OPNET Technologies, Inc.

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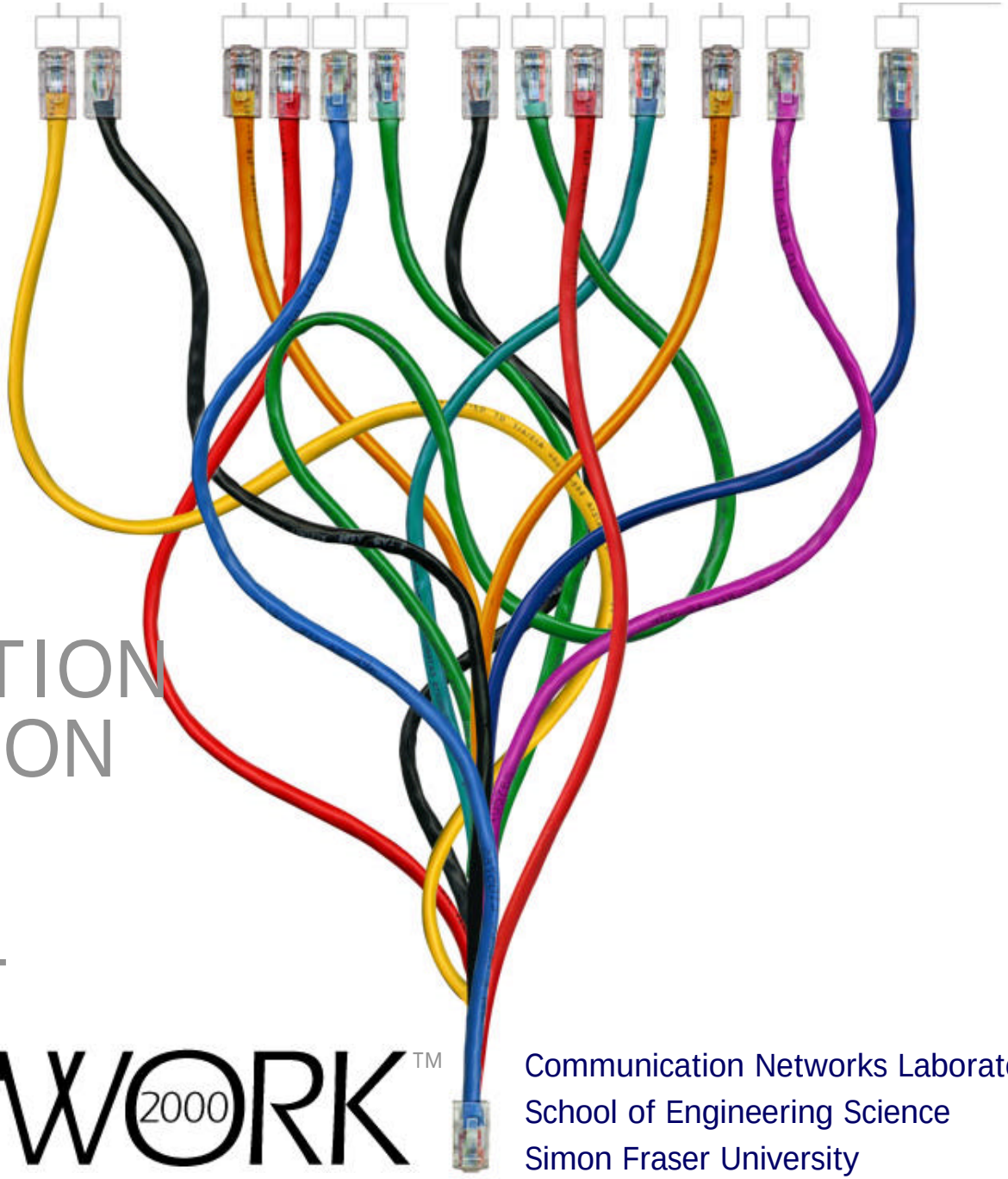

