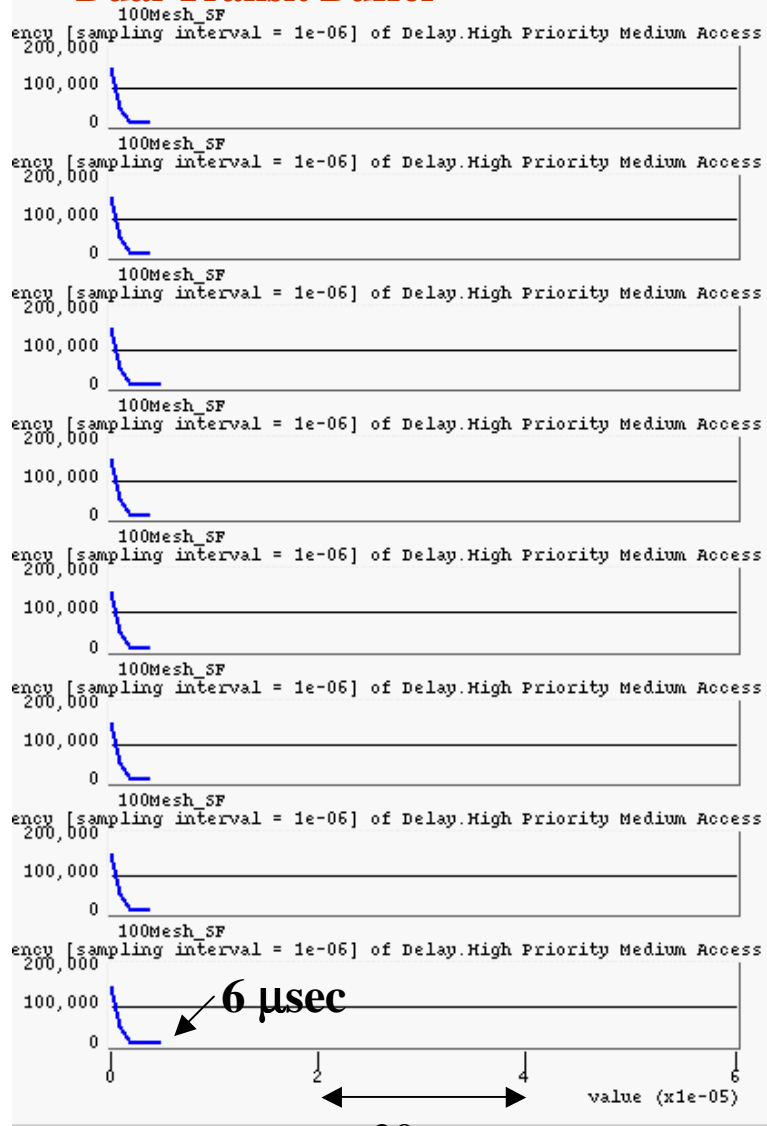


100 km Mesh High Priority Medium Access Delay Histogram



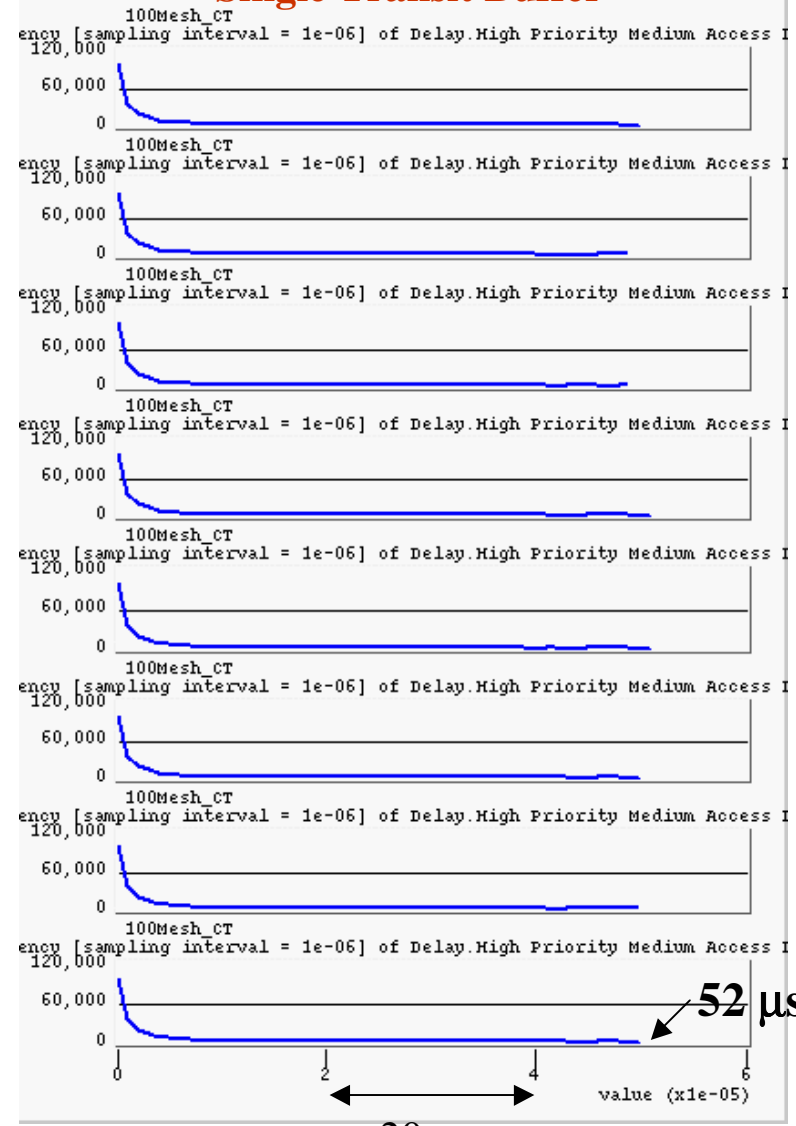
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Dual Transit Buffer

