802.17 Performance modeling

Preliminary performance results from a simple Java model

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RPR performance modeling

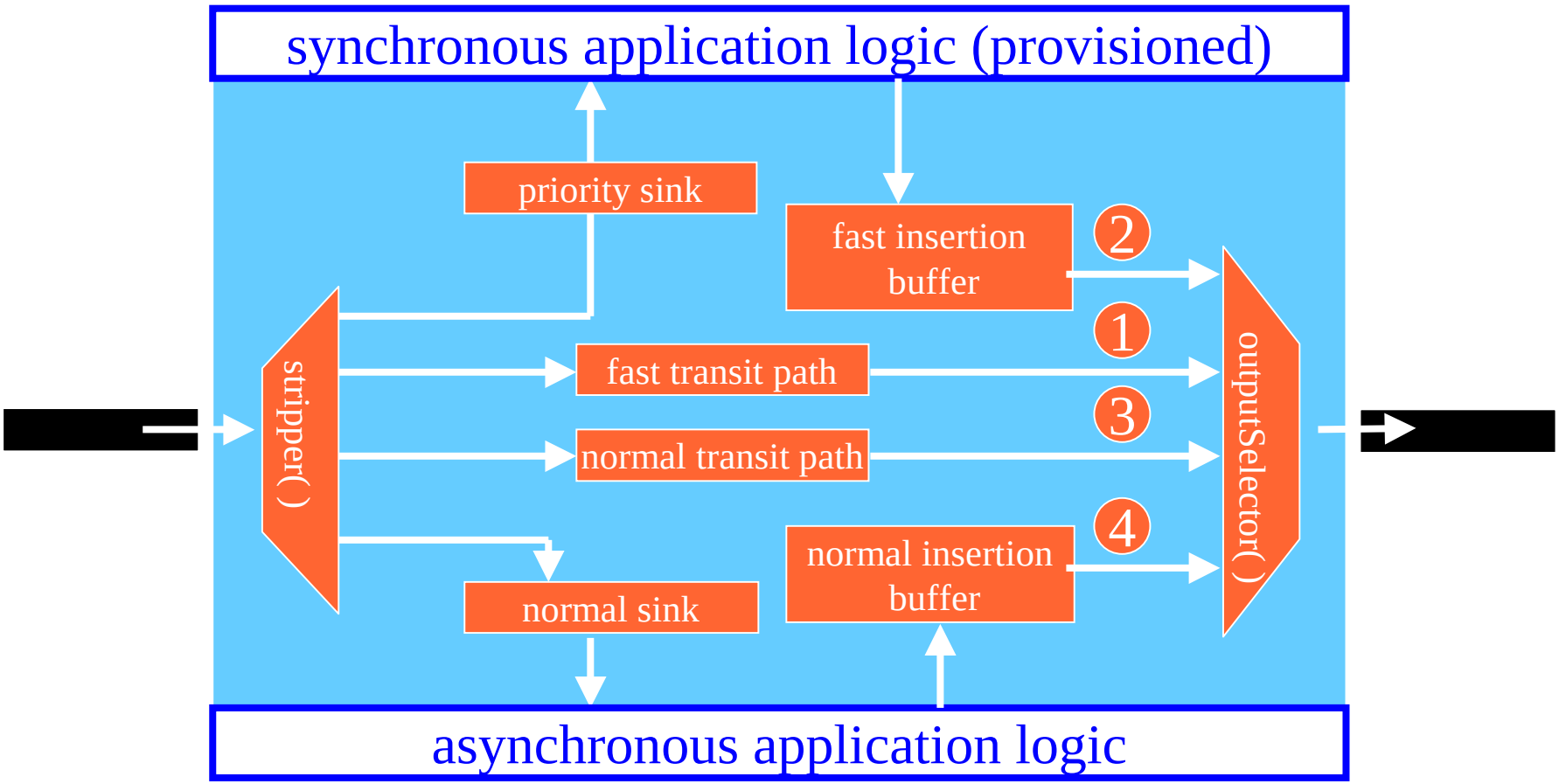
- A simple RPR model written in the programming language Java:

```
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 implemet)
  - 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



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

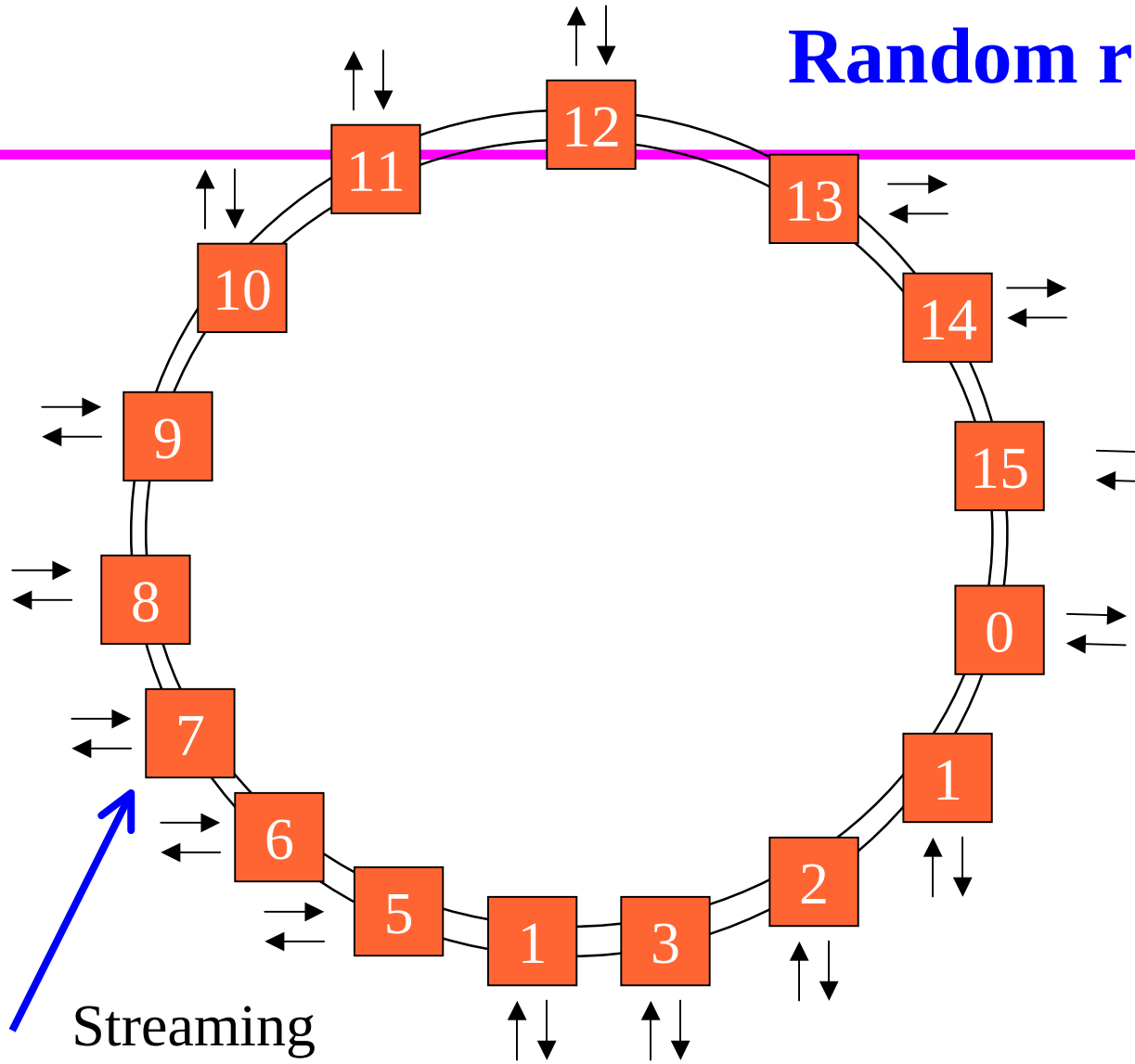
  (~ 50 km between each node)
- 1Gbyte/sec bandwidth (= 10Gbit/sec)

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

Streaming from 7 to 15

Random traffic

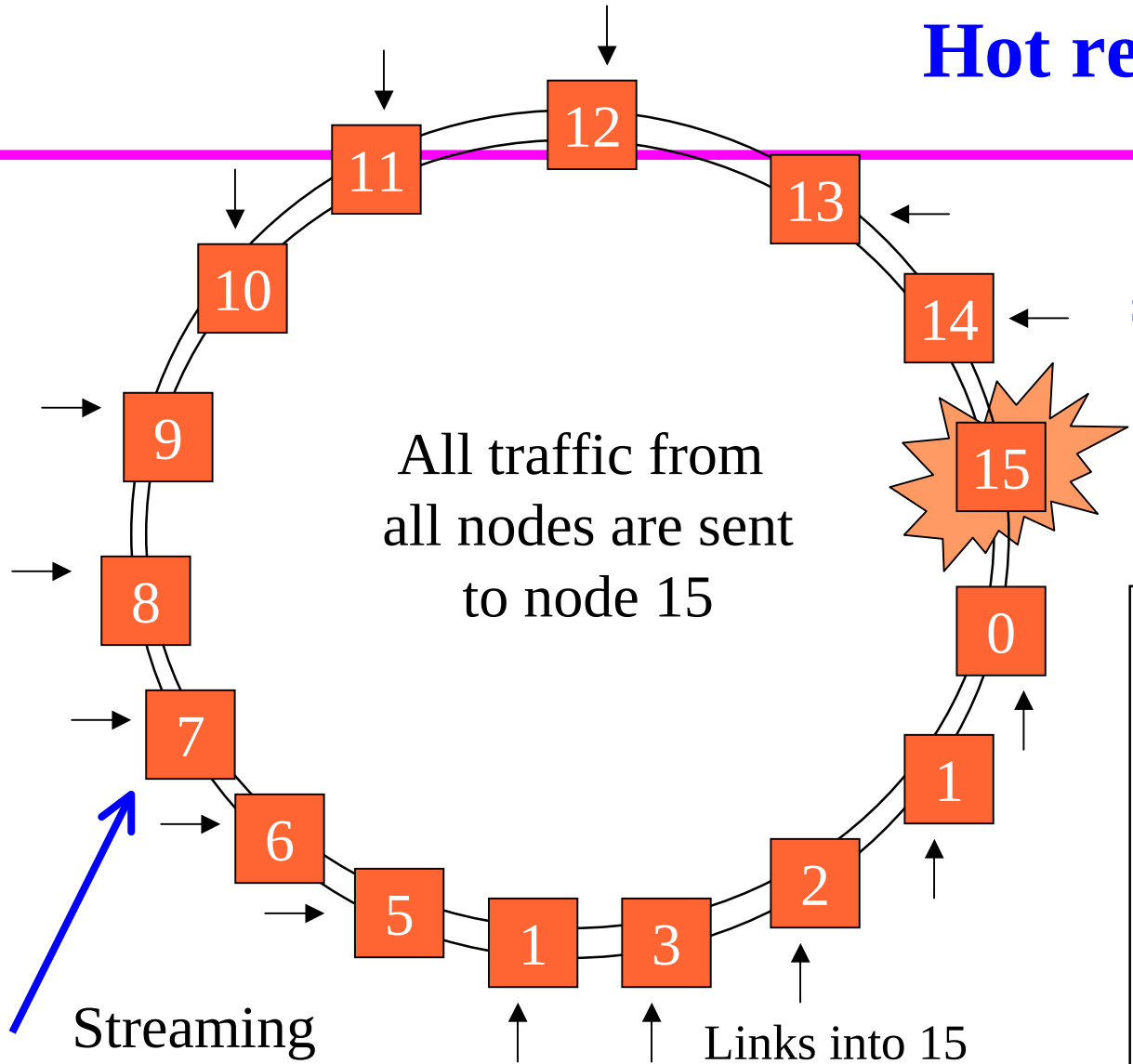
between all nodes.

30% bandwidth
- provisoned
- small high prio.

70% bandwidth
- overloaded,
- large low prio.