IMPLEMENTATION OF CONGESTION CONTROL MECHANISMS USING OPNET

OPNETWORK 2000™

Communication Networks Laboratory
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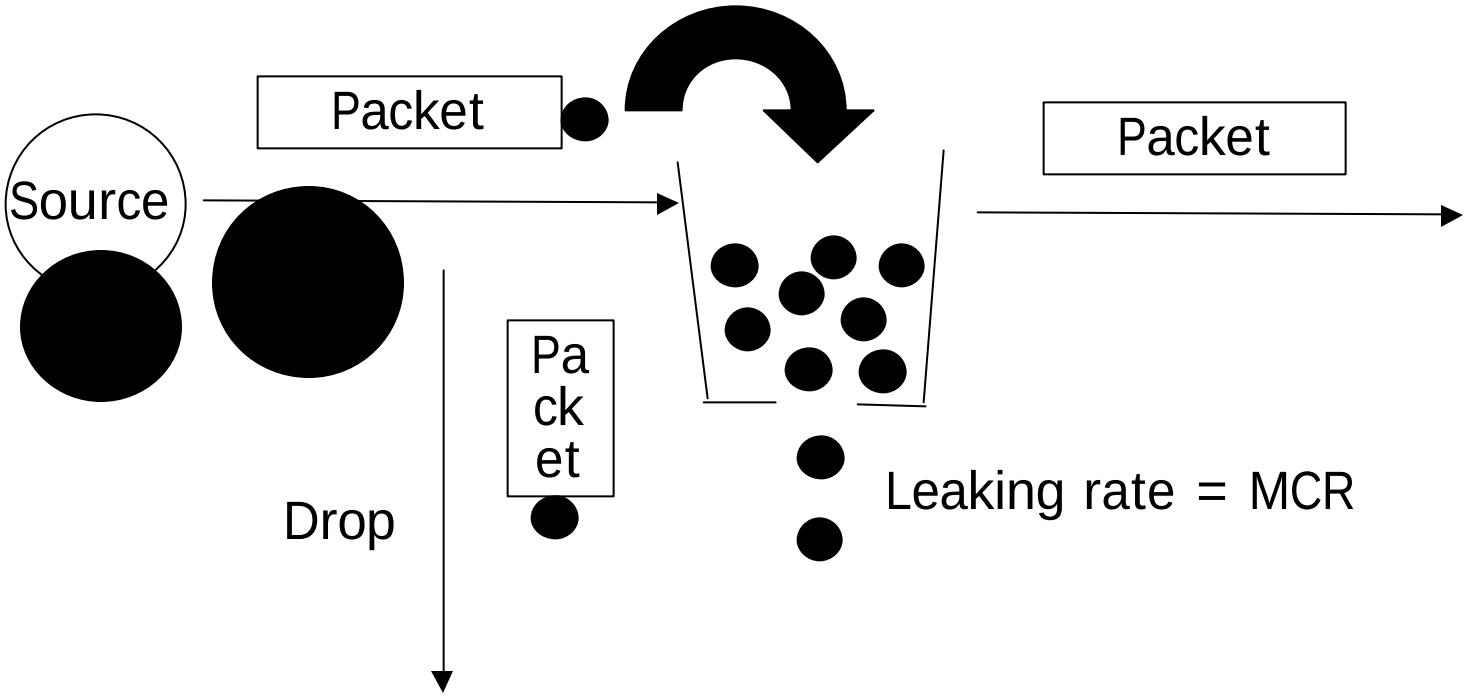
Road map

- Introduction to congestion control mechanisms
  - Policing mechanisms
  - Routing mechanisms
  - Queuing mechanisms
- Leaky bucket policing algorithm
  - Leaky bucket policing algorithm
  - Leaky Bucket process model
  - Leaky bucket in an ATM network model
- Virtual Clock queuing mechanism
  - Virtual Clock process model
  - IP router node model
- Future works

Introduction to congestion control mechanisms

- Policing mechanisms
  - Implemented at the source point
  - Smoothes the rate at which the source sends packets
  - Has effect on the overall network traffic
  - Leaky Bucket is an example
- Routing mechanisms
  - Implemented at the routers
  - Routs packets away from network bottlenecks
- Queuing mechanisms
  - Implemented at the routers
  - Virtual Clock is an example
- Future works