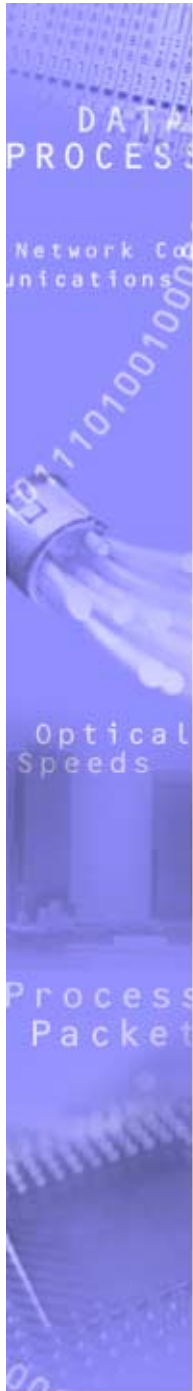


20 μsec

Single Transit Buffer



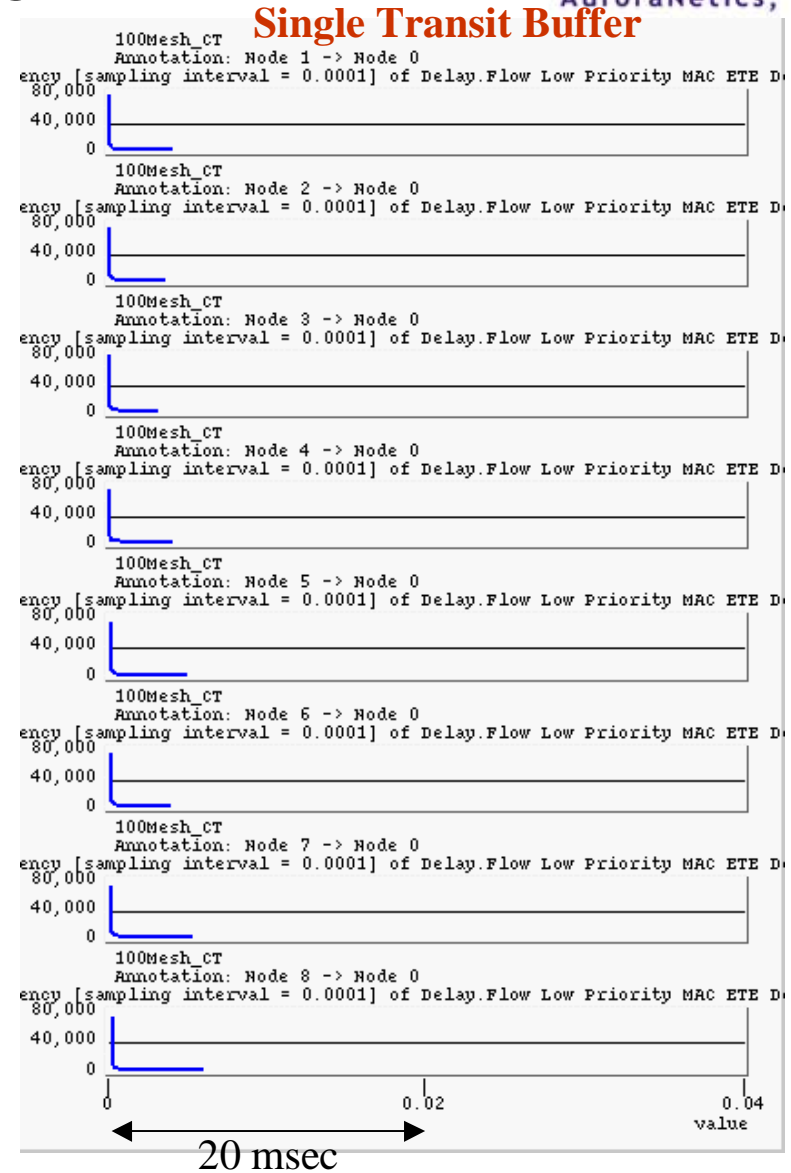
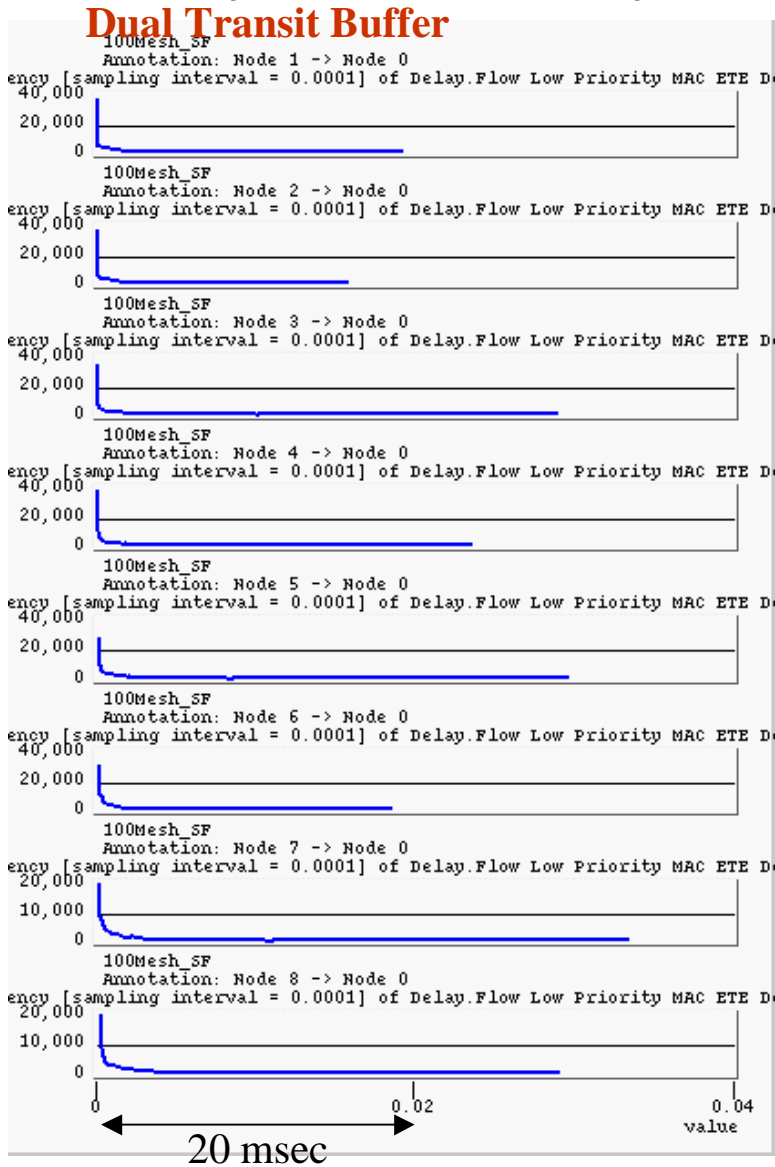
20 μsec