Simulation Scenario - B

Hot receiver



Only traffic streamed from 7 to 15 are logged

15 is hot receiver

30% bandwidth provisoned small high prio.

70% bandwidth large, low prio.

Last link to 15 almost fully used

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

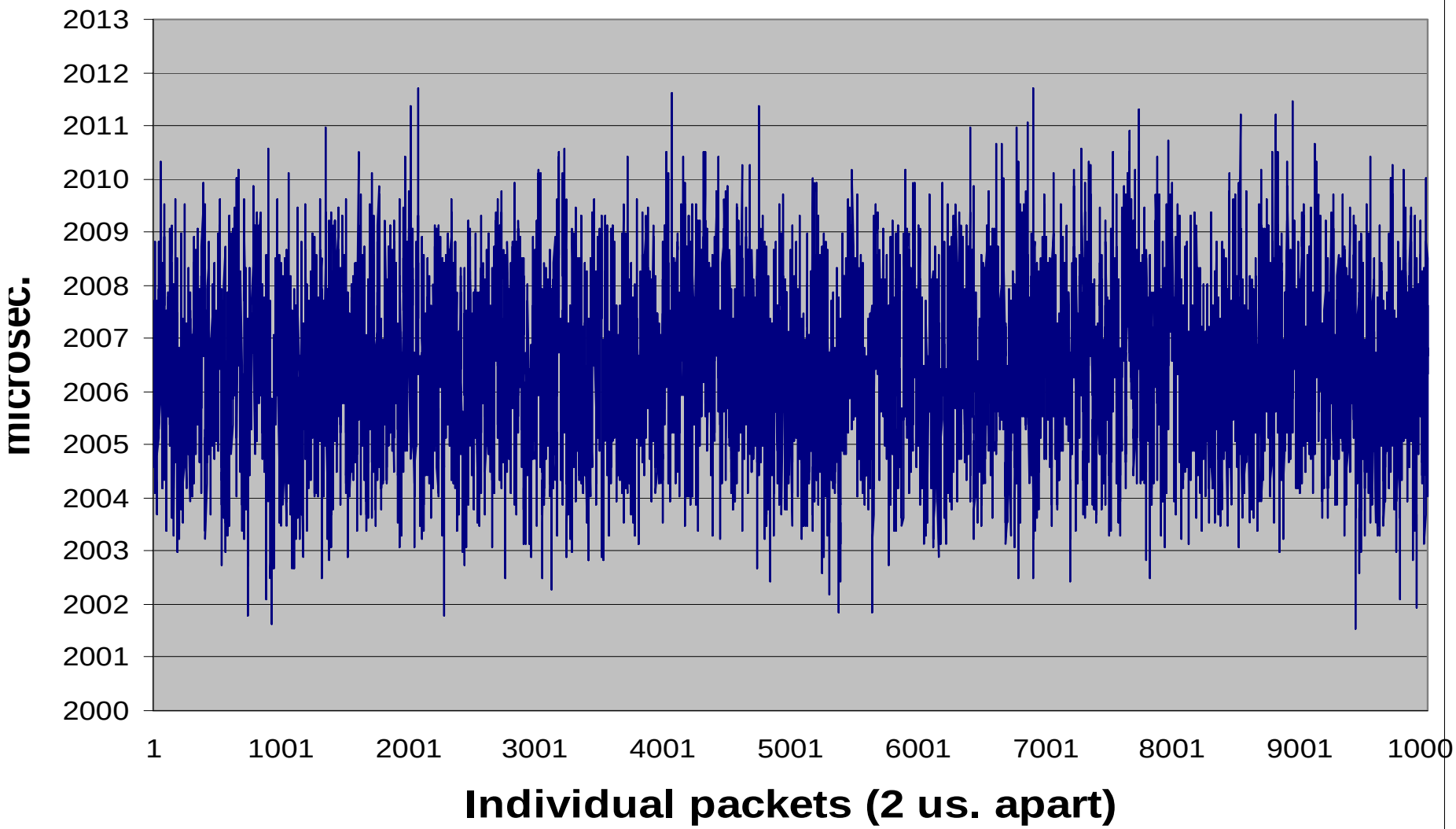
  A3. 16K jumbo packets with preemption (1/2 K)

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

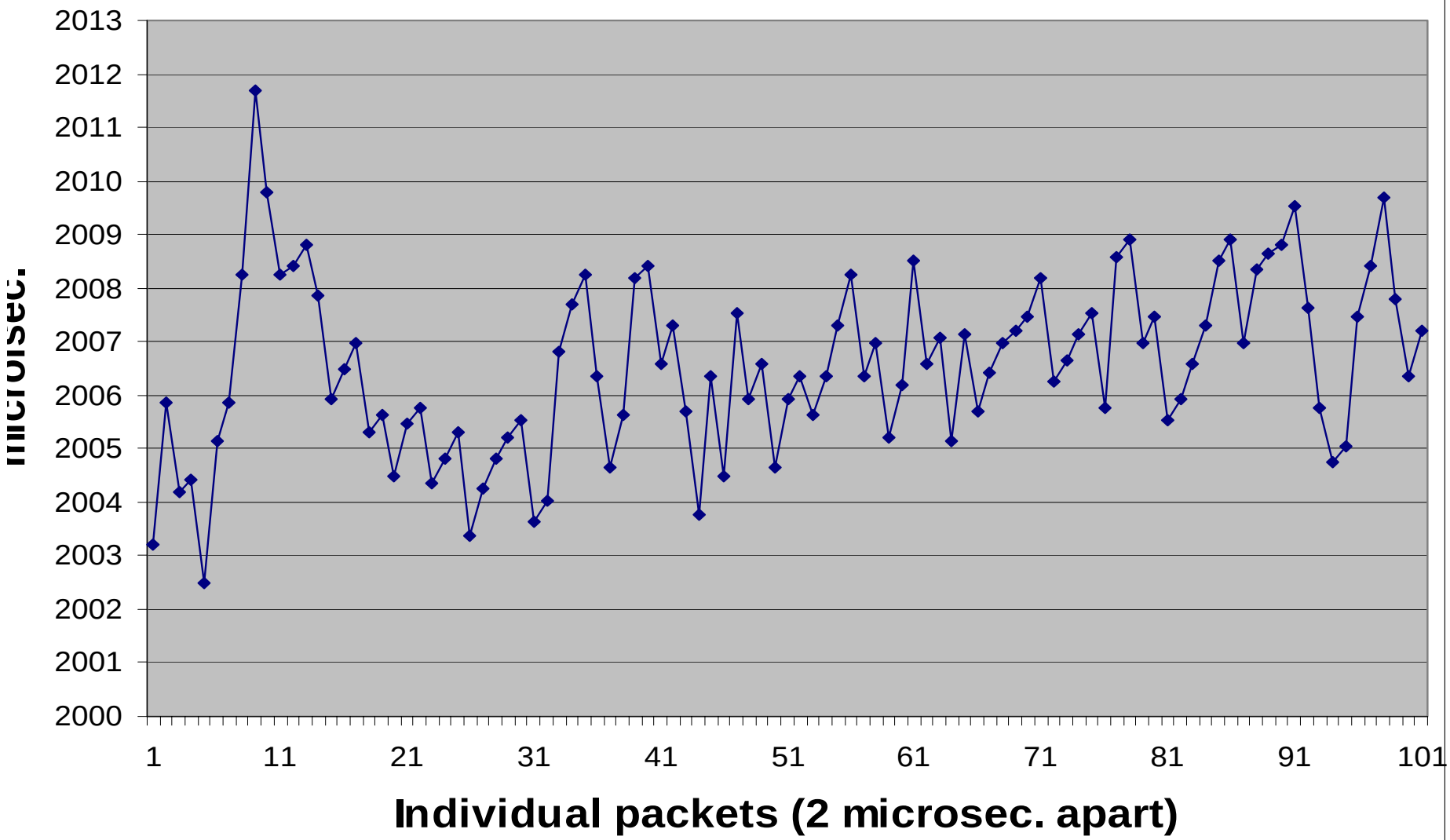
A1. Latency

Streaming high prio. small packets 8 hops (400 km., 2ms.)
with random overloaded ”IP-packets” (1600 byte) background



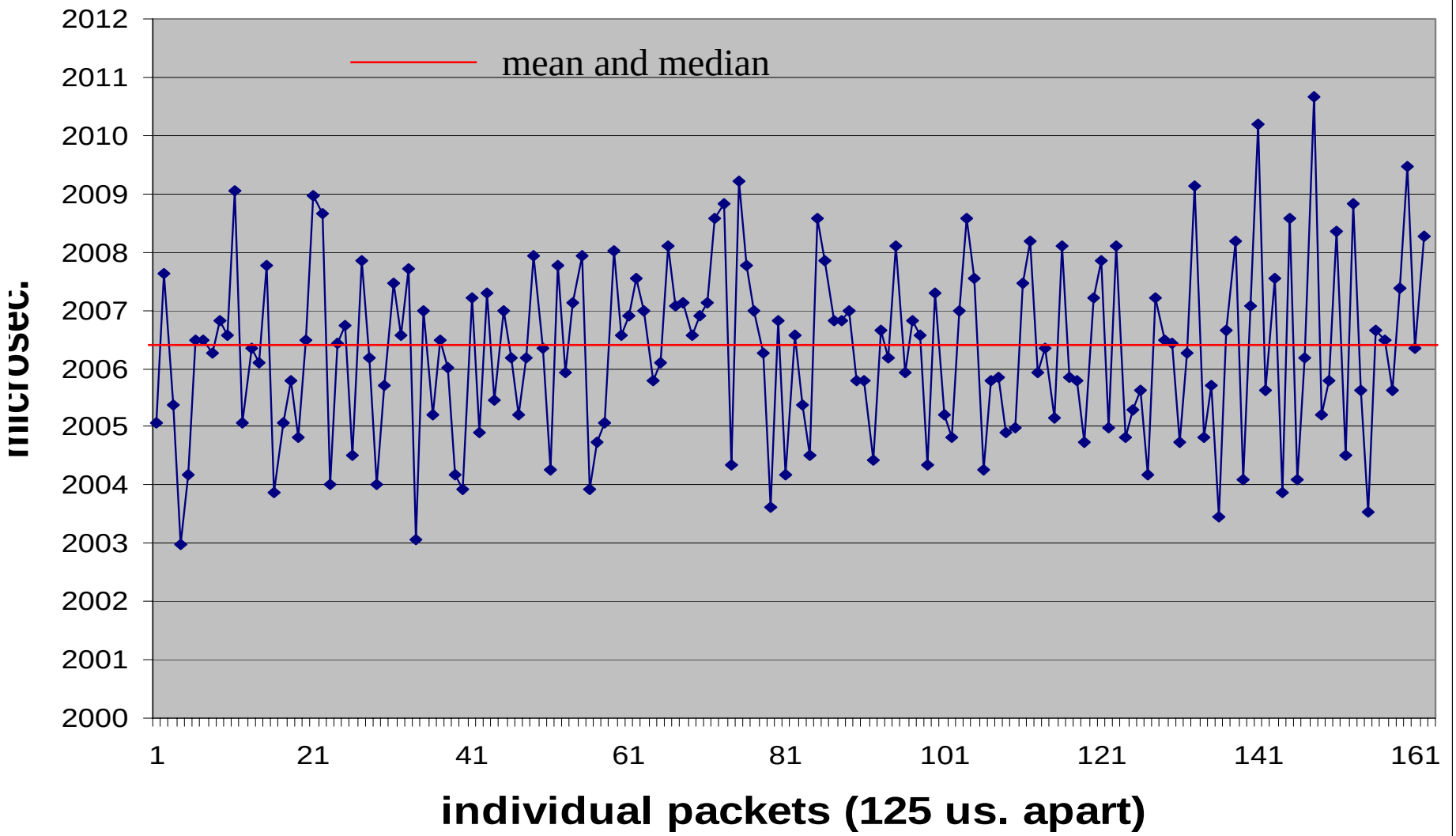
A1. Latency

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

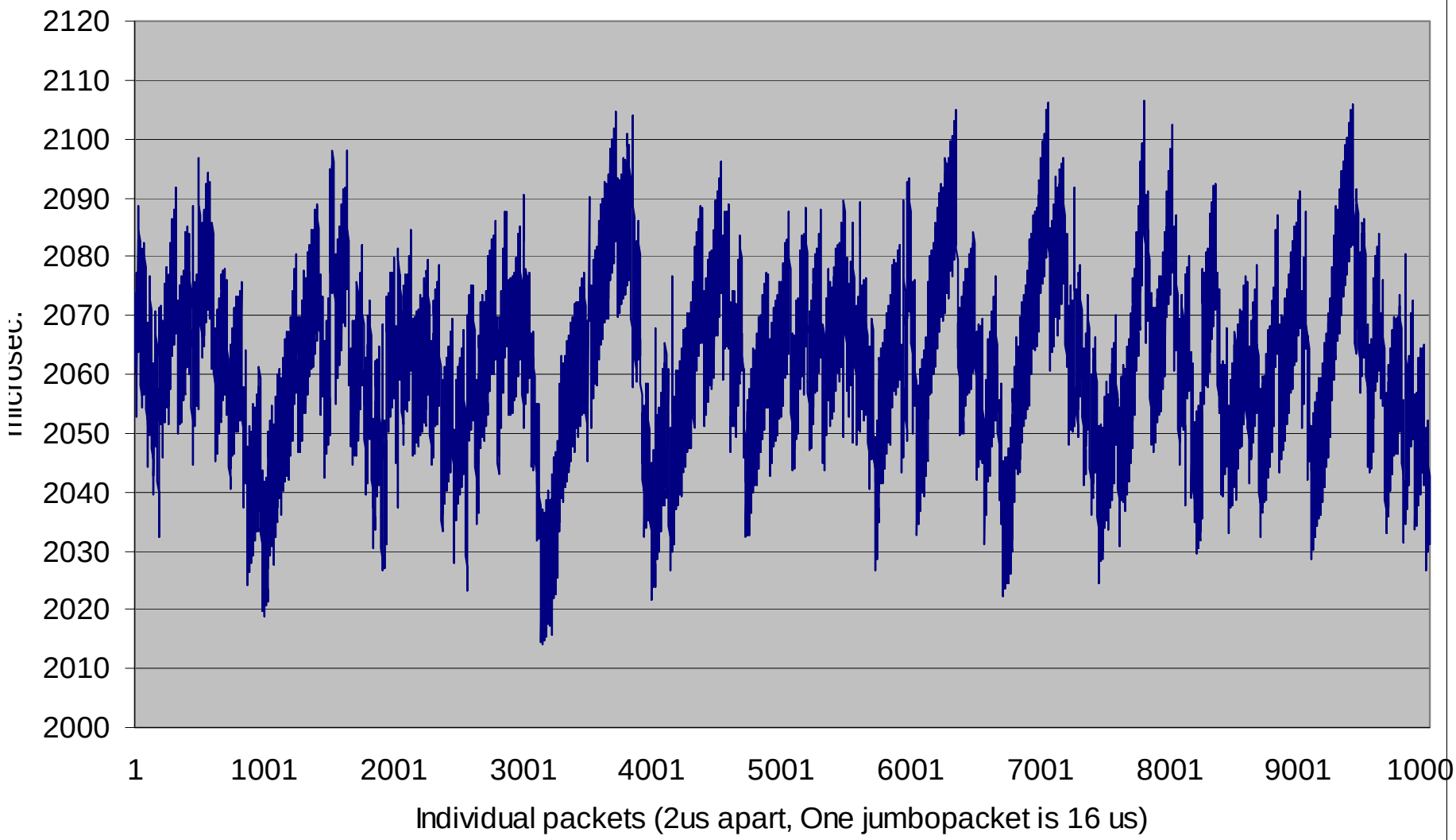
