# Simulation and Analysis of VirtualClock Scheduling Algorithm

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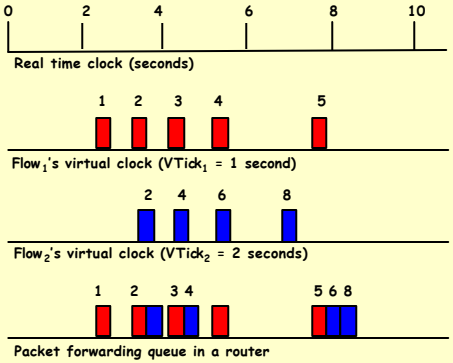
## A. VirtualClock

VirtualClock is a scheduling algorithm for high-speed packet-switched networks. It controls the average transmission rate of data flows, enforces resource usage according to user's reservation, builds firewalls among flows, and supports multi-priority transmissions. The VirtualClock algorithm can be implemented in the routers of packet-switched networks.




**Algorithm:**

- Implement separate clocks for each flow
- Assign a separate queue to each flow according to:
  - IP address of the source
  - IP address of the destination
- Upon receiving packet from $flow_i$ :
  - $VClock_i = \max(VClock_i, realtime)$
  - Clock ticks with $Vtick_i = 1/AR_i$

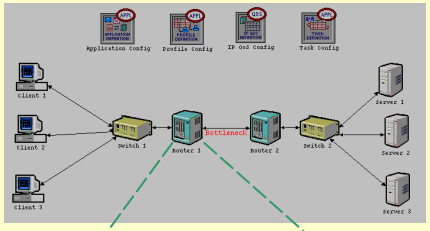
  $VClock_i <= VClock_i + VTick_i$
- Stamp packets with $VClock_i$ values
- Service packets in increasing stamp order

References:

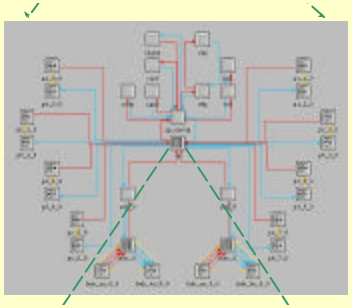
- L. Zhang, "VirtualClock: A new traffic control algorithm for packet switching networks," *ACM SIGCOM*, Sep. 1990.
- Cisco Systems Inc. documentation on QoS: http://www.cisco.com/warp/public/732/Tech/qos
- OPNET Technologies Inc., Washington DC, OPNET documentation V.7.0.L.

## B. Implementation

A scheduler model of VirtualClock has been incorporated into the IP layer output queues of an IP router using the OPNET simulation tool.



IP network model: packet scheduling is implemented in IP routers 1 and 2.



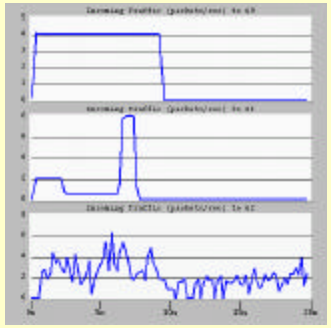
Network hierarchy in the IP router node model.

State transition diagram for VirtualClock process model.

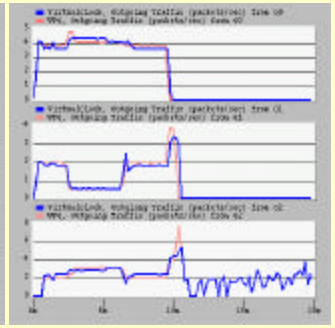
## C. VirtualClock vs. WFQ, CQ, and PQ

We compared the VirtualClock scheduling algorithm with Weighted Fair Queuing (WFQ), Custom Queuing (CQ), and Priority Queuing (PQ):

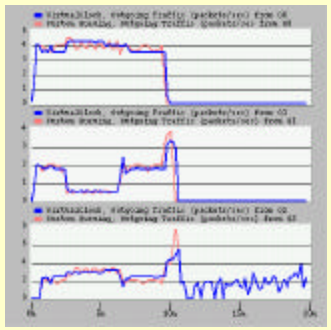
- Our simulation results indicate that VirtualClock exhibits similar performance to WFQ and CQ.
- VirtualClock allocates bandwidth fairly to traffic from different flows according to their specified traffic generation rates.
- PQ provides preferential priority to selected traffic queues while starving low priority queues.



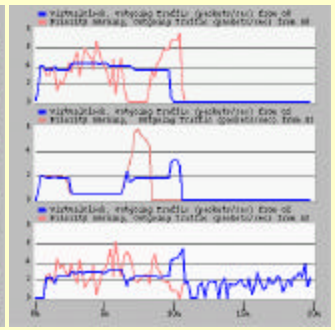
Incoming traffic to queues Q0, Q1, and Q2 in (packets/second) vs. time.



Outgoing traffic from routers: VirtualClock vs. Custom Queuing.



Outgoing traffic from routers: VirtualClock vs. Weighted Fair Queuing.



Outgoing traffic from routers: VirtualClock vs. Priority Queuing.