Fair Medium Access Control Scheme for Packet Ring Networks with Spatial Reuse

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Outline

- **Introduction**
  - ✍ Rings with Spatial Reuse seen as the solution for data services in metro.
- **Existing Access Control Schemes in Spatial Reuse Rings**
  - ✍ Buffer-Insertion Ring (BIR) and fairness Problem
  - ✍ OBJECTIVE: design an access control scheme that dynamically achieve fairness and high utilization.
- **Proposed Access Control Scheme: Source-based Queuing (SBQ)**
- **Performance Evaluation**
- **Summary and Future Researches**

Spatial Reuse Packet Rings to Support Data Services in Metro

Spatial Reuse Rings allow <u>concurrent </u>transmission over distinct segments of the ring by letting the destination remove the packets (Figure 1).

- Increase bandwidth utilization and network throughput.

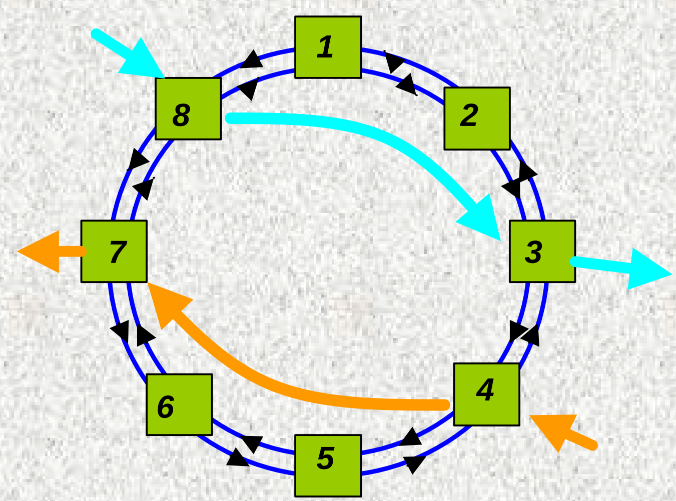


Figure 1: *Illustration of the concept of spatial reuse ring*

Key Challenge: design an access control scheme that achieves fair sharing and high utilization.

Existing Access Control Schemes for Spatial Reuse Rings

- **Buffer-insertion ring (BIR)** is widely used to achieve spatial reuse (Fig. 2).
- ***"starvation" problem*** because non-preemptive priority is given to ring traffic.
- Two approaches to provide fair access for BIR:
  - **Preventive approach:** token based control to regulate the access rate of all the nodes, e.g. MetaRing
    - (-) large complexity and additional access delay
  - **Reactive approach:** react during starvation by sending a backpressure control signal to upstream nodes (Fig. 3), e.g. RPR Standard
    - (-) large reaction time and frequent fair rate calculation

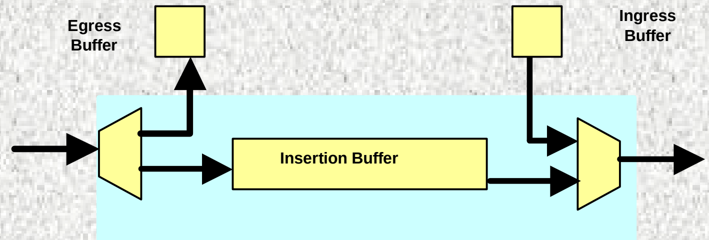


Figure 2: *Block diagram of a BIR node*

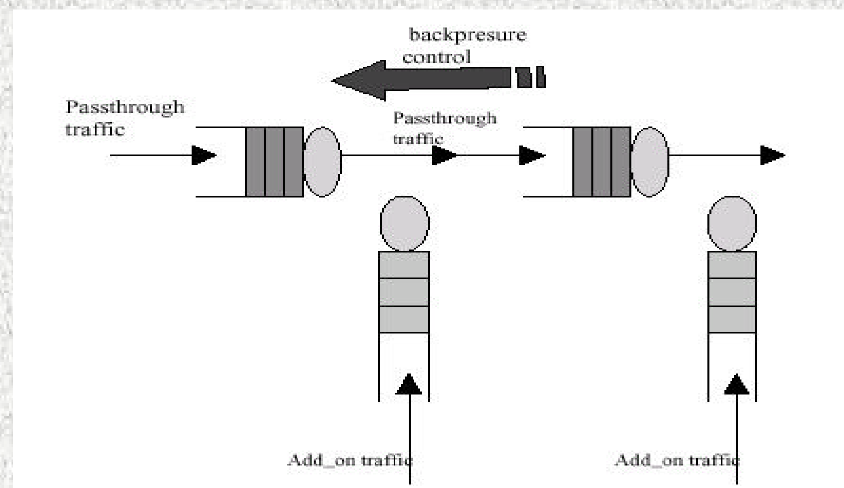


Figure 3: *Illustration of reactive approach*

Our Proposal: Source-based Queuing (SBQ)