- Added latency between 2 and 12 us.
  (going 8 hops, 400 km., 2 ms.)
- Theoretically added latency between 0 and 13us.
- Max 11.7 us. Min. 1.5 us. added latency
- 0.1 %: more than 11us. added latency
- 1%: more than 10us. added latency
- Mean and median is 6.4 us. added latency
- Max jitter almost as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

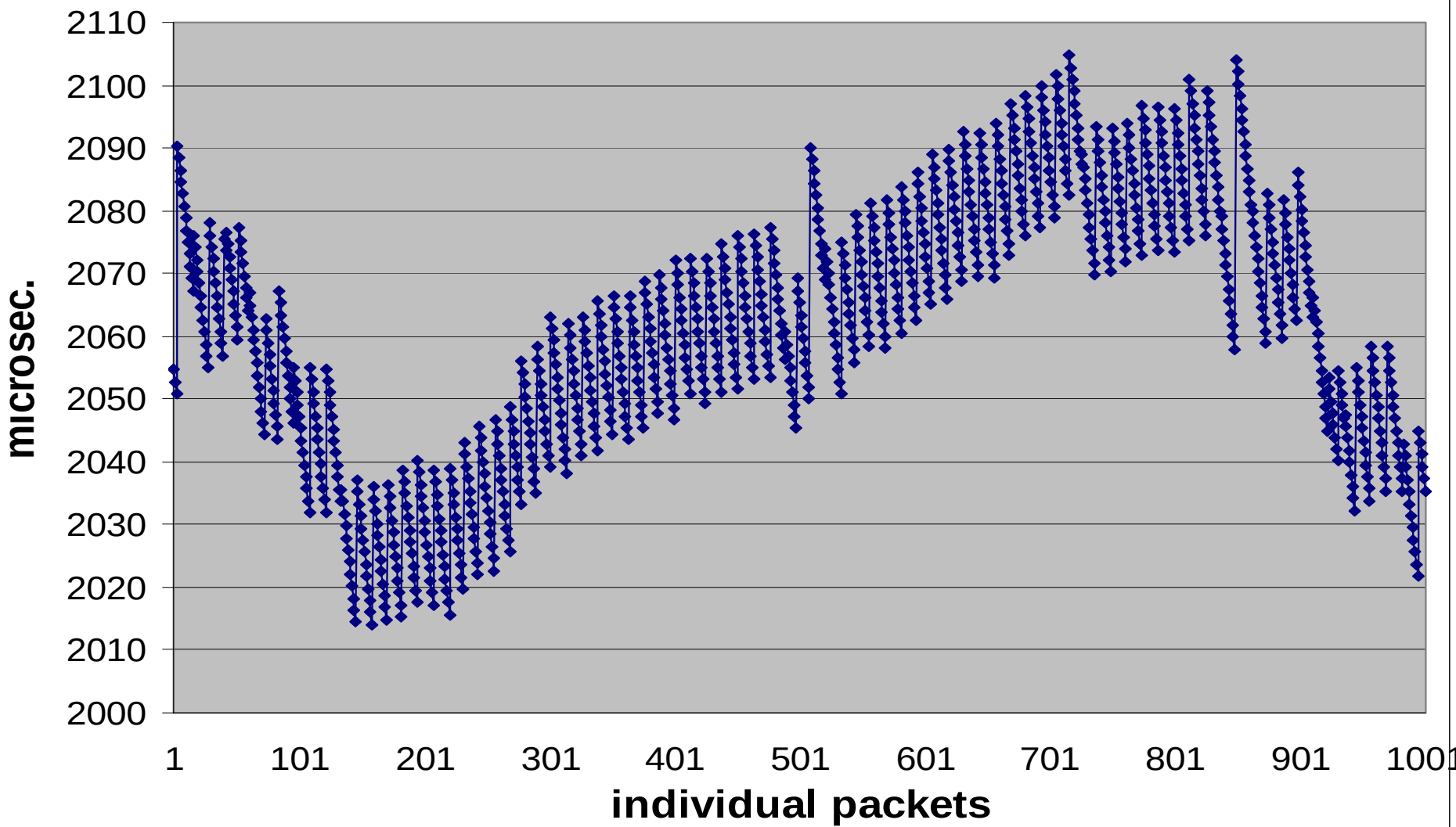
A2. Latency

Streaming small high prio. packets 8 hops (400 km., 2 ms.)
with random overloaded Jumbo-packets (16K) background



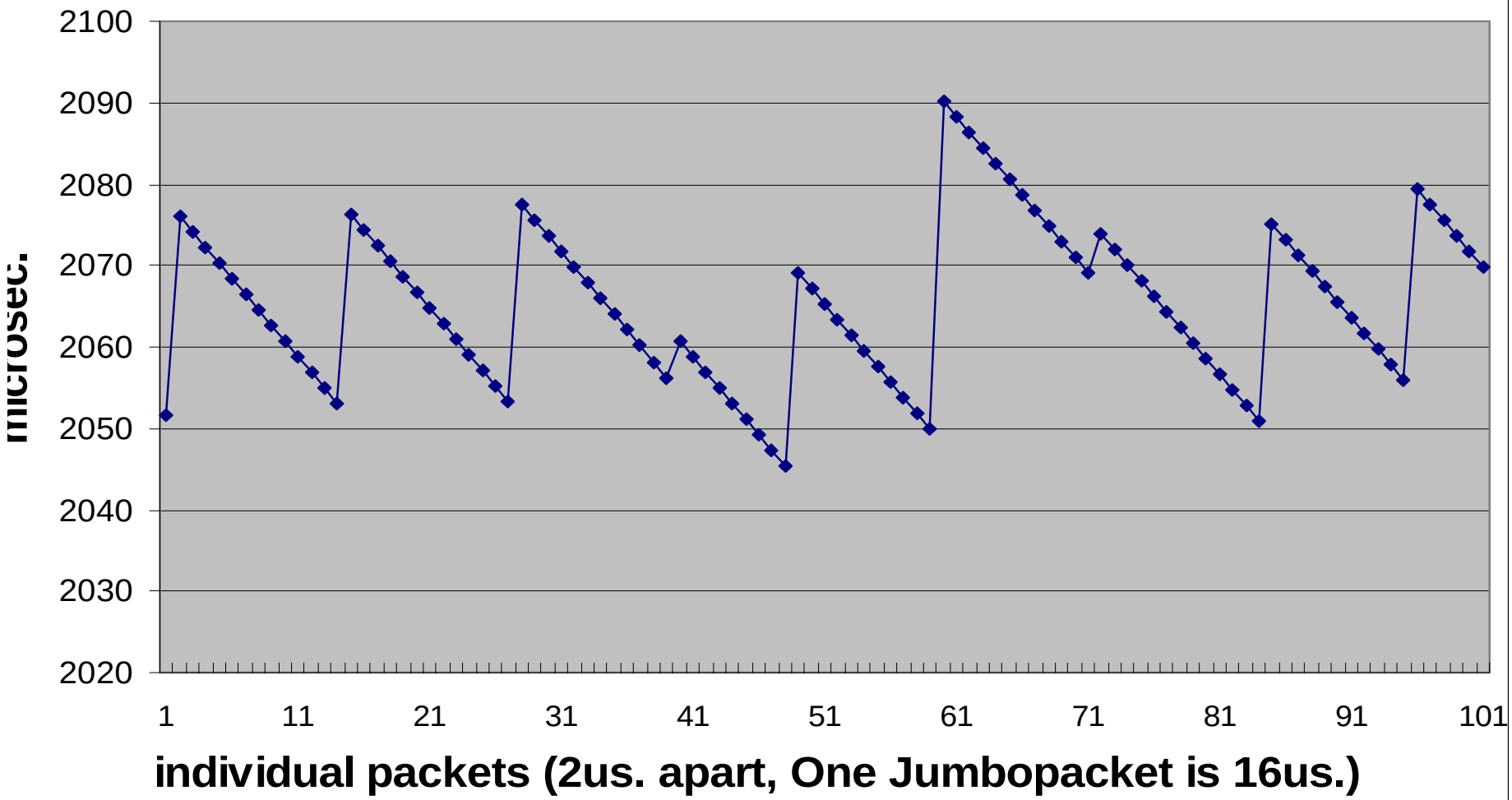
A2. Latency

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



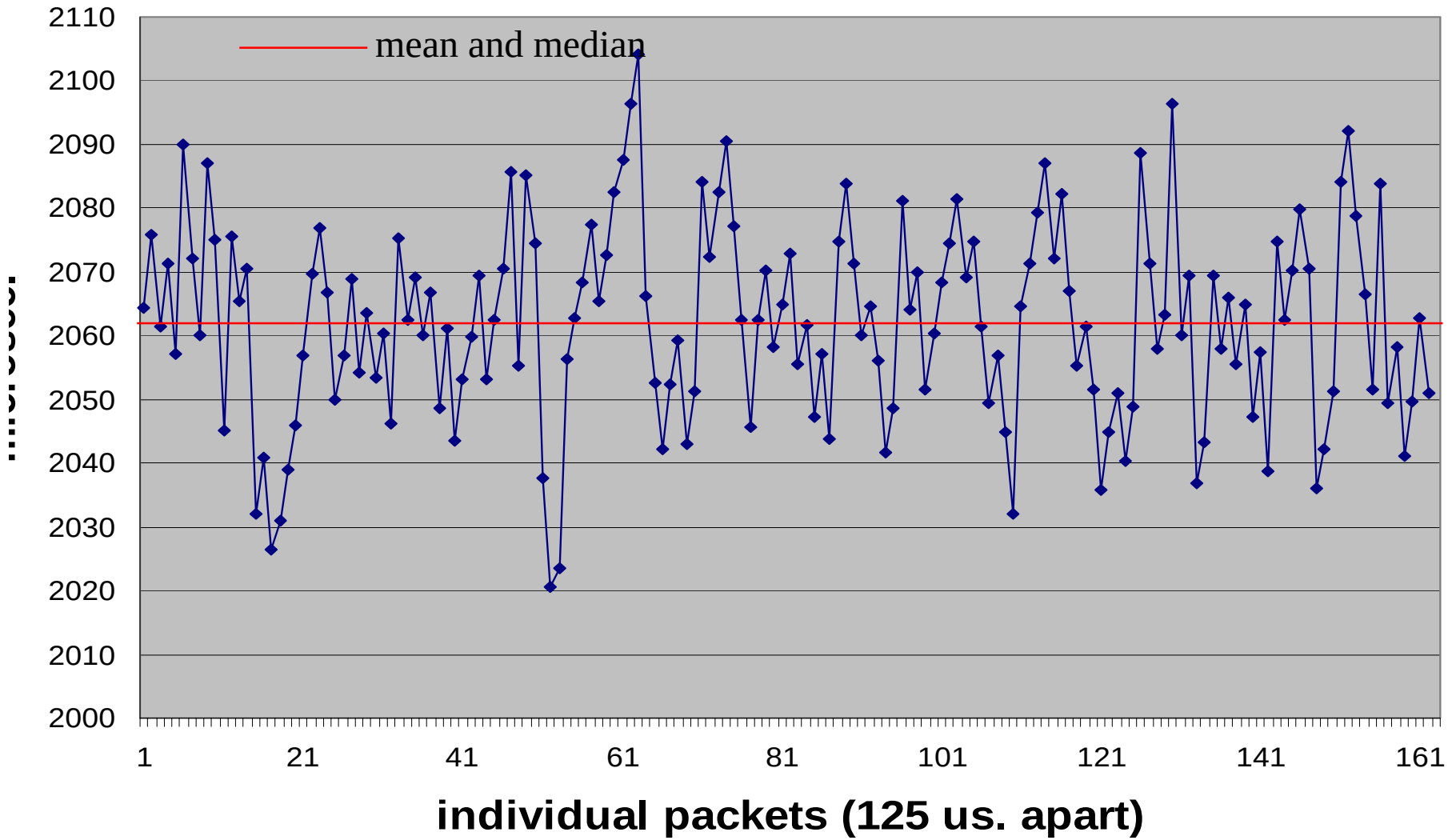
A2. Latency