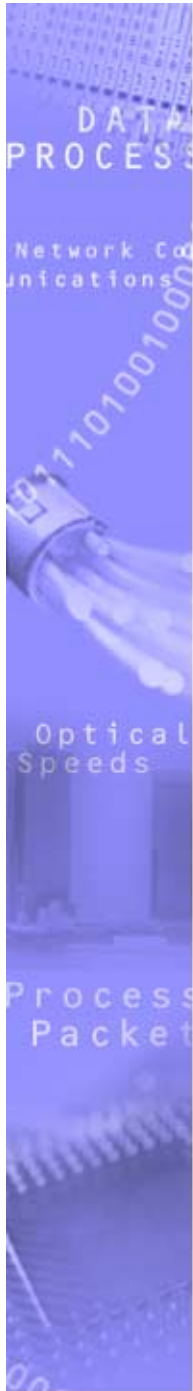


100 km Mesh Low Priority MAC ETE Delay Histogram



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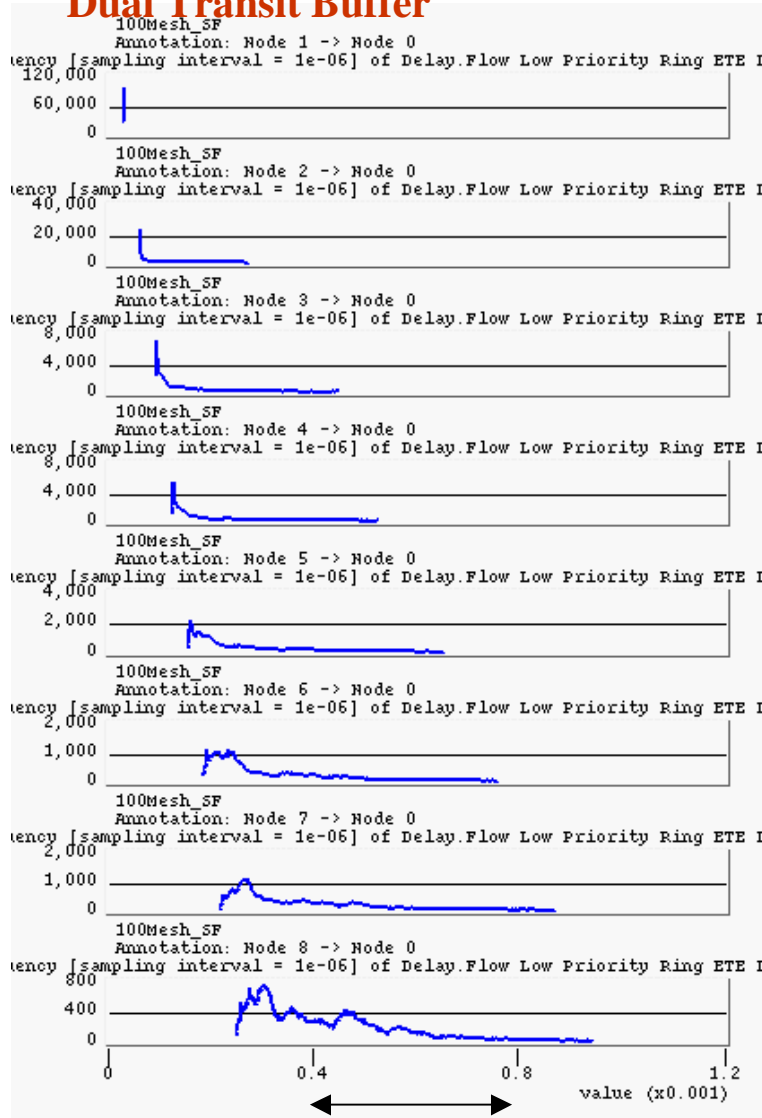


