802.17 Performance modeling

Preliminary performance results from a simple Java model

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RPR performance modeling

- A simple RPR model written in the programming language Java:
  - Class Node // single direction node
  - Class DualNode
  - Class Buffer // several needed in each node
  - Class Link // one (out) for each single Node
  - Class Packet // new one for each packet sent
  - Class Application // generating system load, etc
  - Class Kernel Class Unit // simulation environment
RPR performance modeling

- **RPR model status** as of May 14. 2001:
  - Dual rings with shortest path forwarding
  - Two priority levels with two set of buffers
  - Absolute priority for the highest (provisioned)
  - Choice of preemption (without packet loss (½ K))
  - Cut-through (store&forw. very easy to implement)

Parameters:

- No. of nodes, wire length/wire latency, bandwidth
- Programmable (in Java) load (Class Application) with destination and packet size set individually for each packet sent
- Simple statistics (Class Reporter)

*No flow control yet*
Single Direction Node Model

synchronous application logic (provisioned)

priority sink

fast insertion buffer

outputSelector()

fast transit path

normal transit path

normal sink

normal insertion buffer

asynchronous application logic

Traffic put into correct single node depending on shortest path
Simulation Topology

- 16 nodes (numbered 0 – 15), dual rings
- 250 microsec. cable between each node
  includes one node bypass latency
  ( ~ 50 km between each node )
- 1Gbyte/sec bandwidth (= 10Gbit/sec)
Two basic Scenarios

- **Scenario A – Random receiver**
  Overloaded system – 10Gbit/sec/link
  Three background packet sizes: 1600, 16K and 520 bytes

- **Scenario B – Hot receiver**
  Partly highly loaded system – 10Gbit/sec/link
  Three background packet sizes: 1600, 16K and 520 bytes
Simulation Scenario - A

Random receiver

Only traffic streamed from 7 to 15 are logged

Random traffic
between all nodes.
30% bandwidth provisioned
small high prio.
70% bandwidth overloaded,
large low prio.

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**Simulation Scenario - B**

- **Hot receiver**
  - Only traffic streamed from 7 to 15 are logged
  - 15 is hot receiver
    - 30% bandwidth provisioned (small, high priority)
    - 70% bandwidth large, low priority
    - Last link to 15 almost fully used

- Streaming from 7 to 15
  - All traffic from all nodes are sent to node 15
  - Links into 15 have close to 100% utilization
Measured traffic

- Latency / jitter
- Streaming small high priority packets (80 bytes including header) from node 7 to node 15
  8 hops, ~ 400 km distance = 2ms min. latency
- 2 us. between packets
- 125 us. between packets (TDM frame interval)
Background traffic

- Load distribution
  30% bandwidth high priority small packets
  70% bandwidth low priority
  - ”IP-packets” (1600 bytes)
  - Jumbo-packets (16K)
  - Jumbo-packets with preemption (1/2 K)

- A. Random receiver
  network overloaded

- B. Hot receiver (node 15)
  Almost full utilization of last link into hot receiver
  (i.e. lighter loaded system than A, but not easy to get comparable load in all cases)
Results

- Packet Latency (and Jitter) in a stream of small (80 byte) high priority packets
- How much delay/jitter are caused by other packets blocking?
- Delay caused by
  - Low priority packets on their way out (mostly)
  - Other high priority packets (also)
- Single runs of 20 ms
  (statistics from 10,000 packets)
- No confidence intervals etc.
Scenario A: Random traffic – overloaded

- Traffic from all nodes to all nodes (random destination)
- All linkes full all the time
- Measuring high prio. stream from 7 to 15 with 2 us. or 125 us between packets
- Background traffic is
  - 30% high prio 80 bytes packets (provisioned) and
  - 70% low prio packets:
    - 3 sub-scenarios with 3 packet sizes:
      - A1. 1600 bytes ”IP-packets” or
      - A2. 16K jumbo packets or
      - A3. 16K jumbo packets with preemption (1/2 K)
Scenario A1: Random ”IP-packets” background

- Random background traffic with
  30% bandwidth high prio small packets
  overloaded with ”IP-packets” (1600 bytes)