Streaming small high prio. packets 8 hops with random overloaded Jumbo-packets (16K) background (more details)



A2. Latency

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



A2. Conclusion: Streaming small high prio. packets with Jumbo packets overloaded background

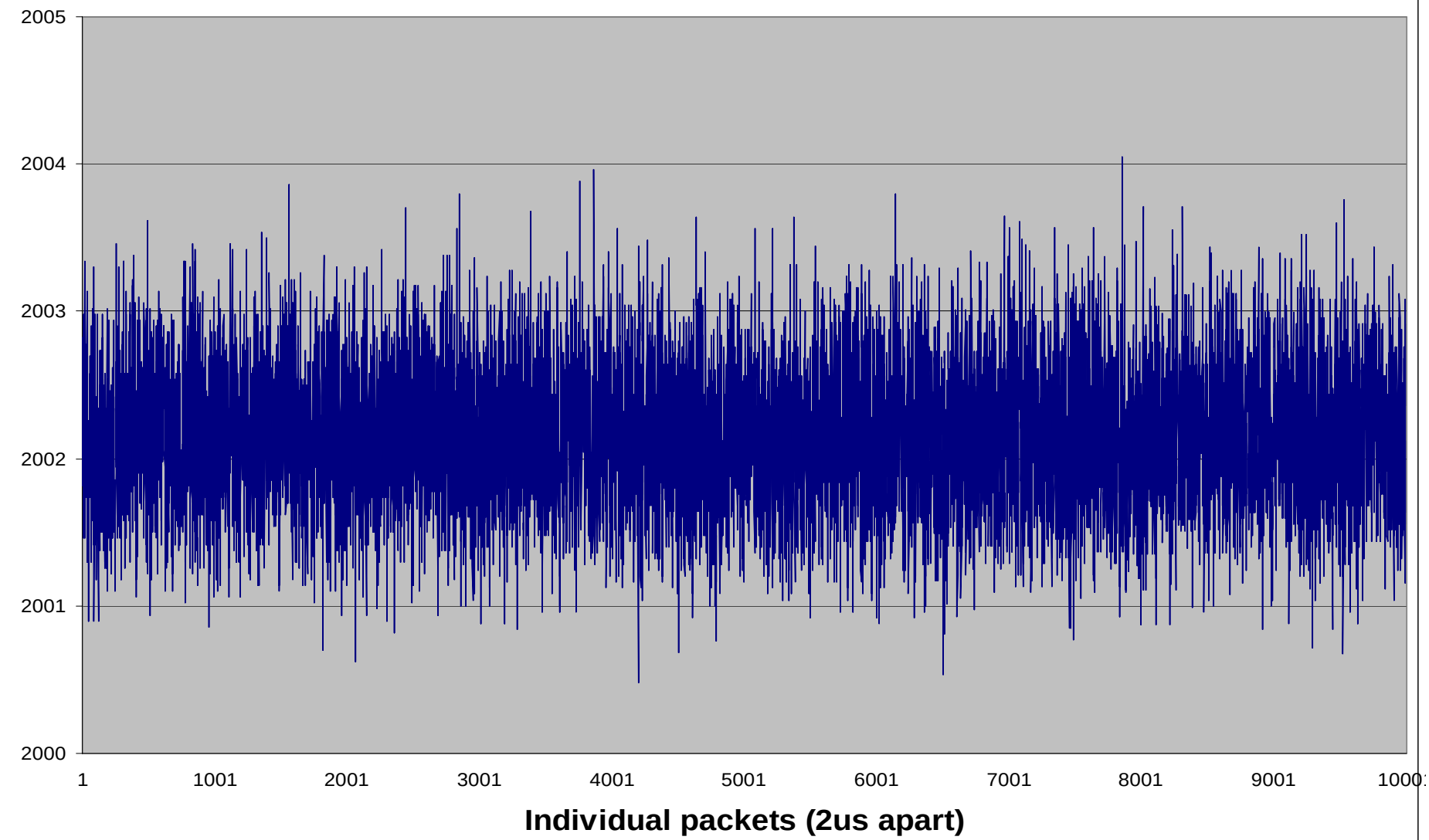
- Added latency between 20 and 100 us.
- Theoretically between 0 and 128 us.
- Min: 14 us. Max: 106.5 us.
- 0.1 % larger than 104 us.
- 1% larger than 96.2 us.
- 10% larger than 81.4 us.
- Mean and median: 62 us.
- Max jitter about half of total latency variation

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

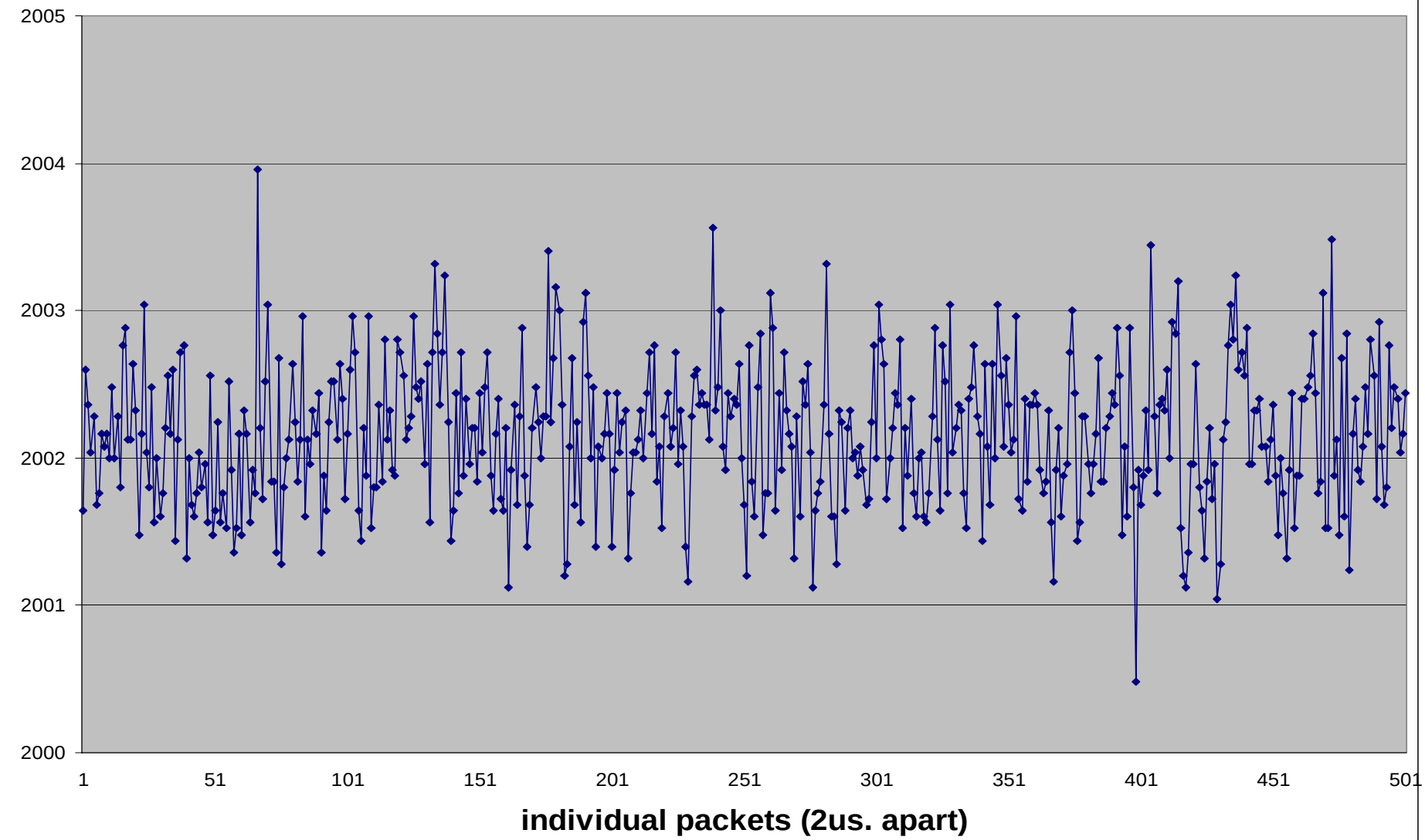
A3. Latency

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