Leaky bucket mechanism



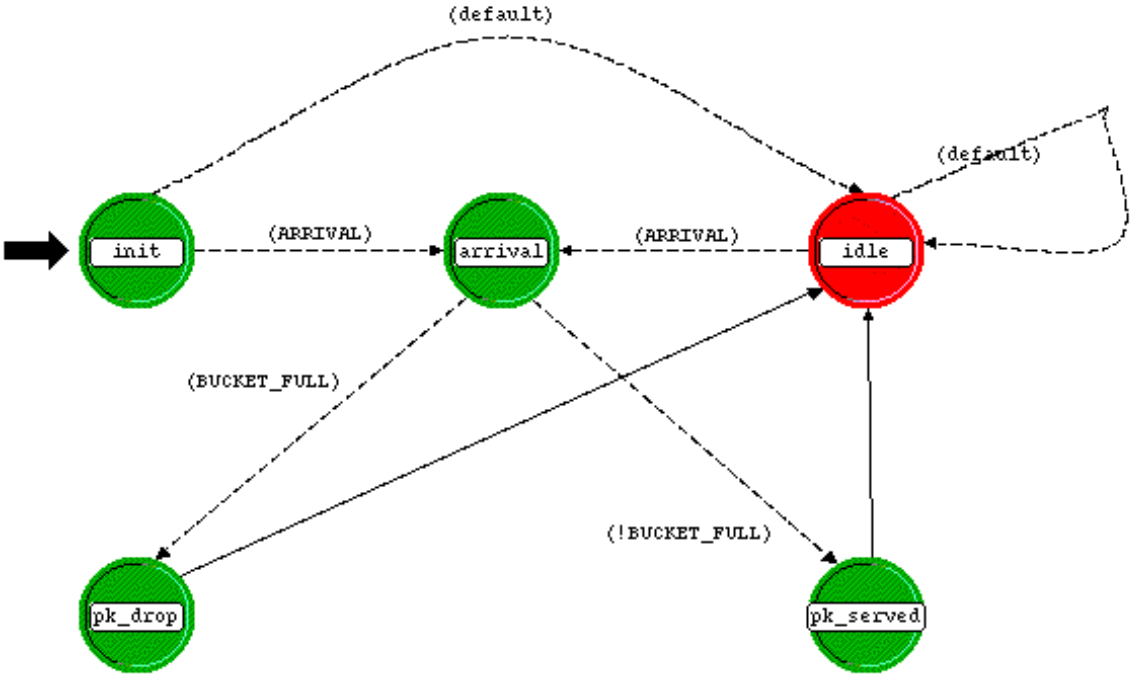
Leaky bucket mechanism

- Single leaky bucket:
  - Used to police CBR sources.
  - The leaking rate is equal to the negotiated MCR (Mean Cell Rate) of the source.
  - The bucket size should be:
    - Small enough to limit the size of the bursts allowed into the network.
    - Large enough, so that cells from well behaving sources are not discarded.

Leaky bucket mechanism (cont.)

- Dual leaky bucket:
  - Used to police VBR sources.
  - Build from two concatenated single buckets.
  - The leaking rate of the first and the second bucket are set to the negotiated PCR (Peak Cell Rate) and MCR (Mean Cell Rate) of the source, respectively.
  - The first bucket's size is a function of PCR and delay jitter.
  - The second bucket's size is set to the maximum burst accepted by the network.

