

Delay and Delay Variation Measurements in a Differentiated Services Test Network

TF-TANT task force

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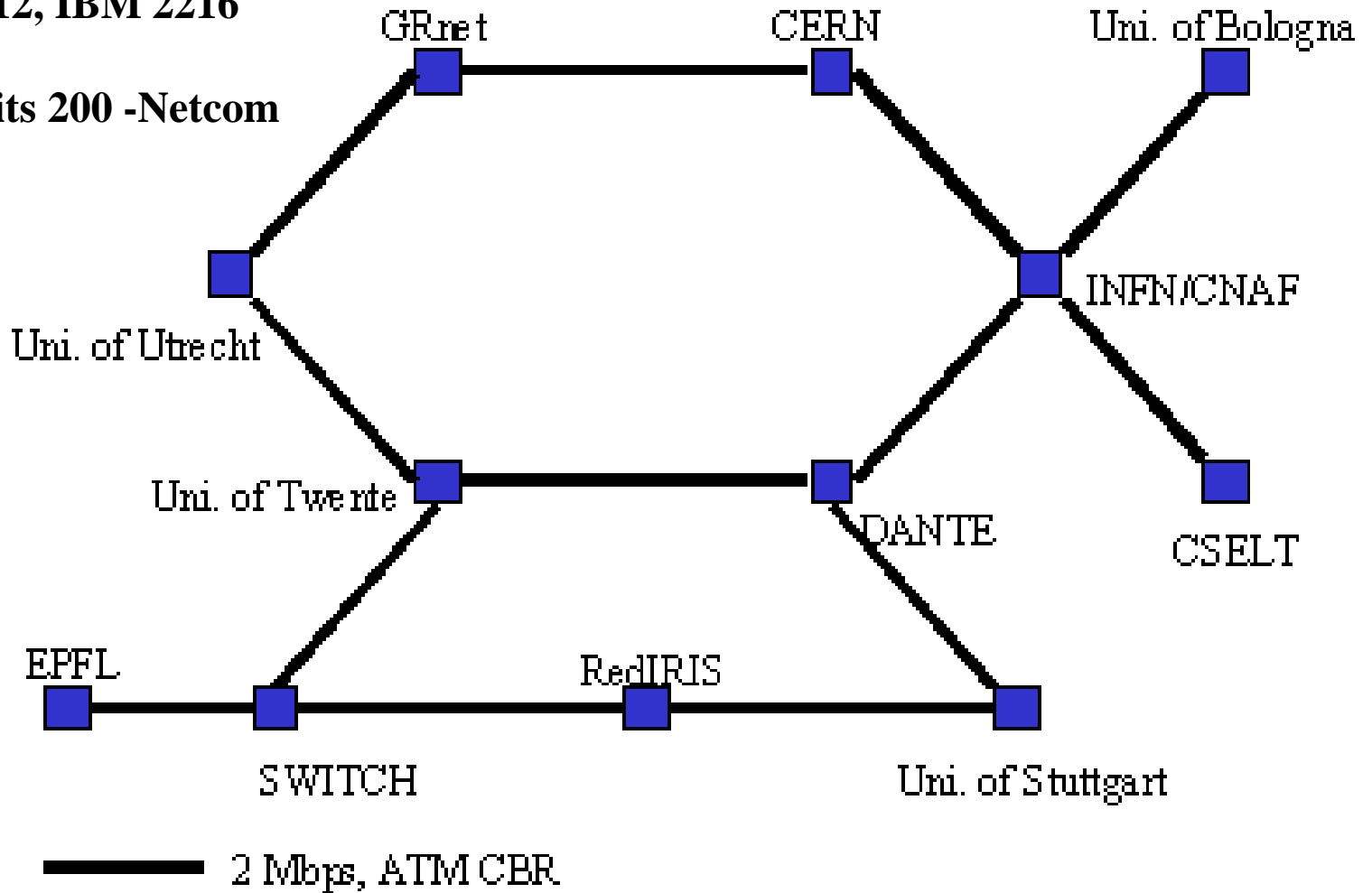
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Overview of diffserv experiments