- **Root cause of BIR starvation problem:**
  - Ring traffic priority
  - No isolation is provided between misbehaved nodes and well-behaved nodes.
- **Our proposal: Source-Based Queuing (SBQ)**
  - At every node, we provide a ***separate*** queue for each source that shares the output link of the node (Fig. 4)-> ***<u>Isolation!</u>***
  - Each queue is assigned a weight.
  - A fair scheduling algorithm serves all the source-based queues and ensure fair sharing of the capacity among all the sources.

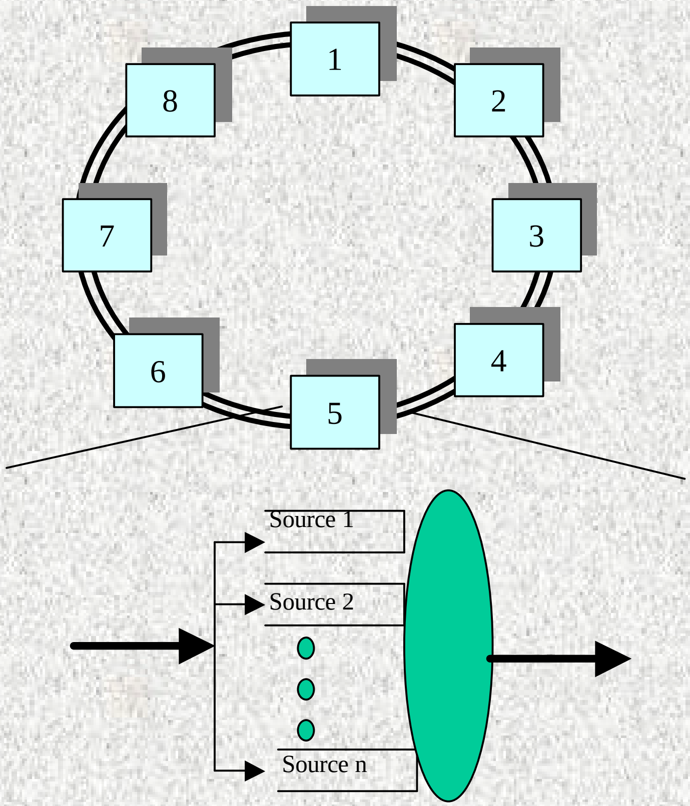


Figure 4: *Illustration of the concept of SBQ*

SBQ Node Architecture

Fig. 5 illustrates the architecture of a SBQ node in a bi-directional ring (east and west-bound):

- **Inbound Buffer:** hold a few packets as the arrival and service time are not synchronized.
- **Outbound Servers:** service the source-based queues using a scheduling scheme,
- **Add/Drop Queues:** Used for adding traffic to the ring from this node or dropping traffic from the ring to this node.
- **Packet Processor:** serves both inbound buffers and add queue with following considerations:
  - place packets in the drop queue if the packets are destined to this node; or insert them to the outbound queue based on their source addresses.