Leaky bucket process model

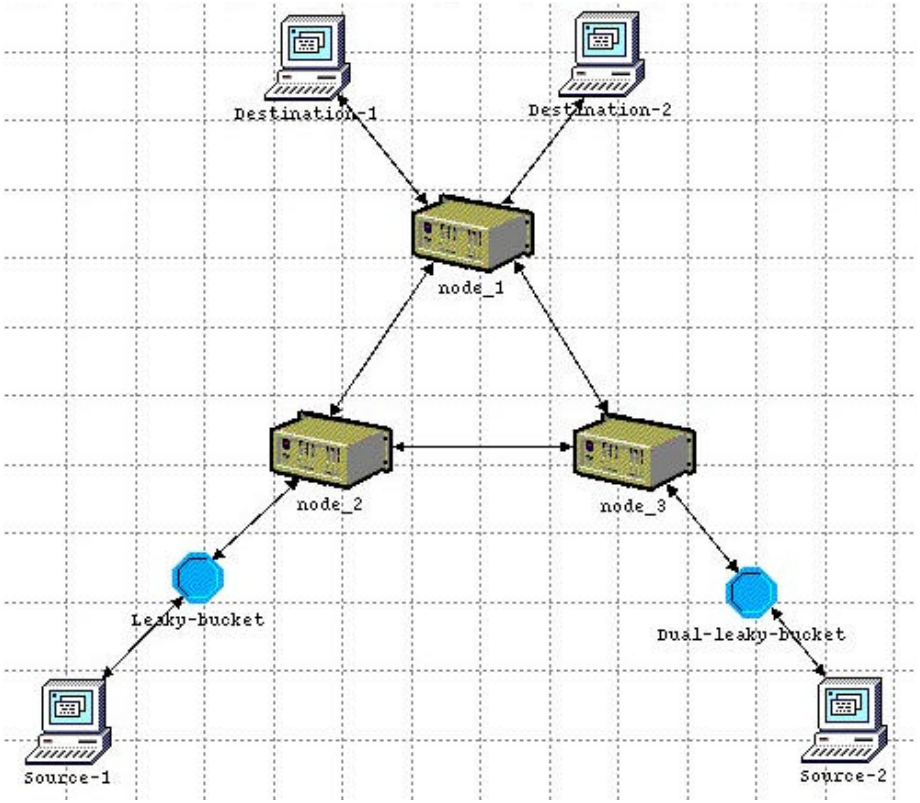


State transition diagram for the leaky bucket process model.

Input and output parameters

- Input parameters:
  - Mean cell rate (Bytes/Sec): Negotiated rate
  - Bucket size (Bytes): Maximum capacity of the bucket
  - Token Leaking rate (Bytes/Sec)
- Output parameters:
  - Loss number (Bytes)
  - Burst Loss : Number of consecutive packets allowed to the network

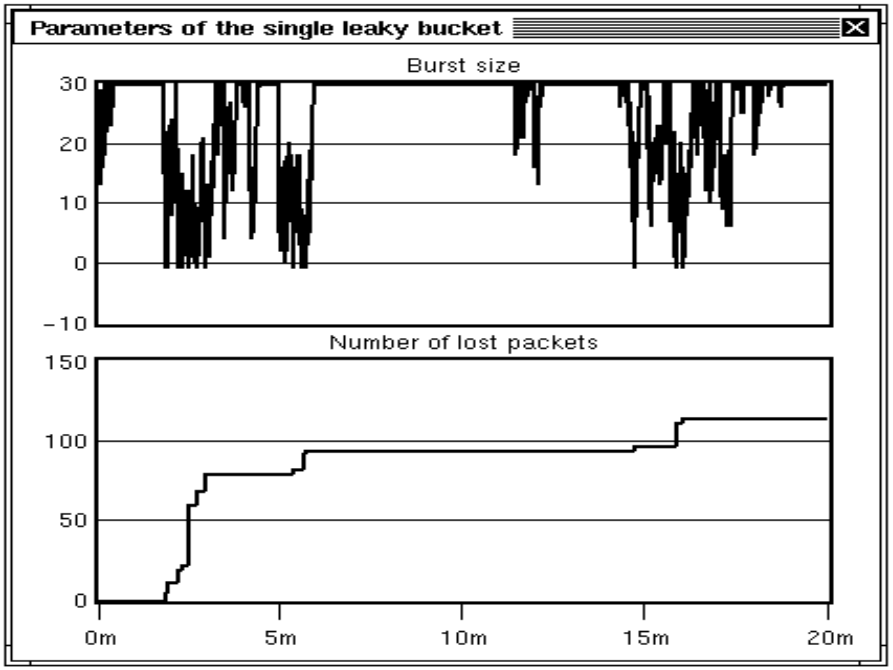
ATM network model



The model consists of CBR (Source-1) and VBR (Source-2) ATM sources, three ATM switches, and two destinations. Source-1 is policed by a single and Source-2 is policed by a dual leaky bucket.