- Policing: Single- and multi-parameter token buckets with TCP traffic
- traffic metering and packet marking (PHB class selectors)
- scheduling: WFQ, SCFQ, PQ
 - * capacity allocation between queues, class isolation
 - * queue dimensioning (buffer depth and TCP burst tolerance, tx queue)
 - * per-class service rate configuration
 - * one-way delay and instantaneous packet delay variation
- **Assured Forwarding**: PHB differentiation through WRED
 - * throughput performance :
 - > packet drop probability
 - > number of TCP streams per AF PHB
 - > minimum threshold
- **Expedited Forwarding**:
 - * multiple congestion points
 - * multiple EF aggregation points
 - * variable EF aggregated load

Diffserv testbed

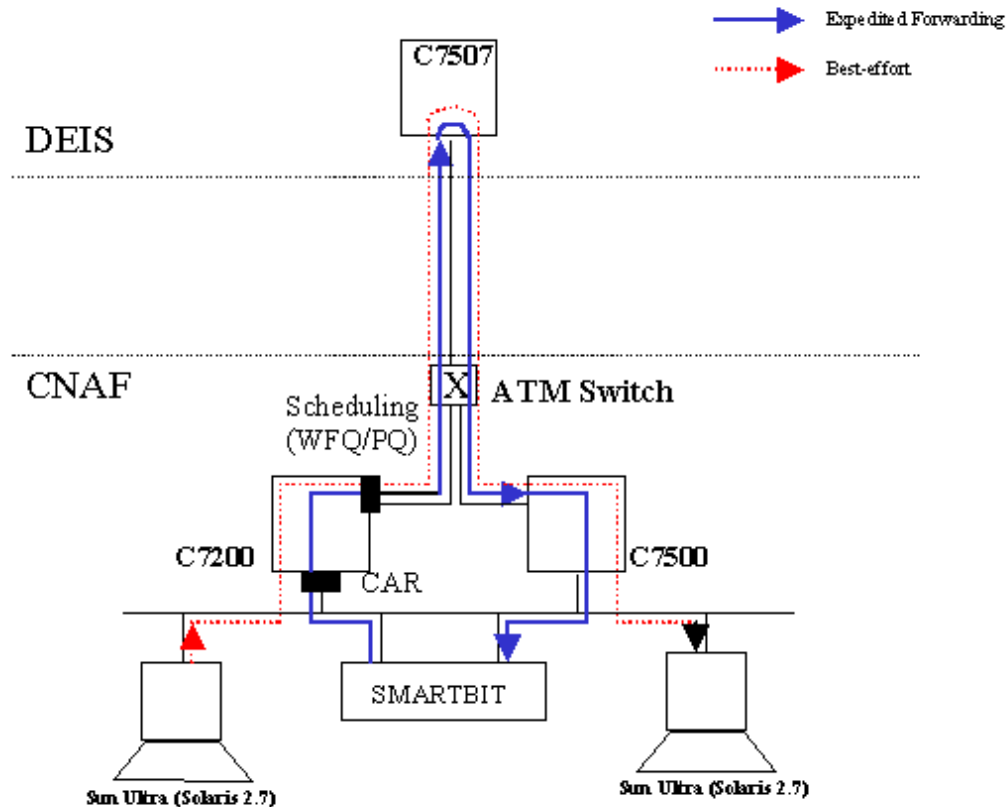
Cabletron Ethernet sw
Cisco 7200, 7500
IBM 2212, IBM 2216
Linux
SmartBits 200 -Netcom



Metrics

- **One-way delay** (RFC 2679): difference between the wire time at which the last bit of a packet was received and the wire time at which the first bit of the packet was sent
 - > cut-through latency + tx time of packet
 - > synchronization, precision: 100 nsec
 - > negligible drift and skew
 - > wire time
- **instantaneous packet delay variation** (IPPM):
 - > based on singleton measurement of Type-P-One-way-ipdv
 - > Type-P-One-way-ipdv-jitter
 - > consecutive packets
- **packet loss percentage**
- sample mean
- variation over time
- frequency distribution

Network configuration 1



Goals: WFQ configuration tuning

- 1 transmission queue (tx queue) size
- 2 EF service rate
- 3 comparison of WFQ and PQ