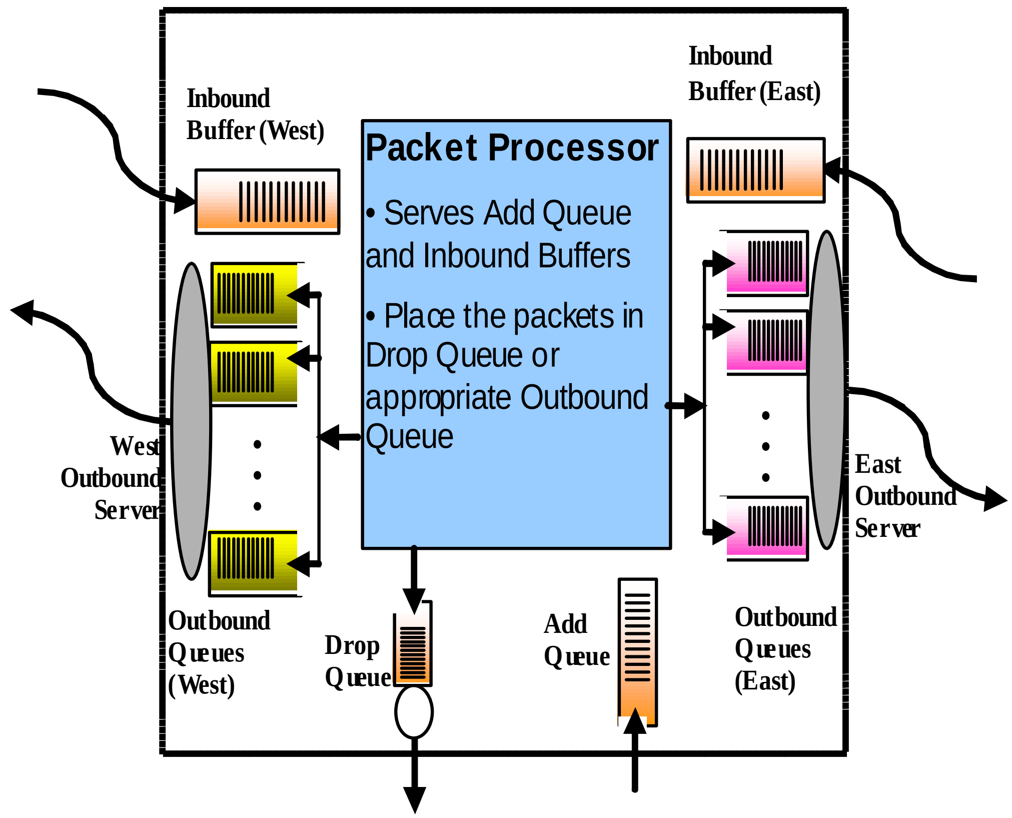


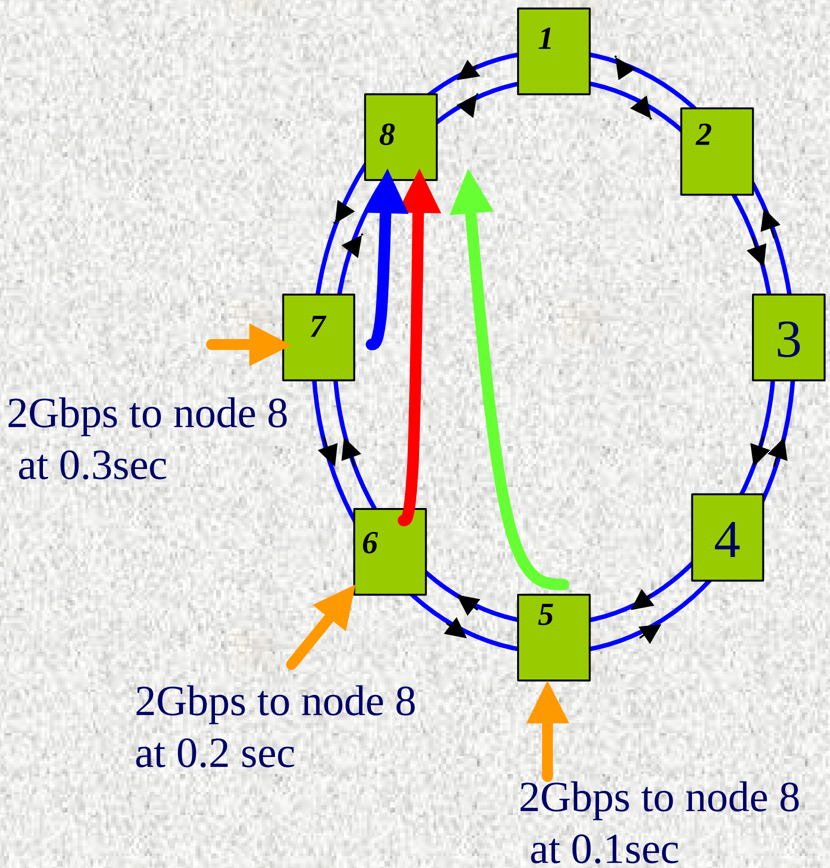
Figure 5: SBQ Node Architecture

Properties of SBQ Approach

- **Access guarantee:** Every node has immediate access for its share.
- **Fairness property:** Fairness is ensured as fair scheduler (e.g. WRR) fairly serves the queues on weighted basis.
- **Simplicity:** No signaling or backpressure mechanism is needed to ensure fairness.
- **Facilitating new applications or services:** easy to add new services for different sources because of the isolation among sources.
- **Requirement:** buffers on the ring!