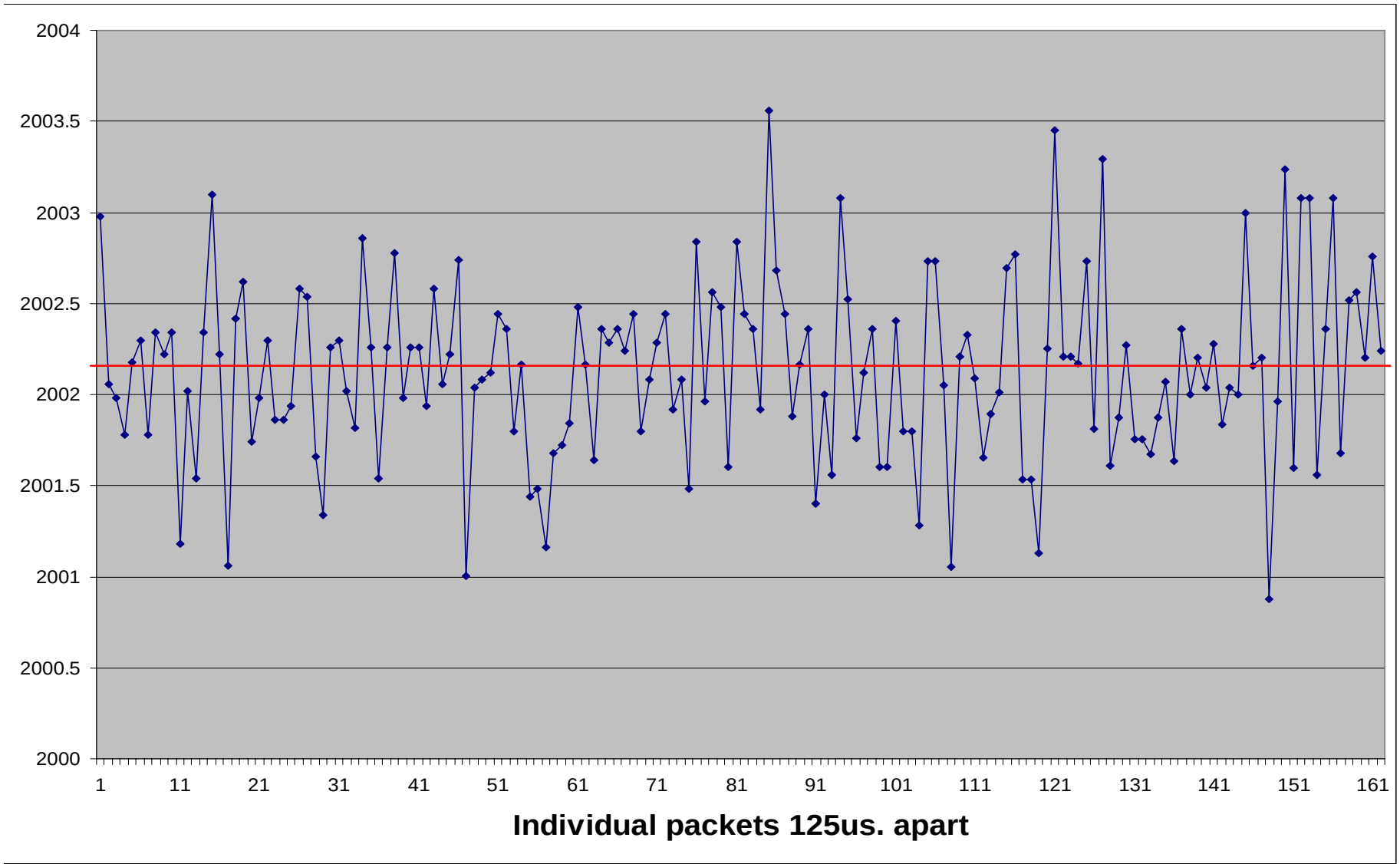
A3. Latency

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

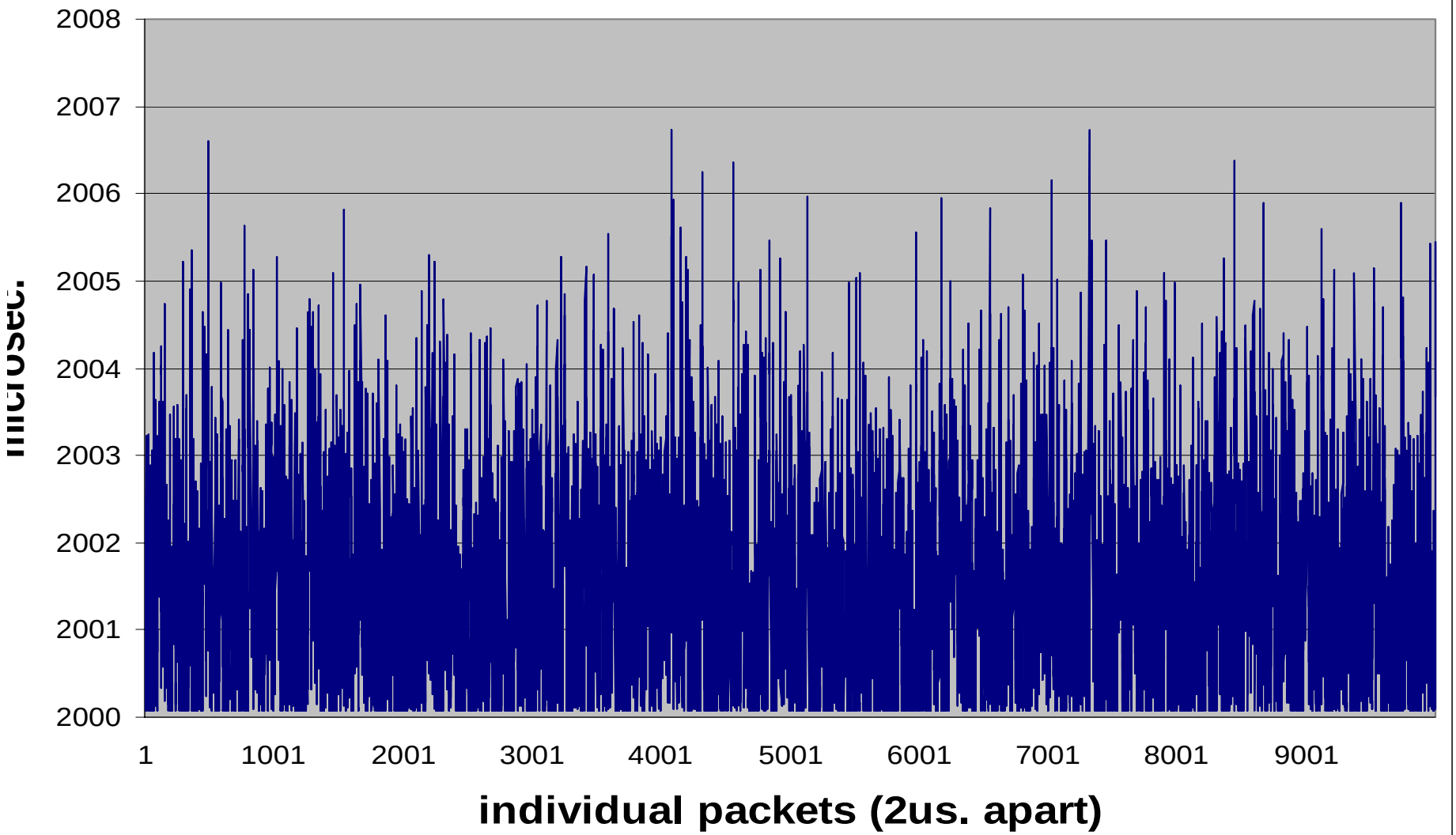
- Traffic from all nodes to hot receiver, node 15
  Last links to receiver is almost fully utilized
  (but can be different in the three cases B1, B2 and B3)
- Measuring high priority stream from 7 to 15
  with 2 us. or 125 us between packets
- Background is
  30% high prio 80 bytes packets (provisioned) 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

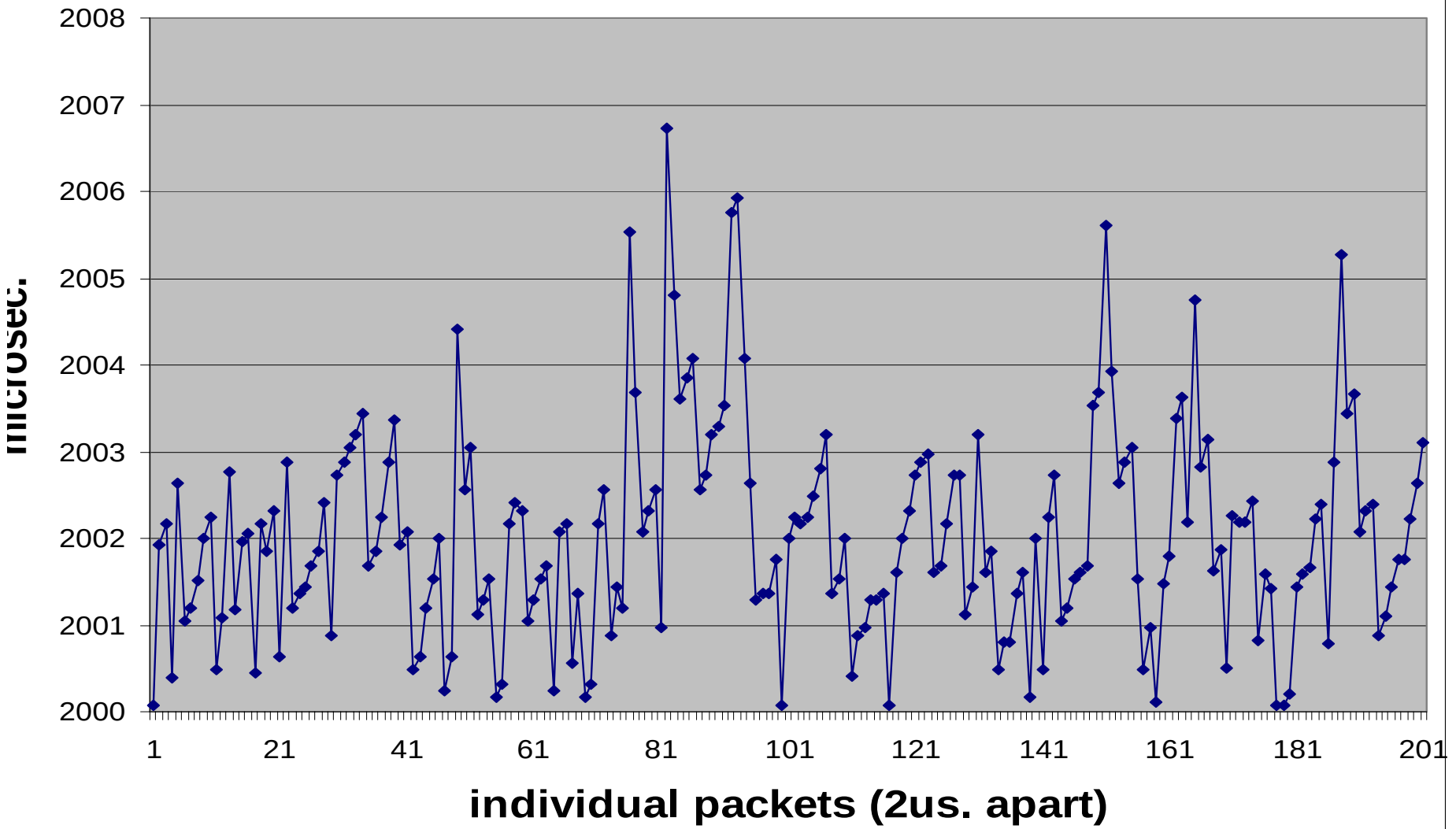
Streaming high prio. small packets 8 hops (400 km., 2ms.)
with hot receiver ”IP-packets” (1600 byte) background



B1. Latency

Streaming small packets 8 hops (2ms.)