Tx queue: one-way delay

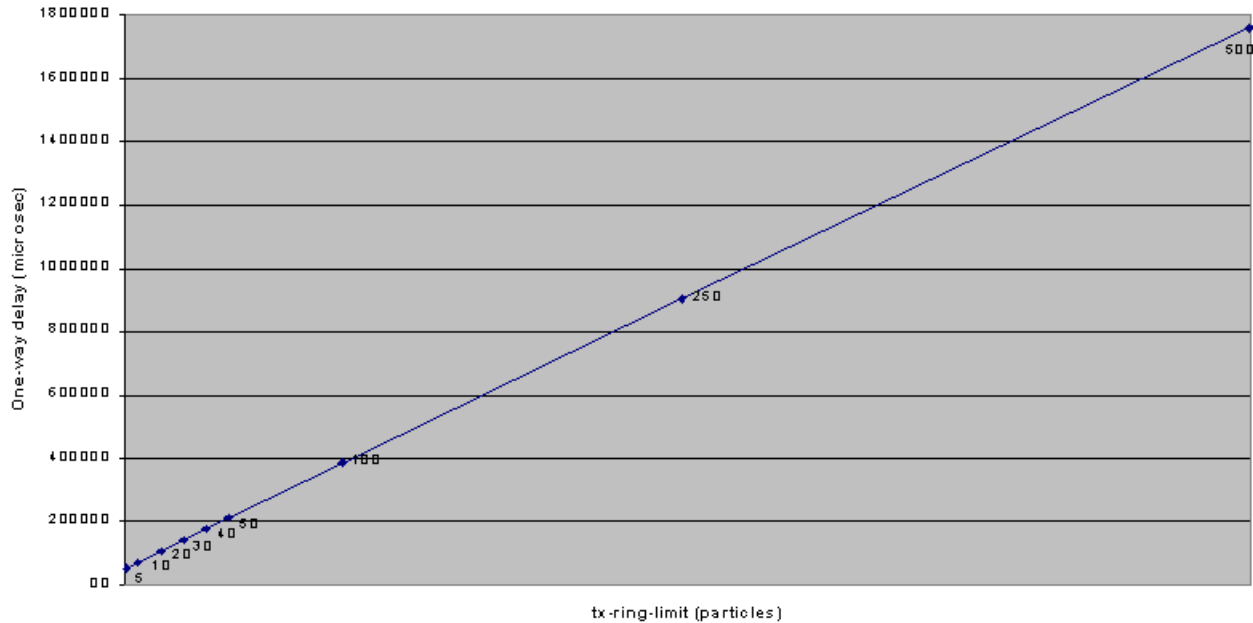
One-way delay vs tx-ring-limit

Packet size=1024 bytes

queue-limit=10 packets

bandwidth=300Kbps

WITH BEST EFFORT TRAFFIC



- One-way delay proportional to the tx queue size
- 1024 by EF frame:
1-way delay(512 by) = 32 * 1-way delay(256 kby)