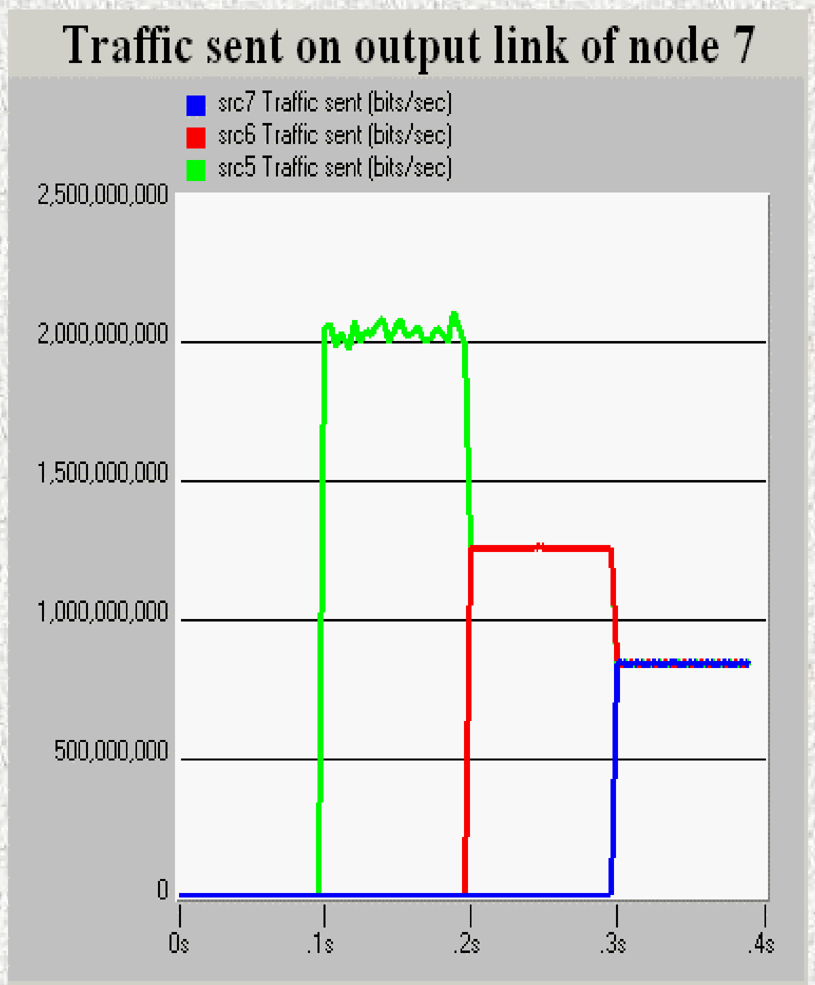
Simulation Results on Fairness Guarantee (1)

- **Simulation Setup:**
  - **OPNET Simulations**
  - **8-Nodes OC-48 Ring (2.5Gbps)**
  - **WRR as Scheduler**
  - **Each node has the same weight.**
  - **Source 5, 6 and 7 start sending 2Gbps to node 8 at time 0.1sec, 0.2sec and 0.3sec respectively.**



Simulation Results on Fairness Guarantee(2)