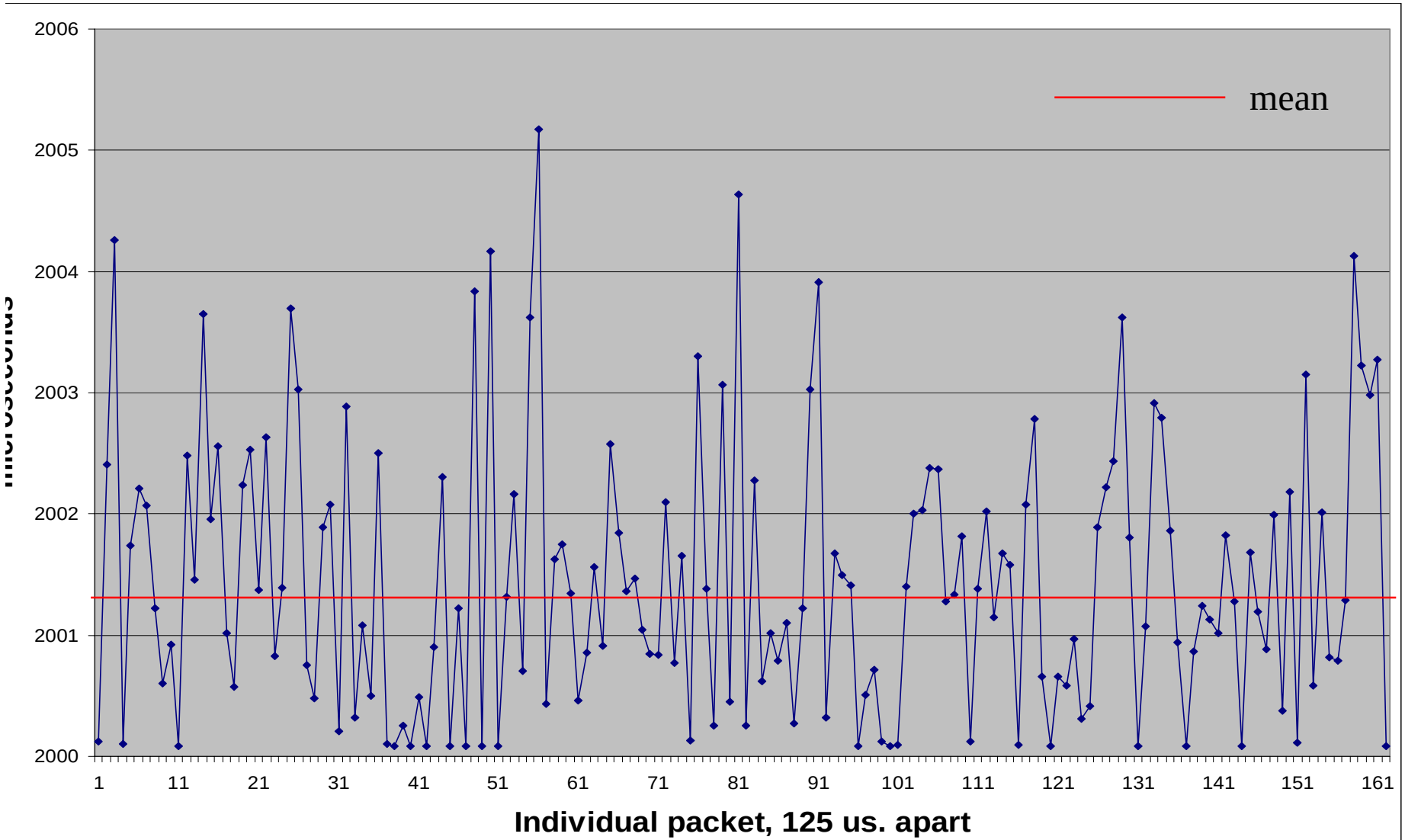
Hot receiver . ”IP-packets” background (details)



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

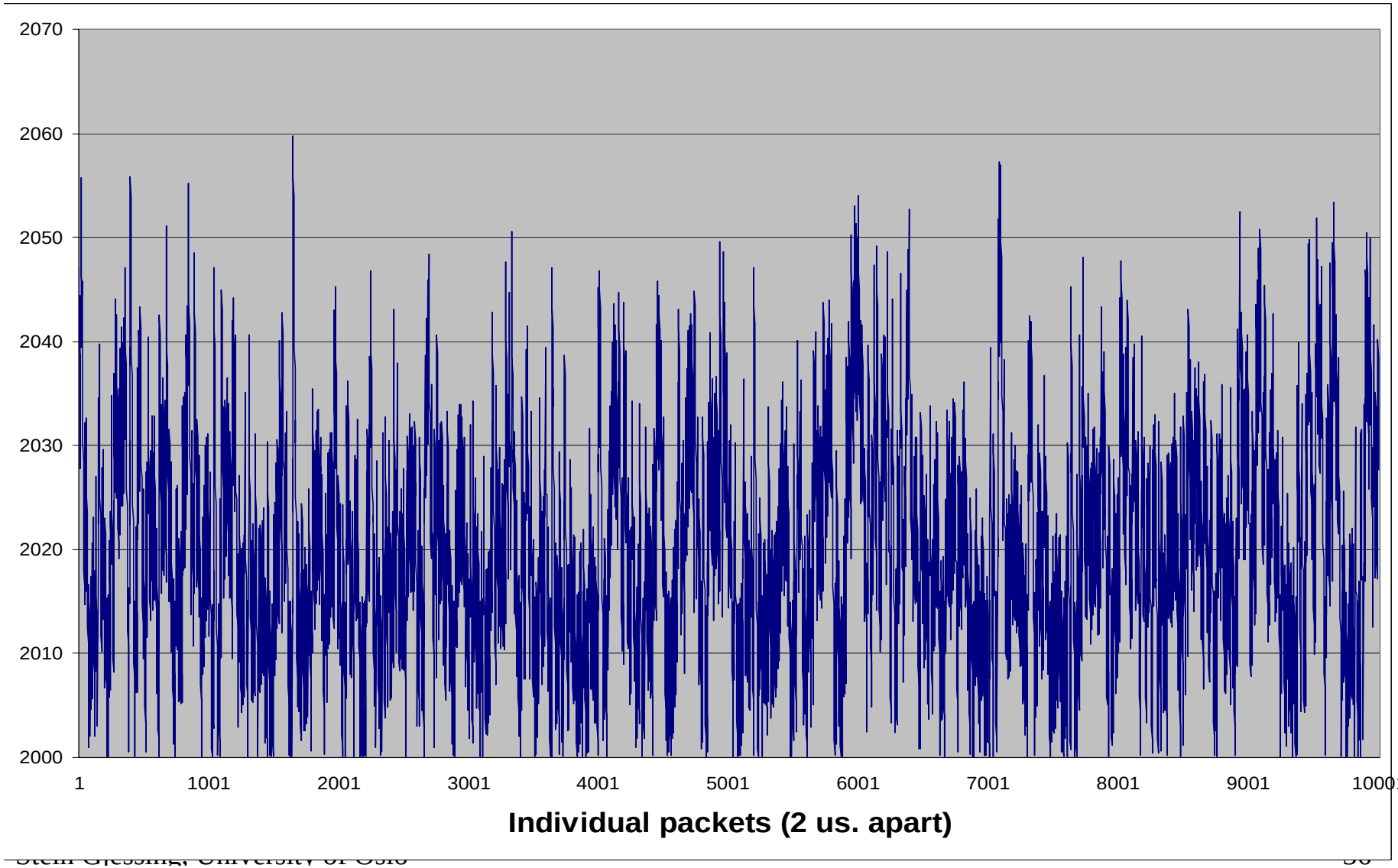
- This is not a fully overloaded system
- Added latency between 0 and 6.5 us.
- Theoretically between 0 and 13 us.
- Max observed added latency is 6.74 us.
- 0.1% added latency greater than 5.9 us.
- 1% aded latency greater than 4.6 us.
- Median 1.36 us. Mean 1.47us.
- 10% went through with no added 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

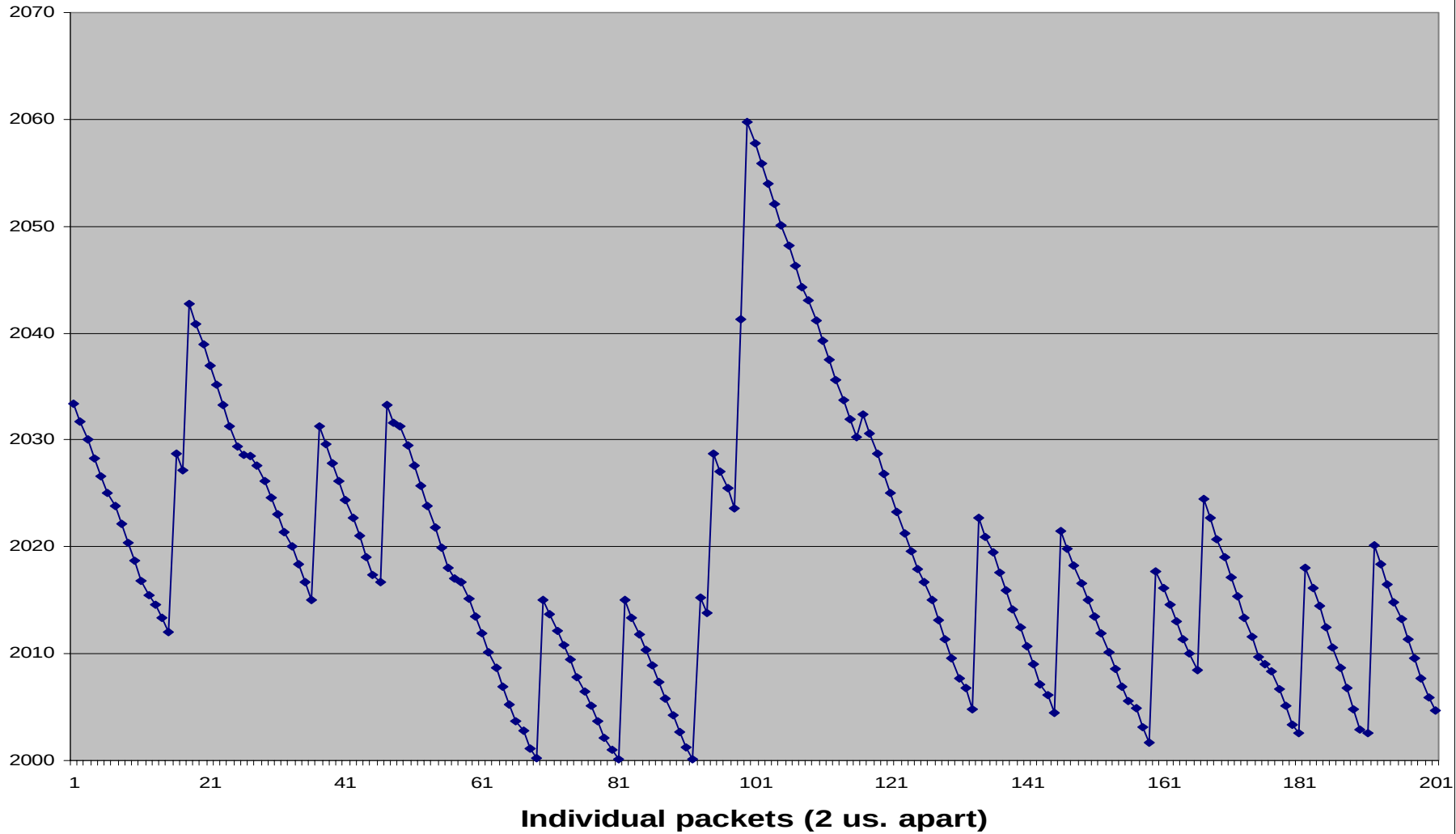
B2. Latency

Streaming high prio. small packets 8 hops (400 km., 2ms.)