Simulation results

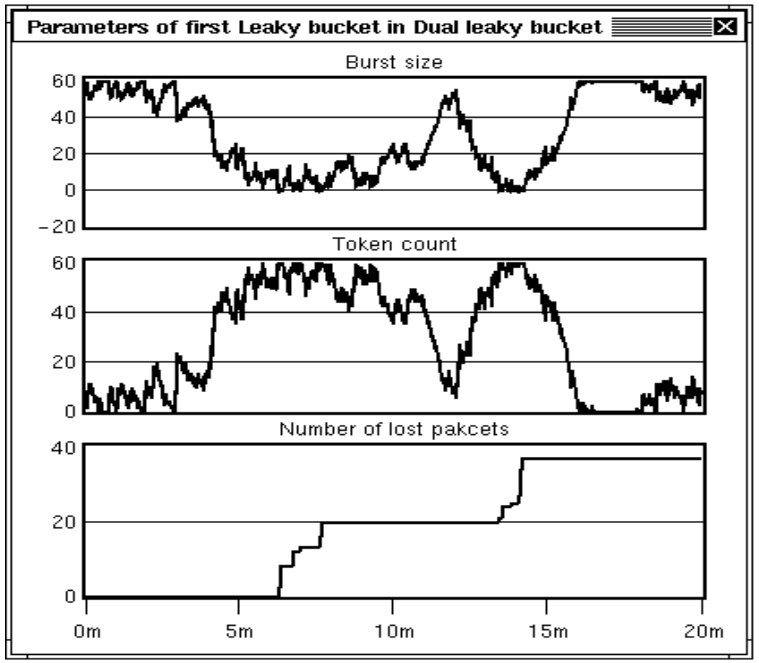
Single leaky bucket



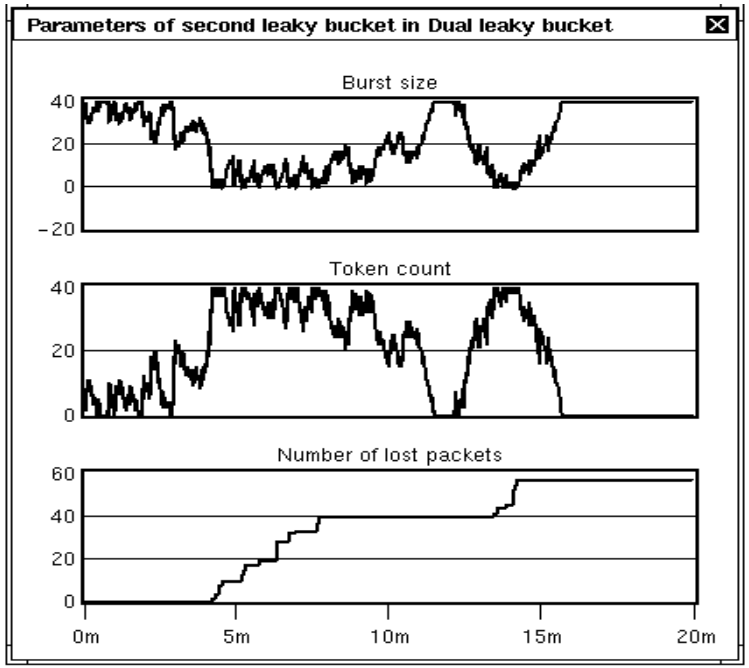
Top: Burst size (cells) allowed into the network. Bottom: Number of lost cells. Burst size is limited by the bucket size (30 cells). The number of lost cells is a function of the leaking rate and the bucket size.

Simulation results (cont.)

First leaky bucket



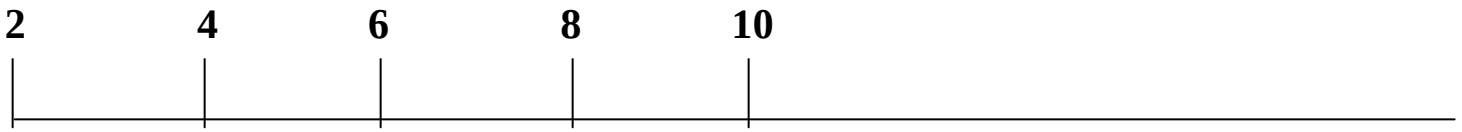
Second leaky bucket



Dual leaky bucket: Burst size (top), number of tokens in the bucket (middle), and number of lost cells (bottom). Burst size is limited by the bucket size.