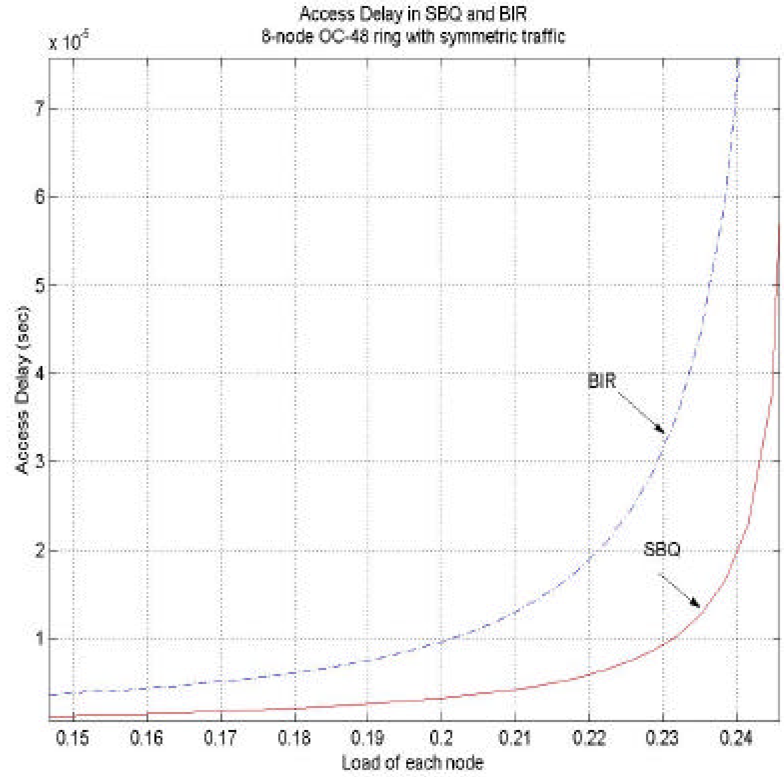
- **Simulation Results:**
  - ✍SBQ can ensure fairness among the competing sources. After source 7 starts sending traffic at time 0.3 second, each source gets one third of the bandwidth on the output link of node 7 (2.5Gbps), which is 833 Mbps.
  - ✍The convergence time is negligible.
  - ✍The maximum throughput of 2.5Gbps is obtained.



Access Delay Comparisons: SBQ vs BIR

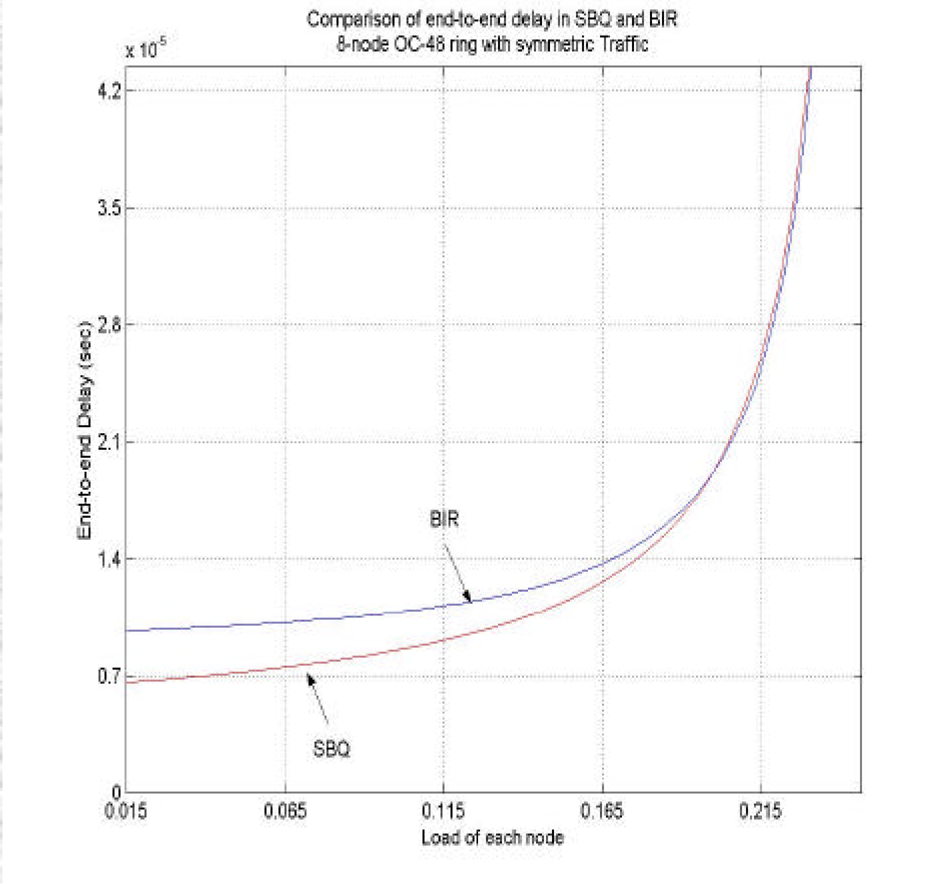
- **Model assumptions:**
  - uni-directional OC-48 rate ring with 8 nodes;
  - Symmetric traffic pattern;
  - packet size is assumed to be generally distributed with average size of 500bytes;
  - Equal weights in SBQ scheme.