Tx queue: ipdv

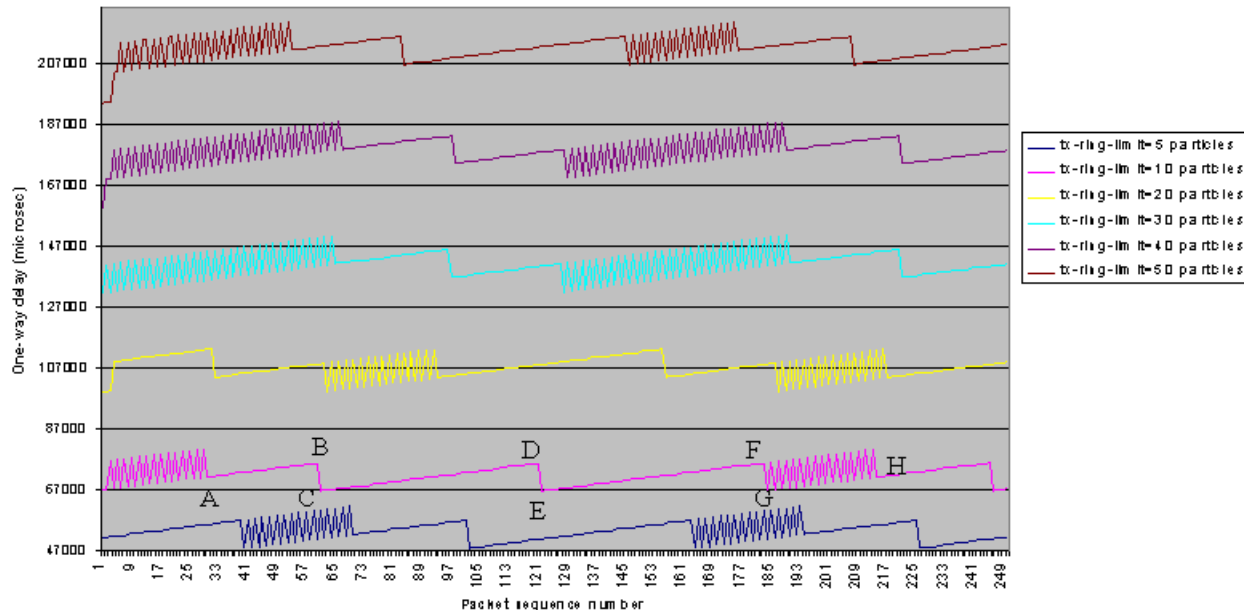
One-way delay vs time

Packet size=1024 bytes

queue-limit=10 packets

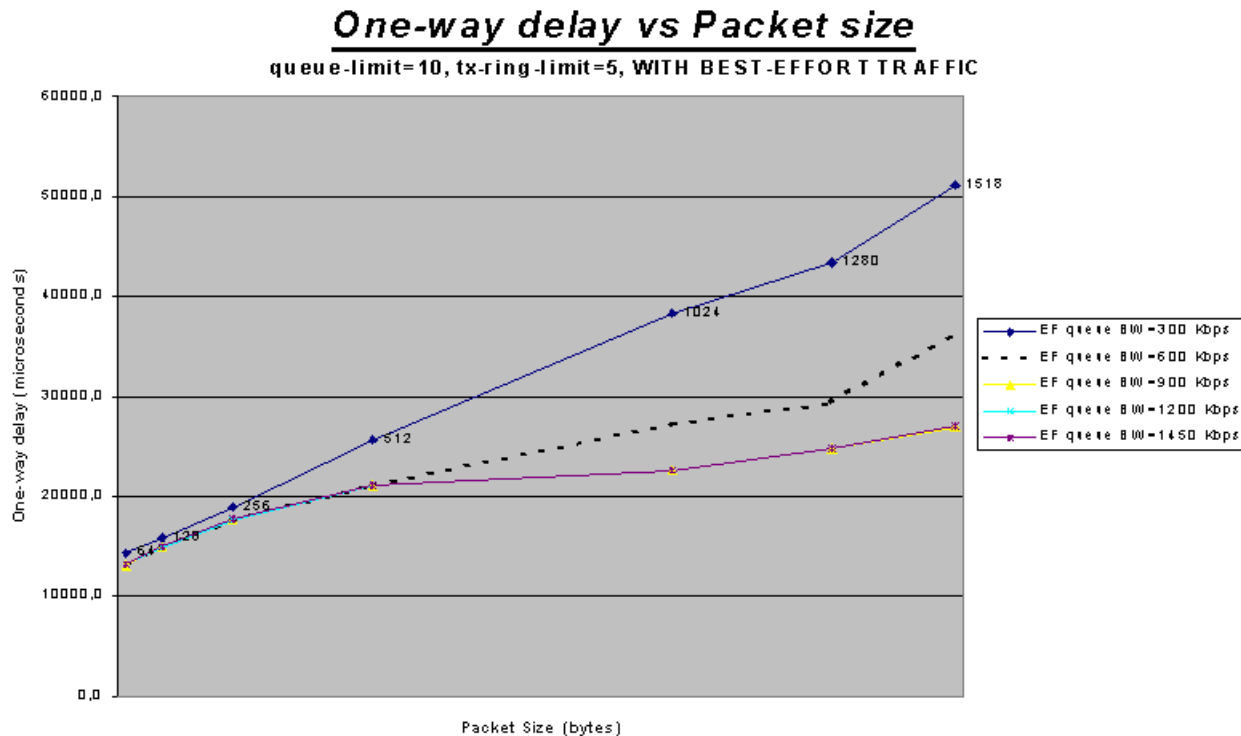
bandwidth=300 Kbps

WITH BEST EFFORT TRAFFIC



- *ipdv independent of the tx queue size*
- max ipdv = tx time of 1 best-effort packet
- highly regular patterns of both the EF and BE streams cause periodicity (1 stream per PHB)