100 km Mesh Low Priority Ring ETE Delay Histogram



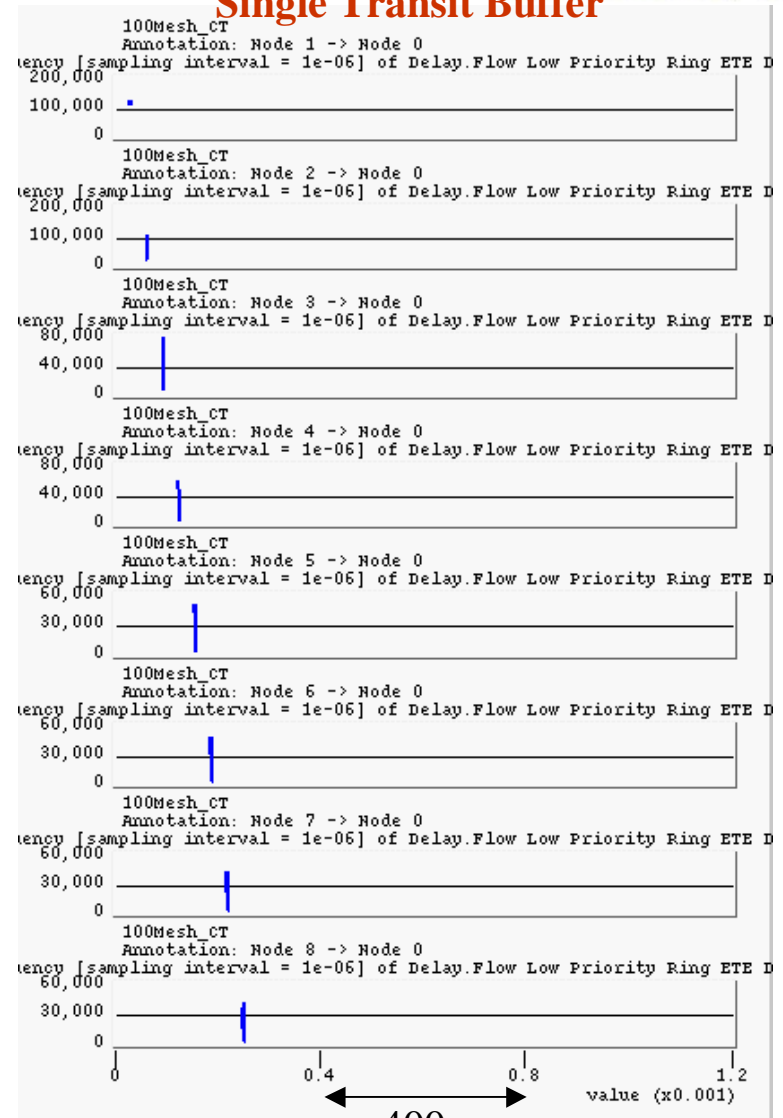
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Dual Transit Buffer