with hot receiver Jumbo packets (16K byte) background



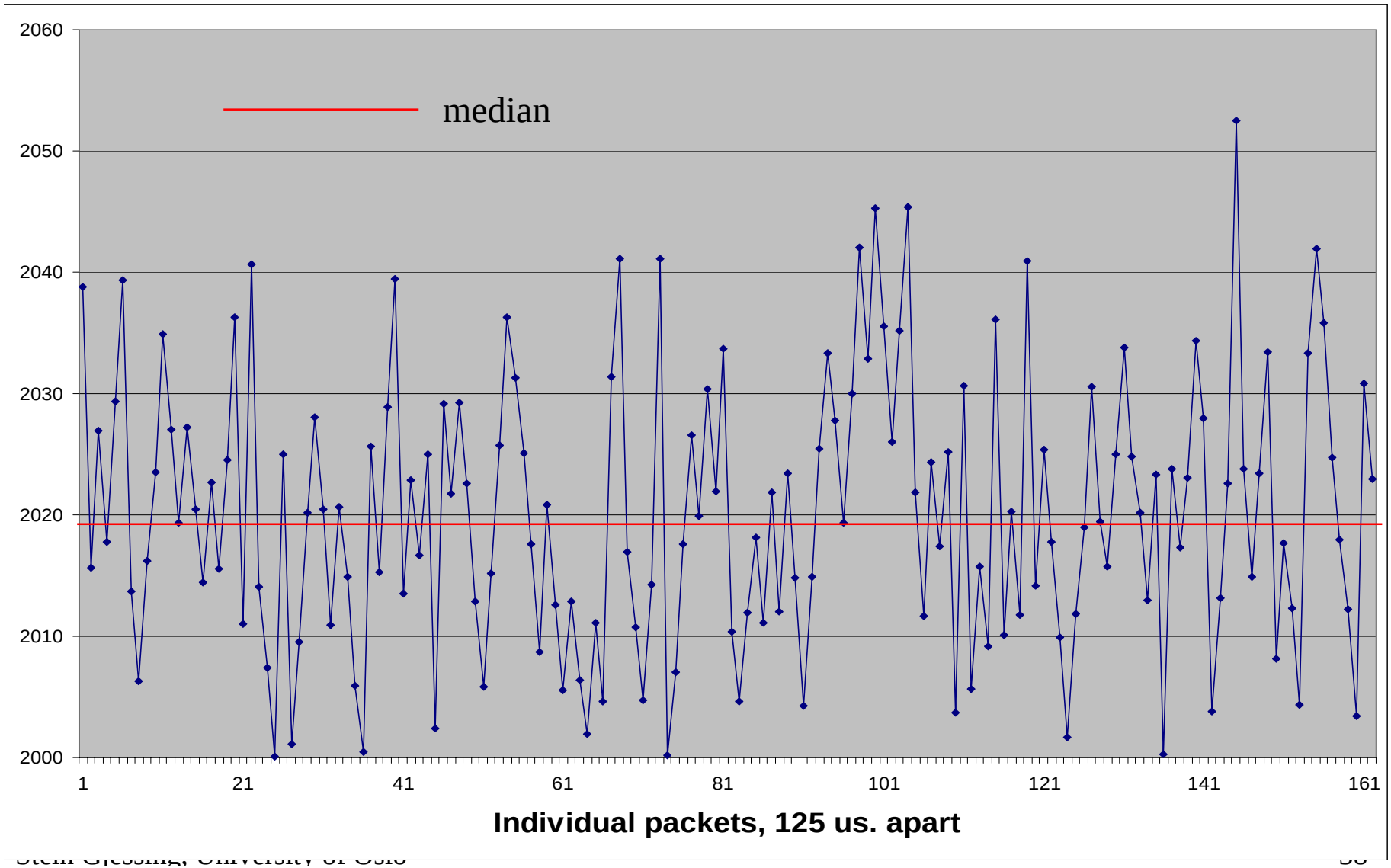
B2. Latency

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

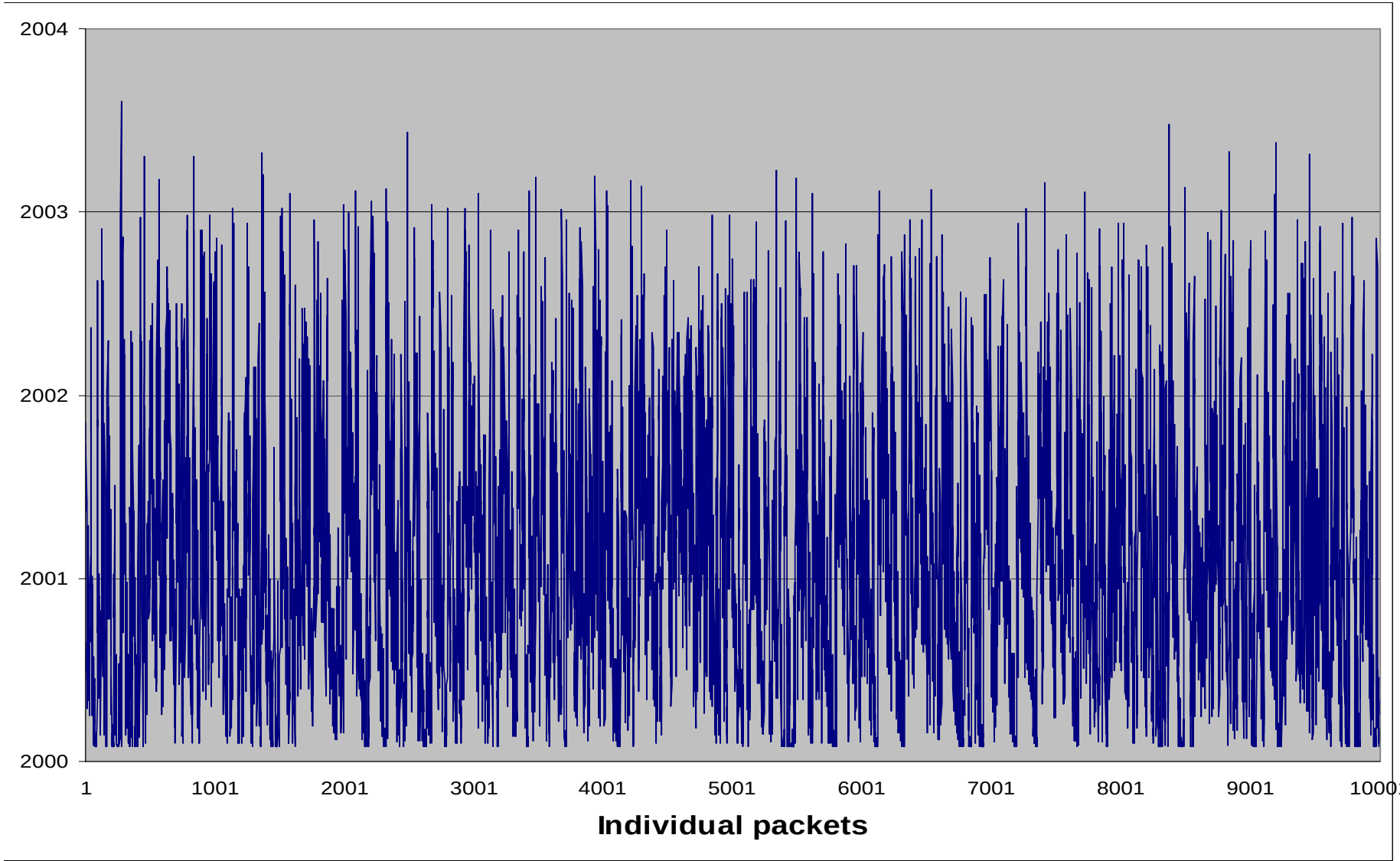
- This is not a fully overloaded system
- Added latency between 0 and 55 us.
- Theoretically between 0 and 128 us.
- Max observed added latency is 59.7 us.
- 0.1% added latency greater than 55 us.
- 1% added latency greater than 47 us.
- Median 18.8 us. Mean 19.9 us.
- 1% went through with no added latency
- 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

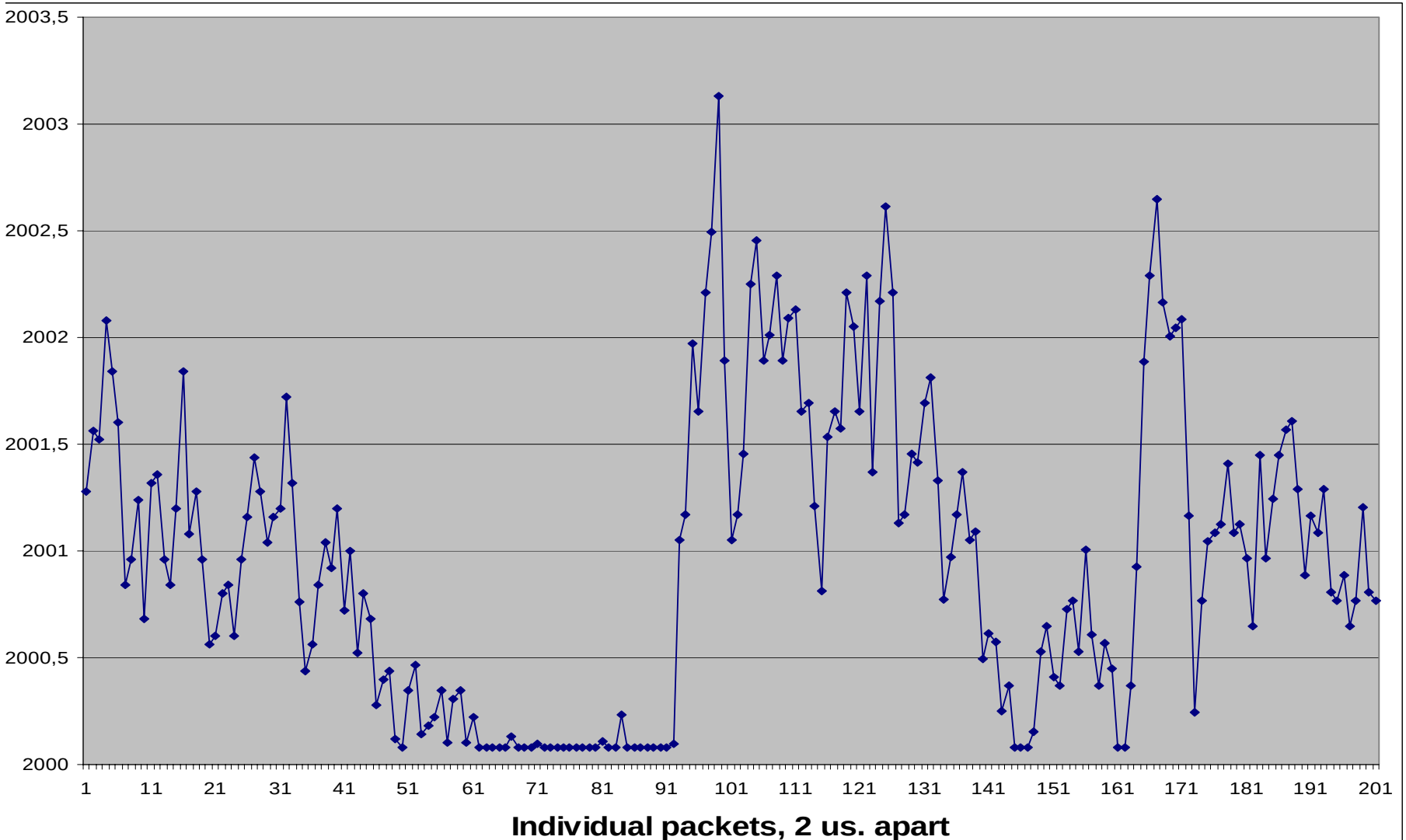
Streaming high prio. small packets 8 hops (400 km., 2ms.)