Virtual Clock queuing algorithm

- Follows TDM (Time Devision Multiplexing idea)
- In TDM
  - N channels want to transmit over an outgoing link
  - There is a master clock for these N channels
  - At each tick of the clock outgoing channel is allocated to one of these channels in a sequential order
- In Virtual Clock
  - Each channel has its own clock
  - Upon receiving each packet from flowi:
    - Vclocki = max (Vclocki, realtime)
    - Clock ticks with (1/ARi), Vclock <= Vclocki + Vticki (= 1/ARi)
  - Stamp packets with Vclocki value
  - Services packets in increasing stamp order



Real time clock (second)

Flow-1's virtual clock(AR=1 Pkt/Sec)

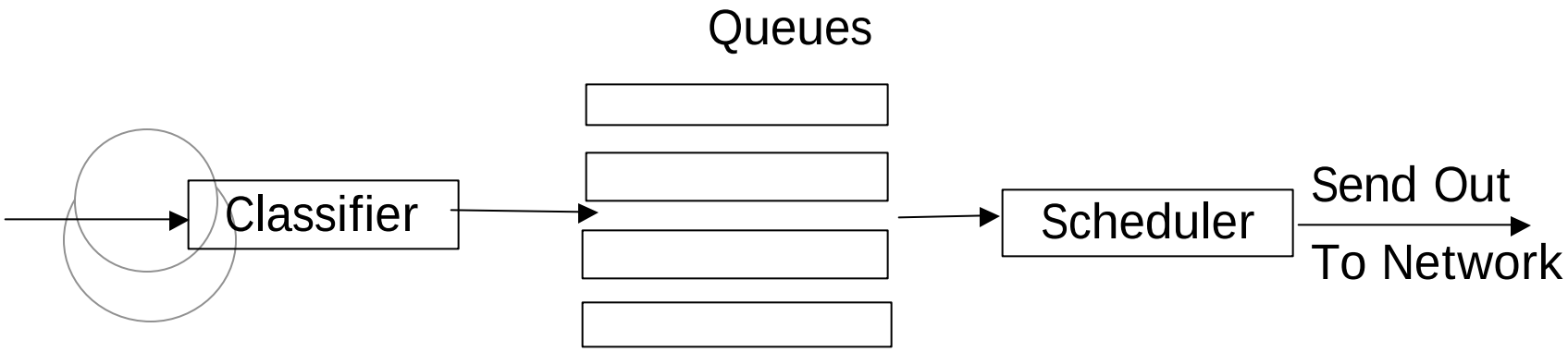
Flow-2's virtual clock(AR= 0.5 Pkt/Sec)