EF queue service rate: one-way delay

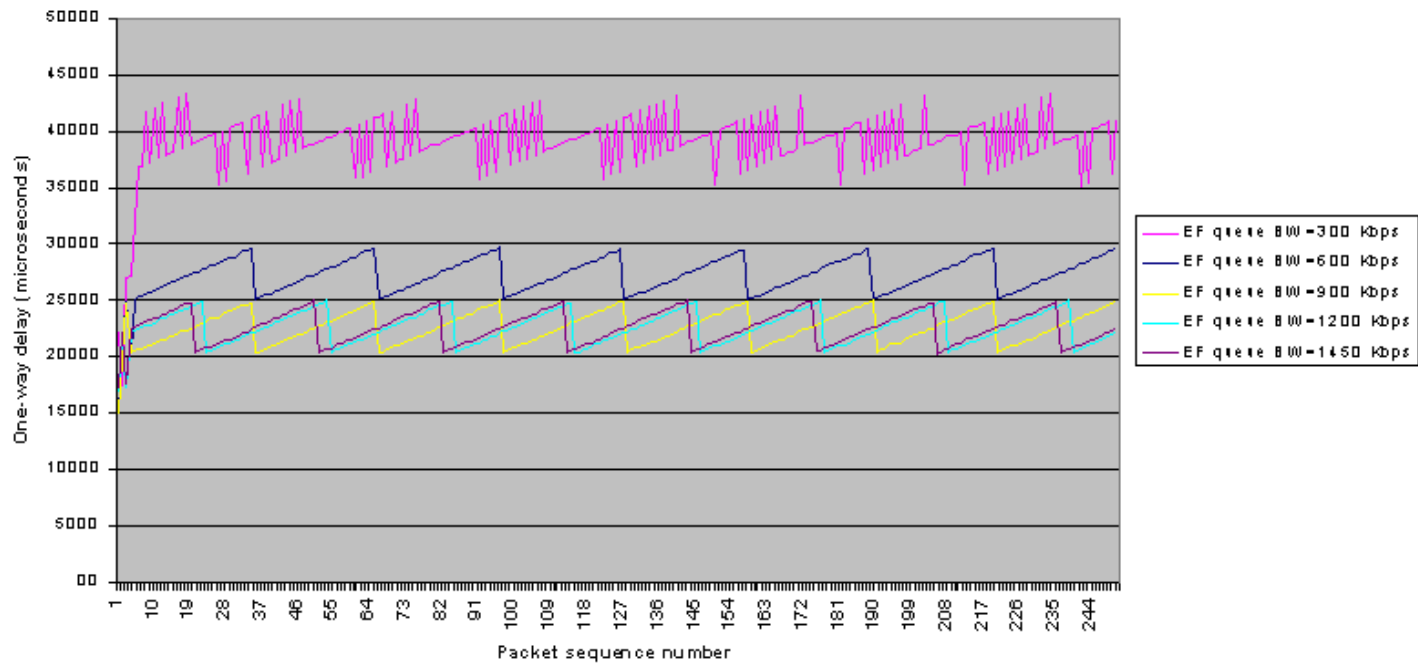


- Service-To-Arrival-Ratio (STAR) - $output_rate/input_rate$ - : [1, 5]
- 1-way delay independent of STAR when pack size ≤ 256 by
- for STAR > 3 no further decrease in one-way delay
- for small packet sizes, WFQ converges to PQ