with hot receiver Preemptive (½ K) Jumbo packets background



B3. Latency

Streaming high prio. small packets 8 hops with hot receiver

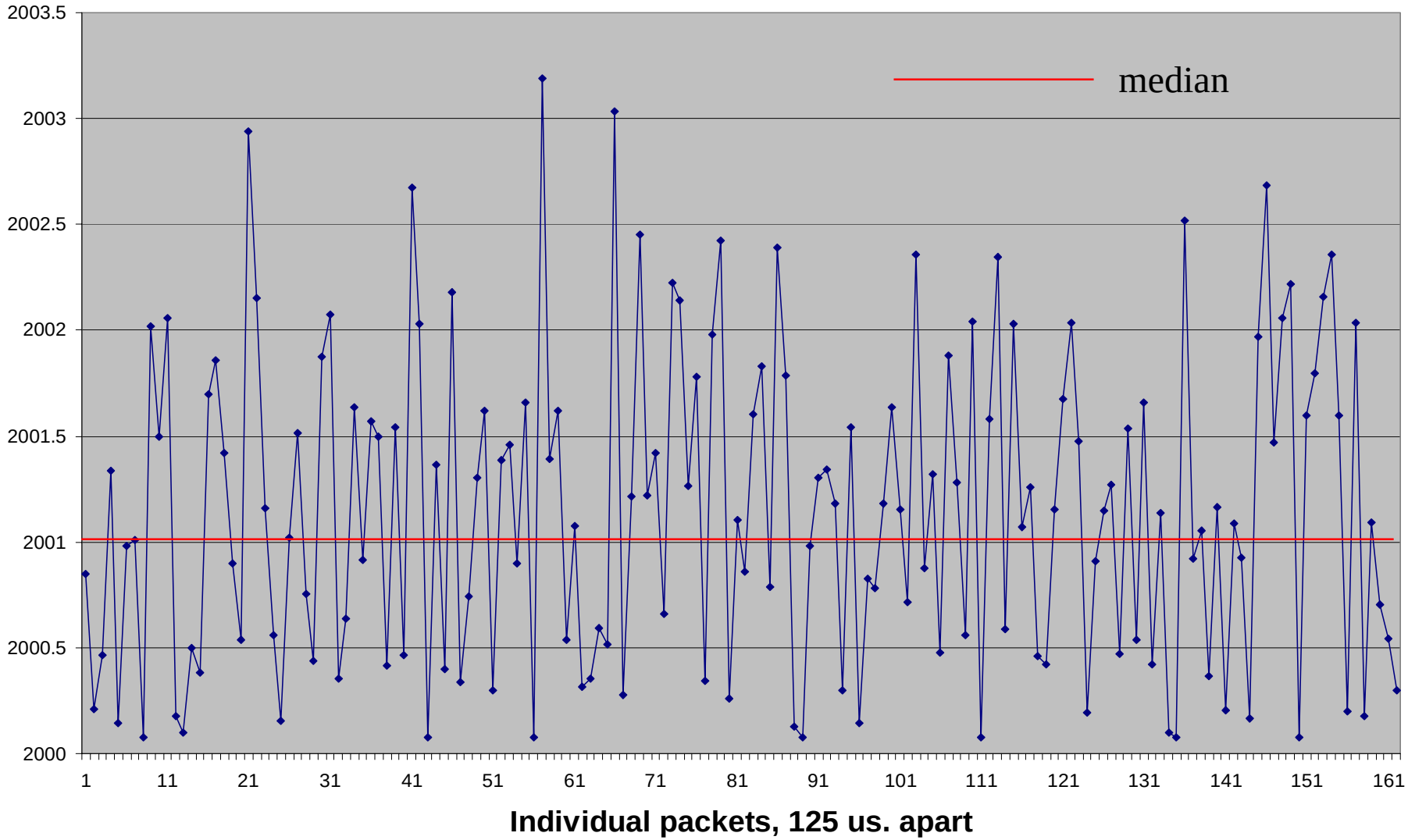
Preemptive (½ K) Jumbo packets background (Details)



B3. Latency

Streaming high prio. small packets 8 hops with hot receiver

Preemptive (½ K) Jumbo packets background 125 us. stream



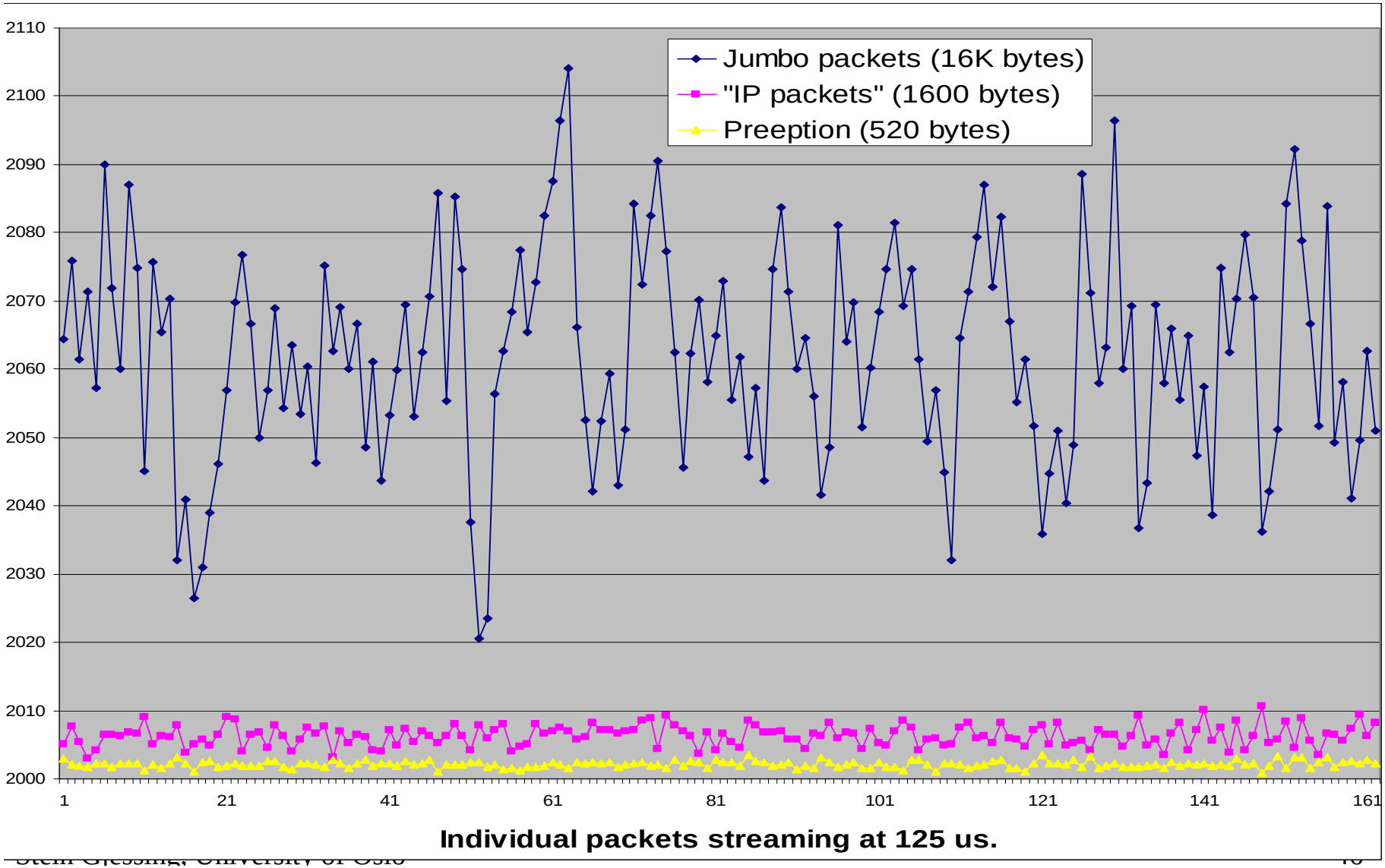
B3. Conclusion: Streaming small high prio. packets with Hot receiver and Preemptive Jumbo packets

- 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

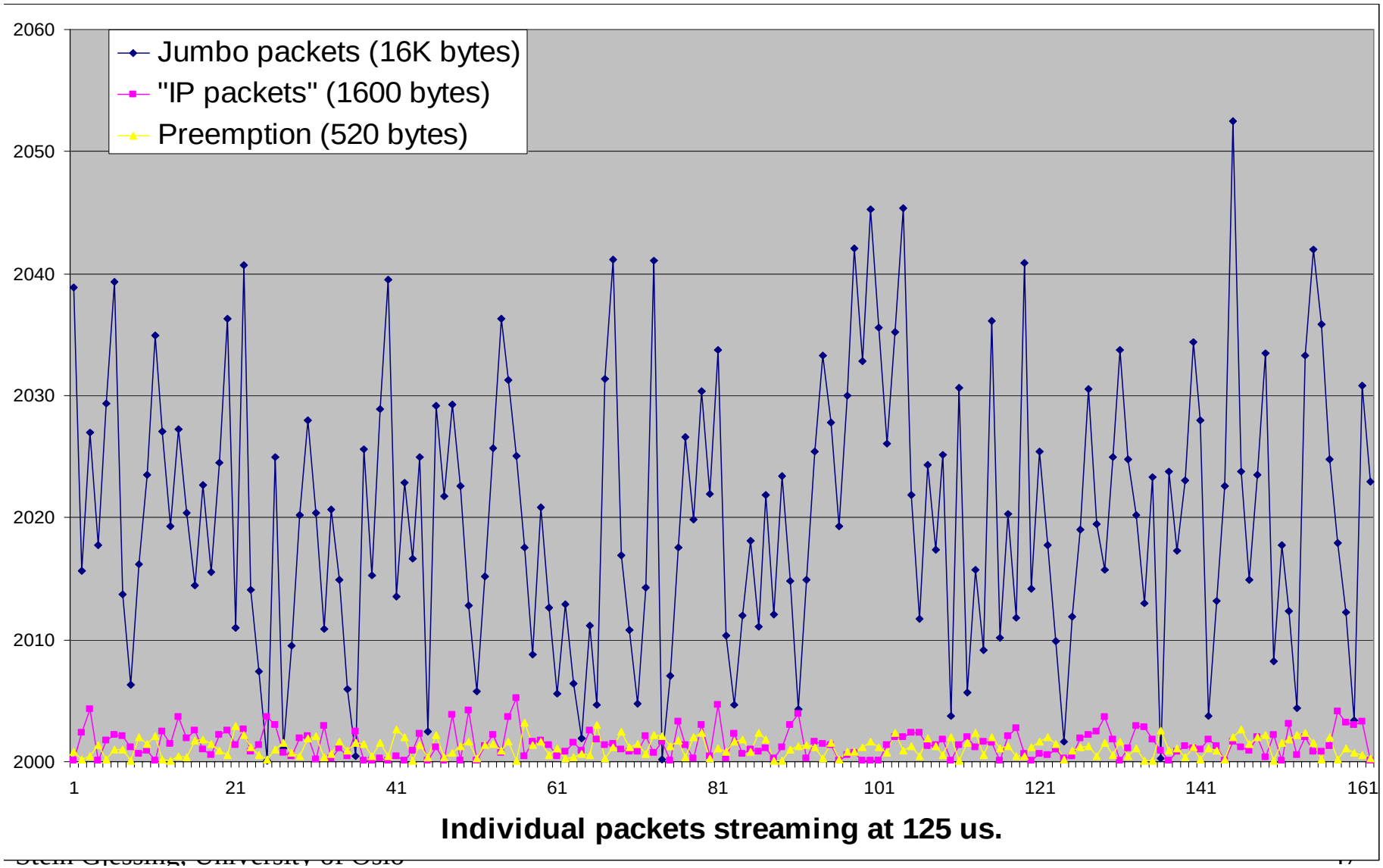
Overall conclusion

- 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)



Overall Conclusion – 10Gbit/sec system

- 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