Router's Packet forwarding queue

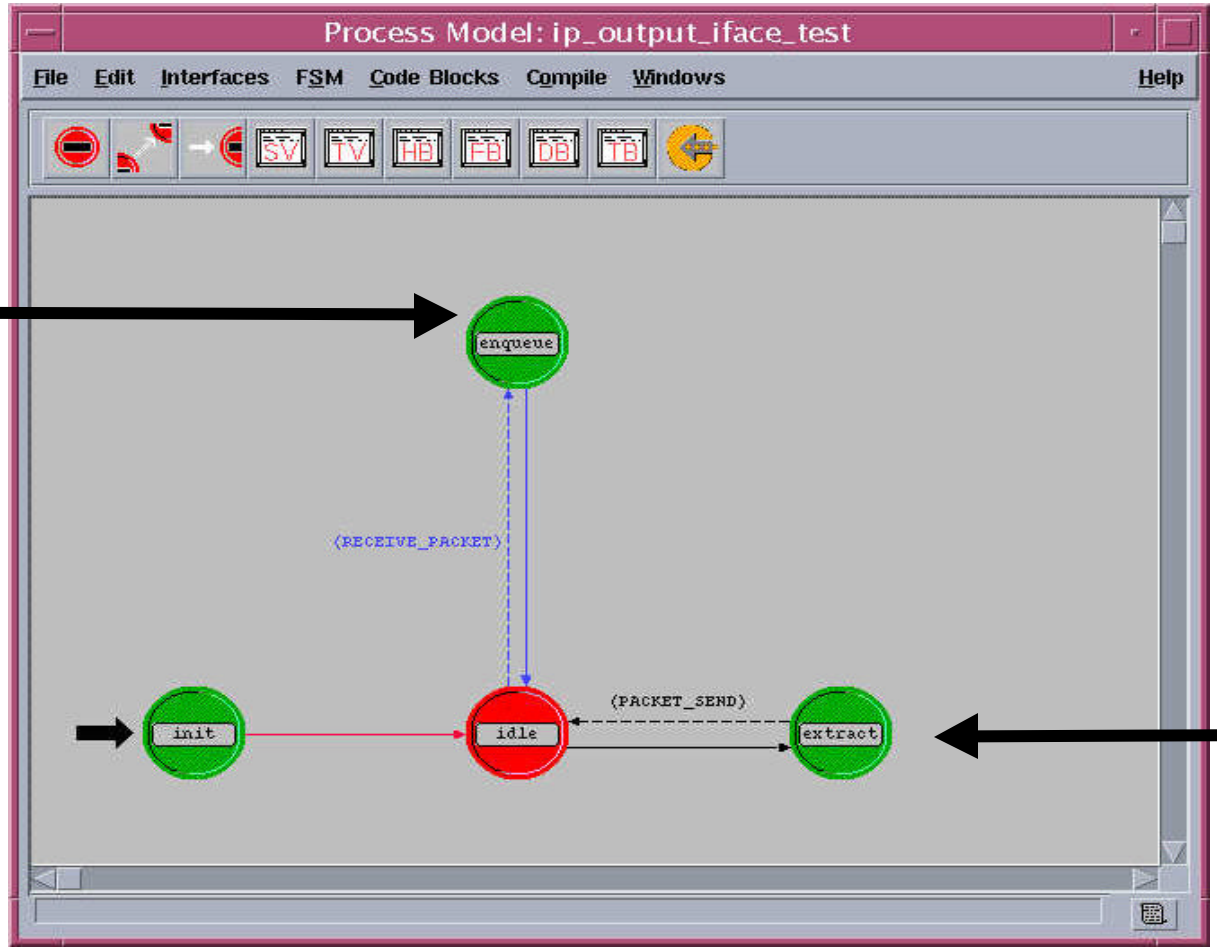
Virtual Clock implementation in Opnet

- Process model
- IP router node model

Basic blocks of queuing algorithms?



Virtual Clock process model



State transition diagram for the Virtual Clock process model.

Classifier (Enqueue state)