EF queue service rate: ipdv

One-way delay vs time

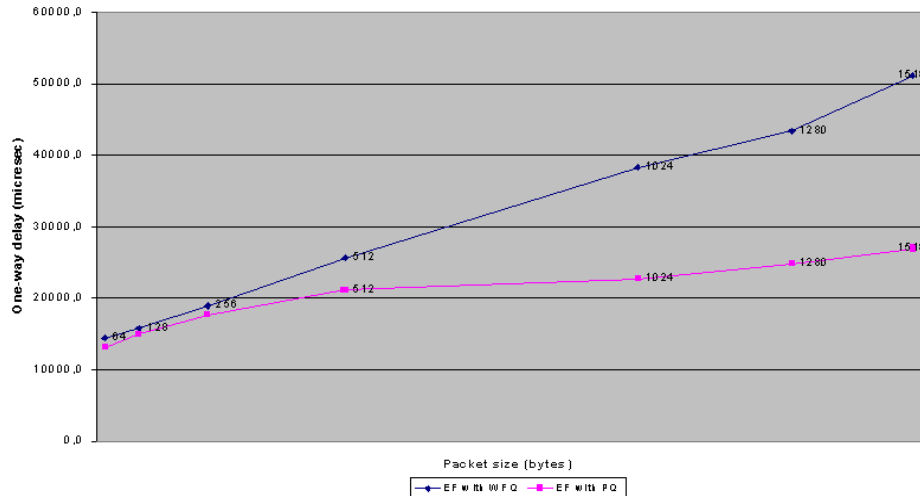
queue-limit=10, tx-ring-limit=5, WITH BEST-EFFORT TRAFFIC
Packet Size= 1024 bytes



- ipdv independent of STAR (max ipdv = tx time of 1 BE pack)

WFQ vs PQ: one-way delay

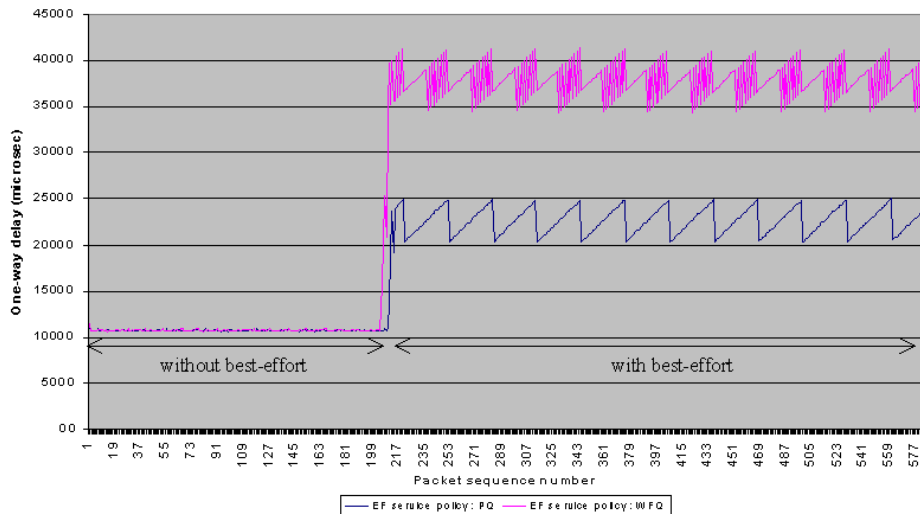
Average one-way delay vs packet size
 queue-limit=10, tx-ring-limit=5, Bandwidth = 400 Kbps,
 WITH BEST-EFFORT TRAFFIC