- Streaming from node 7 to node 15
  8 hops, ~ 400 km distance = 2ms min latency
  2 us between packets
  125 us. between packets
**A1. Latency**
Streaming high prio. small packets 8 hops (400 km., 2ms.) with random overloaded ”IP-packets” (1600 byte) background
A1. Latency
Streaming small packets 8 hops with overloaded "IP-packets" background. More detailed sample.
A1. Latency
Streaming small packets 8 hops with overloaded "IP-packets" background. 125 us. between packets.
A1. Conclusion:
Streaming small high prio. packets
with ”IP packets” overloaded background

- Added latency between 2 and 12 us.
  (going 8 hops, 400 km., 2 ms.)
- Theoretically added latency between 0 and 13us.
- Max 11.7 us.  Min. 1.5 us. added latency
- 0.1 %: more than 11us. added latency
- 1%: more than 10us. added latency
- Mean and median is 6.4 us. added latency
- Max jitter almost as large as total latency variation
Scenario A2: Random Jumbo packets background

- Random background traffic with
  30% bandwidth high prio small packets
  overloaded with Jumbo packets (16K bytes)
- Streaming from node 7 to node 15
  8 hops, ~ 400 km distance = 2ms min latency
  2 us between packets
  125 us. between packets
A2. Latency
Streaming small high prio. packets 8 hops (400 km., 2 ms.) with random overloaded Jumbo-packets (16K) background
A2. Latency
Streaming small high prio. packets 8 hops with random overloaded Jumbo-packets (16K) background (details)
A2. Latency
Streaming small high prio. packets 8 hops with
random overloaded Jumbo-packets (16K) background (more details)

individual packets (2us. apart, One Jumbopacket is 16us.)
A2. Latency

Streaming small high prio. packets 8 hops with random overloaded Jumbo-packets (16K) background. 125 us. stream

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![Graph showing individual packets (125 us. apart) with mean and median lines.](image-url)
A2. Conclusion:
Streaming small high prio. packets with Jumbo packets overloaded background

- Added latency between 20 and 100 us.
- Theoretically between 0 and 128 us.
- Min: 14 us. Max: 106.5 us.
- 0.1% larger than 104 us.
- 1% larger than 96.2 us.
- 10% larger than 81.4 us.
- Mean and median: 62 us.
- Max jitter about half of total latency variation
Scenario A3.
Background traffic with Preemption

- Random background traffic with
  - 30% bandwidth high prio small packets
  - 70% (overloaded) with Jumbo packets with preemption (slide in at every ½ K)

- Streaming from node 7 to node 15
  - 8 hops, ~ 400 km distance = 2ms min latency
  - 2 us between packets
  - 125 us between packets
**A3. Latency**

Streaming small high prio. packets 8 hops (400 km., 2 ms.) with overloaded random background **preemptable** (½ K) Jumbo-packets
A3. Latency
Streaming small high prio. packets 8 hops with overloaded background preemptable (½ K) Jumbo-packets (details)
A3. Latency

Streaming small high prio. packets 8 hops with overloaded background preemptable (½ K) Jumbo-packets. 125 us. stream.
A3. Conclusion:
Streaming small high prio. packets with preemptable overloaded background

- Added latency between 0.5 and 4 us.
- Theoretically between 0 and 4.1 us.
- Min: 0.5 us.    Max: 4.05 us.
- 0.1 % larger than 3.7 us.
- 1% larger than 3.3 us.
- 10% larger than 2.8 us
- Mean and median: 2.15 us.
- Max jitter almost as large as total latency variation
B. Hot receiver – lighter load

- Traffic from all nodes to hot receiver, node 15
  Last links to receiver is almost fully utilized
  (but can be different in the three cases B1, B2 and B3)
- Measuring high priority stream from 7 to 15
  with 2 us. or 125 us between packets
- Background is
  30% high prio 80 bytes packets (provisioned) and
  70% low prio packets.
  3 sub-scenarios with 3 different packet sizes
  B1. 1600 bytes ”IP-packets” or
  B2. 16K jumbo packets or
  B3. 16K jumbo packets with preemption (1/2 K)
Scenario B1.
Hot receiver, "IP-packets" background

- Hot receiver (15) background traffic with
  30% bandwidth high prio small packets
  70% "IP-packets" (1600 bytes)
  Almost full utilization of last links to 15