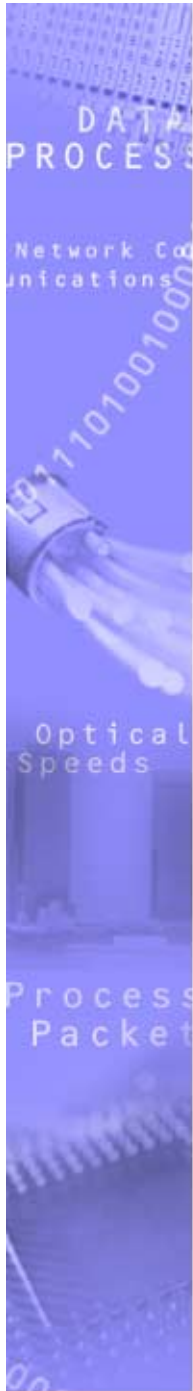


400 μ sec

Single Transit Buffer



400 μ sec

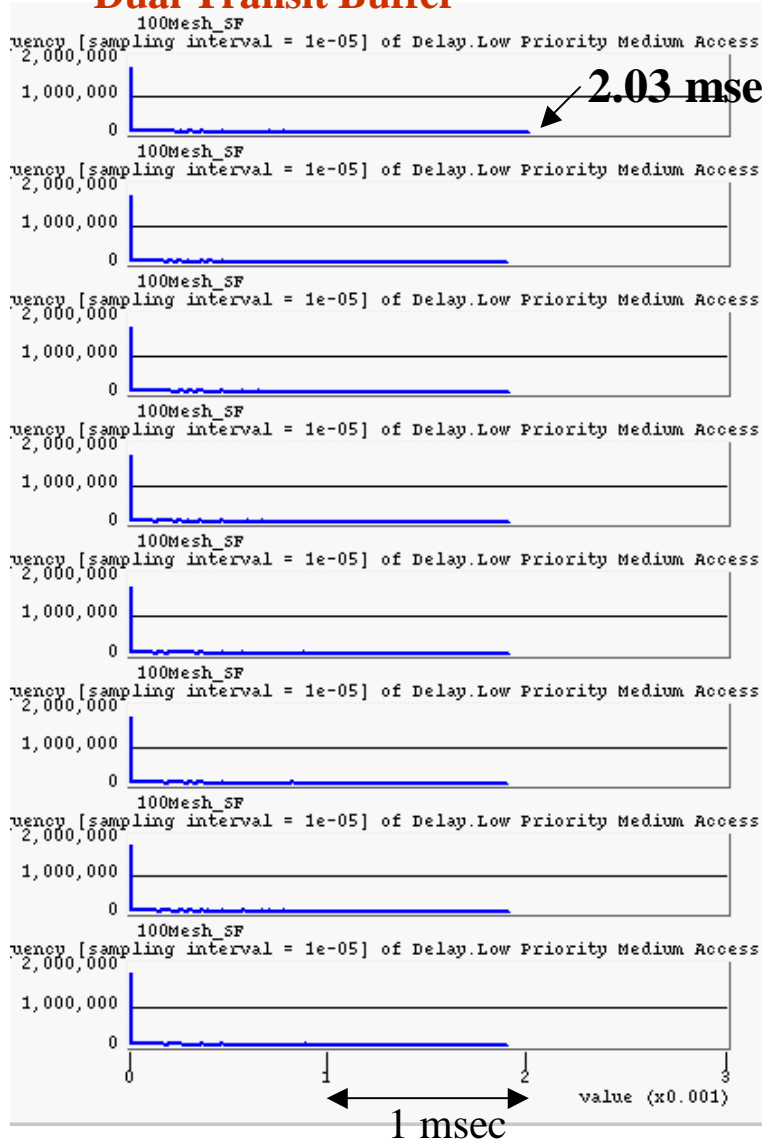


100 km Mesh Low Priority Medium Access Delay Histogram

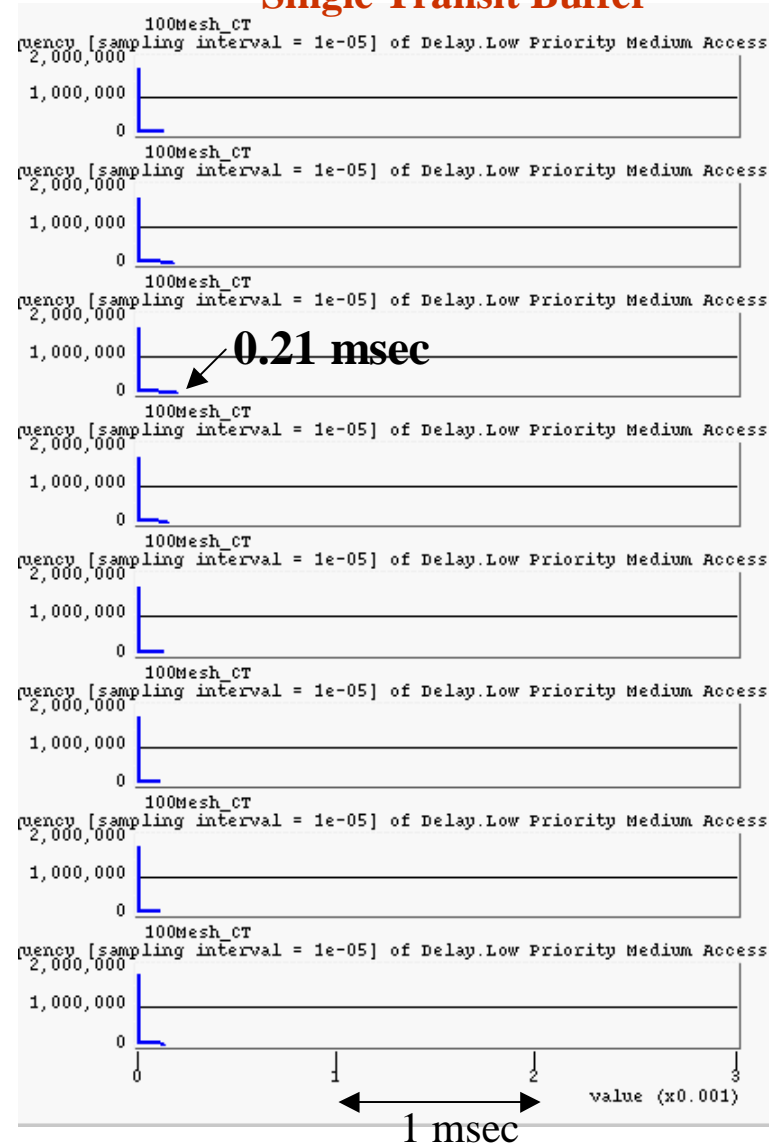


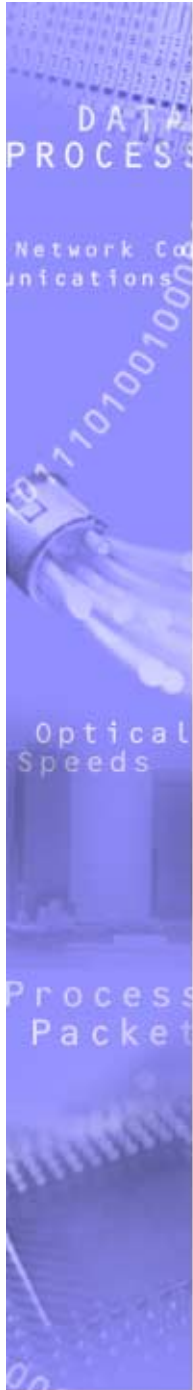
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Dual Transit Buffer



Single Transit Buffer





HP Jitter Comparison



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- Single transit buffer implementation compromises HP jitter
 - Nodes are bombarded with LP transit packets
 - Transit packets do not give HP transmit packets a chance to get into the ring
- Multi transit buffer implementation guarantees HP jitter bound by decoupling HP and LP traffic
 - For a store-and-forward buffer, while a transit packet is being stored, a transmit packet gets a chance to enter to the ring