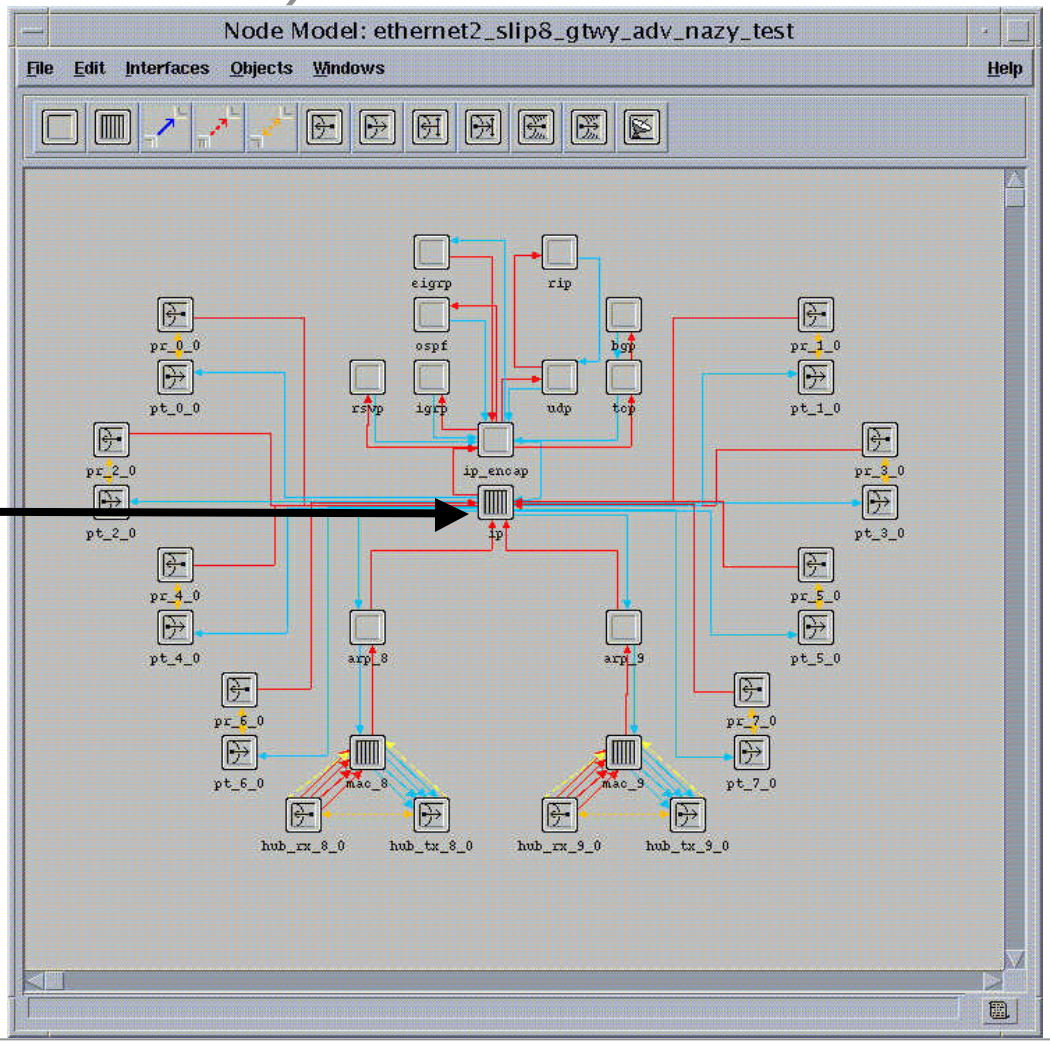
- Flows are classified according to:
  - Source IP address
  - Destination IP address
  - Source port number
  - Destination port number
- Allocates each flow a separate queue
- Calculates the VClock upon arrival of each packet to the flow
- Stamps packets with the VClock
- Sends interrupt to enter “extract” state at time = VClocki
- Returns to the idle state

Scheduler (Extract state)

- Schedules the packets
- Send out the packets to the output interface
- Update the statistics
- Returns to the idle state waiting for another packet arrival or an interrupt at time = VClocki

IP (Internet Protocol) router node model

IP Process model in which Virtual clock process is called



Future work

- Building an IP network model
- Analyzing the functionality of the VC algorithm under different traffic sources feeding the IP router
- Collecting the following statistics:
  - Average end to end delay for the packets of each flow
  - Queuing delay
  - Dropped packets from each queue
- Running the simulation for the same network setup with different queuing algorithms like WFQ (Weighted Fair Queuing), CQ (Custom Queuing), and PQ (Priority Queuing) and comparing their functionality

References

- [1] J. Walrand, P. Varaiya, " *High-performance Communication Networks,"* Morgan Kaufmann Publishers, Inc. San Francisco, California.
- [2] L. Zhang, "Virtual clock: A new traffic control algorithm for packet switching networks," ACM SIGCOM,Sep. 1990.
- [3] E. P. Rathgeb and T. H. Theimer, "The policing function in ATM networks," *Proceeding of the International Switching Symposium*, Stockholm, Sweden, June 1990, vol. 5, pp. 127-130.
- [4] G. Niestegge, "The leaky bucket policing method in asynchronous transfer mode networks," *International Journal of Digital and Analog Communication Systems*, vol. 3, pp. 187-197, 1990.
- [5] OPNET Contributed Model Depot: *http://www.opnet.com/services/depot/home.html*.

How queuing algorithms affect congestion?

- Do not affect congestion directly
- No effect on total traffic of the router's outgoing link
- Assigns each flow a specific queue (classifying)
- Determines
  - The order of sending packets from different sources to the outgoing link.
  - How many packets get transmitted (Bandwidth)
  - When those packets get transmitted (scheduling)
- Control the usage of router's buffer space
  - Which packets are discarded when buffer is full