- Streaming from node 7 to node 15
  8 hops, ~ 400 km distance = 2ms min latency
  2 us between packets
  125 us. between packets
B1. Latency
Streaming high prio. small packets 8 hops (400 km., 2ms.)
with hot receiver ”IP-packets” (1600 byte) background
B1. Latency
Streaming small packets 8 hops (2ms.)
Hot receiver. "IP-packets" background (details)
B1. Latency
Streaming small packets 8 hops (2ms.)
Hot receiver. "IP-packets" background. 125 us. stream
B1. Conclusion:
Streaming small high prio. packets with hot receiver and "IP-packets" background

- This is not a fully overloaded system
- Added latency between 0 and 6.5 us.
- Theoretically between 0 and 13 us.
- Max observed added latency is 6.74 us.
- 0.1% added latency greater than 5.9 us.
- 1% added latency greater than 4.6 us.
- Median 1.36 us. Mean 1.47us.
- 10% went through with no added latency
- Max jitter as large as total latency variation
Scenario B2.
Hot receiver, Jumbo packets background

- Hot receiver (#15) background traffic with
  30% bandwidth high prio small packets
  70% Jumbo packets (16K bytes)
  Almost full utilization of last links to 15

- Streaming from node 7 to node 15
  8 hops, ~400 km distance = 2ms min latency
  2 us between packets
  125 us. between packets
B2. Latency
Streaming high prio. small packets 8 hops (400 km., 2ms.) with hot receiver Jumbo packets (16K byte) background
B2. Latency
Streaming high prio. small packets 8 hops with hot receiver Jumbo packets (16K byte) background (Details)
B2. Latency
Streaming high prio. small packets 8 hops with hot receiver Jumbo packets (16K byte) background. 125 us. stream
B2. Conclusion:
Streaming small high prio. packets with hot receiver and Jumbo packets background

- This is not a fully overloaded system
- Added latency between 0 and 55 us.
- Theoretically between 0 and 128 us.
- Max observed added latency is 59.7 us.
- 0.1% added latency greater than 55 us.
- 1% added latency greater than 47 us.
- Median 18.8 us. Mean 19.9 us.
- 1% went through with no added latency
- 10% less than 6 us.
- Max jitter about half of total latency variation
Scenario B3.
Hot receiver, preemptive background

- Hot receiver (15) background traffic with
  30% bandwidth high prio small packets
  70% Jumbo packets with preemption (½ K)
  Almost full utilization of last links to 15
- Streaming from node 7 to node 15
  8 hops, ~ 400 km distance = 2ms min latency
  2 us between packets
  125 us. between packets
B3. Latency
Streaming high prio. small packets 8 hops (400 km., 2ms.)
with hot receiver Preemptive (½ K) Jumbo packets background

[Graph depicting individual packets over years 2000 to 2004]
B3. Latency
Streaming high prio. small packets 8 hops with hot receiver
Preemptive (½ K) Jumbo packets background (Details)

Individual packets, 2 us. apart
B3. Latency
Streaming high prio. small packets 8 hops with hot receiver
Preemptive (½ K) Jumbo packets background 125 us. stream
B3. Conclusion:
Streaming small high prio. packets with Hot receiver and Preemptive Jumbo packets

- This is not a fully overloaded system
- Observed added latency between 0 and 3.4 us.
- Theoretically between 0 and 4.1 us.
- Max observed added latency is 3.6 us.
- 0.1% added latency greater than 3.3 us.
- 1% added latency greater than 2.9 us.
- Median 1.0 us. Mean 1.1 us.
- 0.5% went through with no added latency
- 10% less than 0.2 us.
- Max jitter as large as the total latency variation
Overall conclusion

- Scenario A – Random background
  Overloaded system
  Different background low priority packet sizes clearly give difference foreground packet latency

- Scenario B – Hot receiver background
  More variably loaded system
  Still differently sized background packets clearly influence foreground packet latency

- Jitter almost as large as total latency variation
Conclusion Scenario A:
Streaming small high prio. packets with random overloaded background (3 packet sizes)
Conclusion Scenario B:
Streaming small high prio. packets with hot receiver, high load, background (3 packet sizes)

Individual packets streaming at 125 us.
In a "high load" system 1% of the packets observe half of the theoretical max latency

In an overloaded system 1% of the packets observe close to the theoretical max latency

Hence with Jumbo packets (16K) and no preemption it is possible to get 100 us. added latency with 8 nodes (128 us. theoretical max). This is close to the 125 us. synchronous stream interval (TDM frame interval)

Jitter almost as large as total latency variation