- **Numerical Results:**
  - ***SBQ has less access delay than BIR***
  - ***Example: when the load at every node is 0.2, which equals to ring BW utilization of 160%, the average access delay is 9 microseconds for BIR scheme while 2 microseconds for SBQ scheme.***



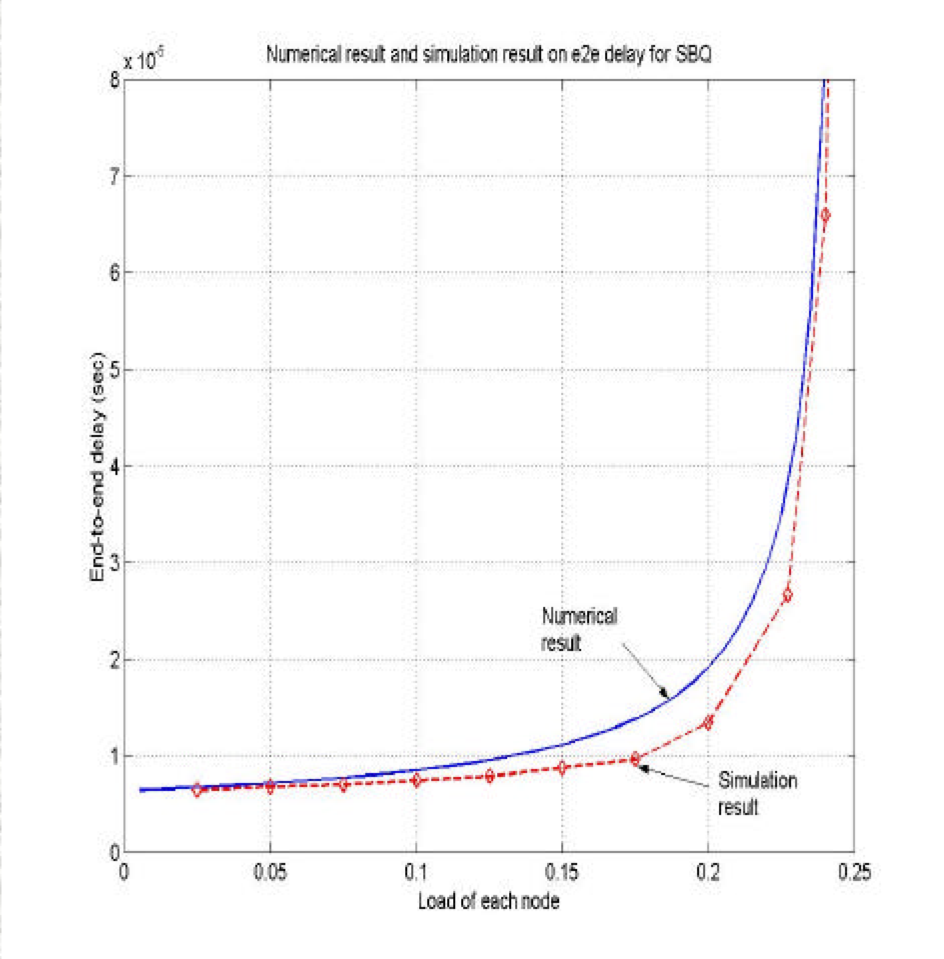
End-to-end Delay Comparisons: SBQ vs BIR

- When the node load is below 20%, SBQ has less end-to-end delay, while when the node load is above 20%, SBQ and BIR has similar end-to-end delay.
- Reason is that at high load, the queuing delay dominants the end-to-end delay, thus, the advantage of SBQ on access delay diminishes.



Validation of Analytical Results

- Compare simulation results with the numerical results.
- The simulation results (drawn with symbols) and the numerical results (plotted in lines) are very close and the simulation results are upper bounded by the numerical results.



Summary and Future Researches

- There is an inherent **fairness problem** of the unregulated operation of Buffer Insertion Rings (BIR).
- SBQ is a simple, efficient access control scheme that guarantees fairness.
- SBQ is more cost effective than BIR and has great potential in Medium Access Control for optical ring networks where spatial reuse is of vital interest.
- Future Researches:
  - ✍ Providing flow control to avoid packet loss for finite buffer size;
  - ✍ Provide guidelines for parameter settings for sources with different QoS requirements;

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