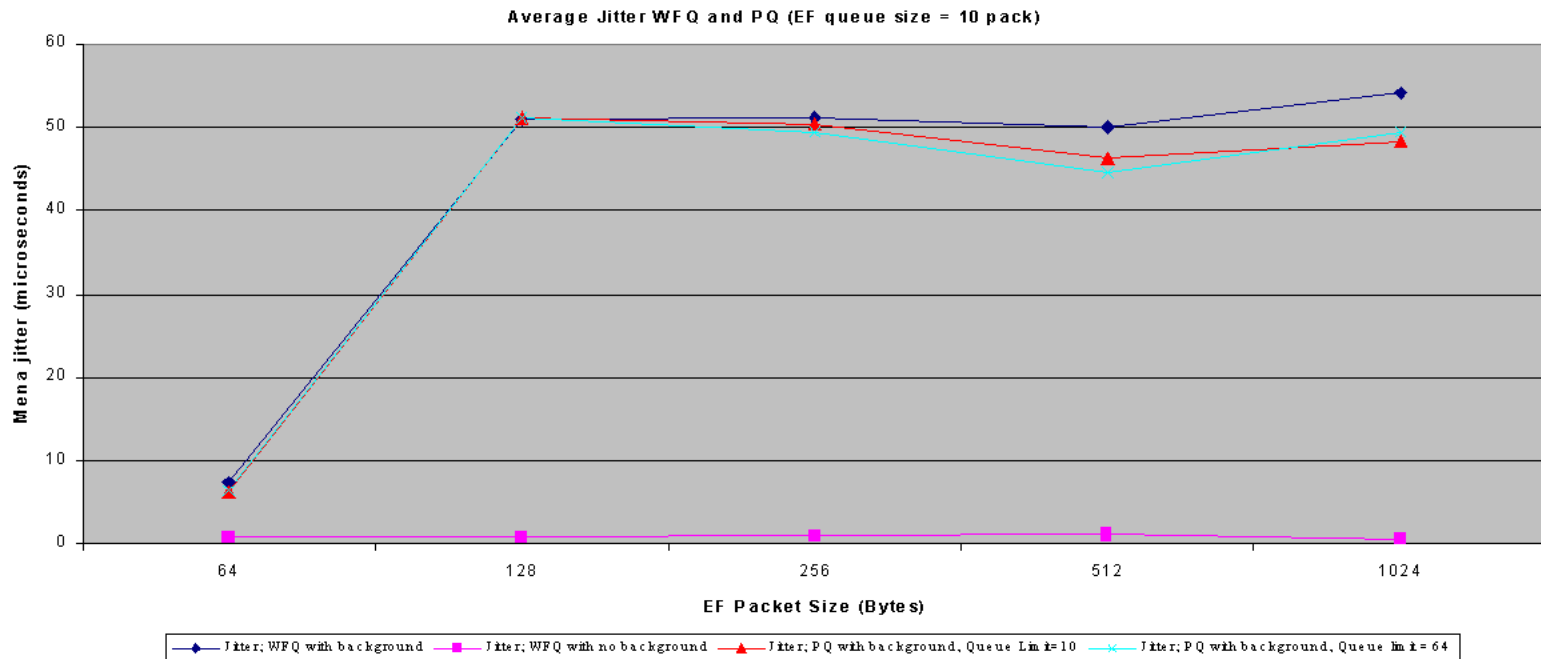
- PQ and WFQ equivalent for pack size ≤ 256 by
- 1-way delay gain for larger IP packets with PQ
- both PQ and WFQ affected by the queuing delay introduced by the tx-queue (as expected)

One-way delay vs time

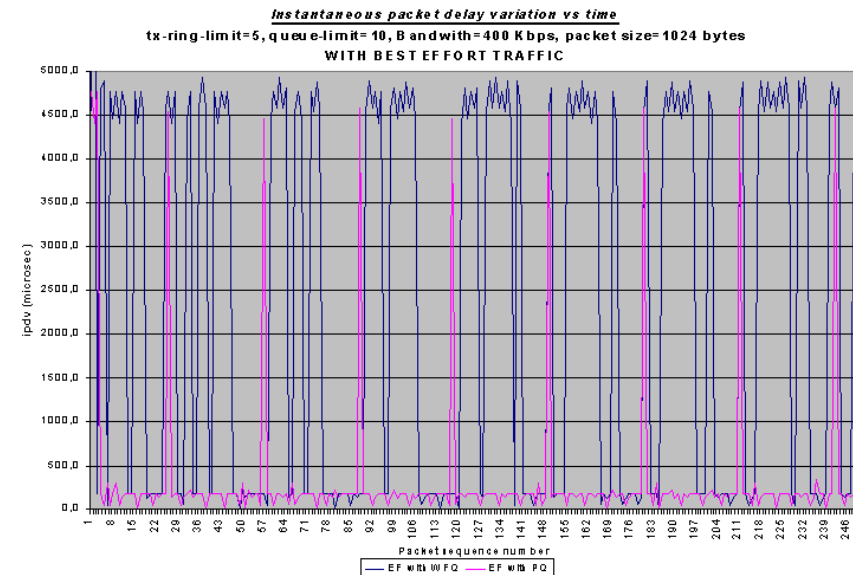
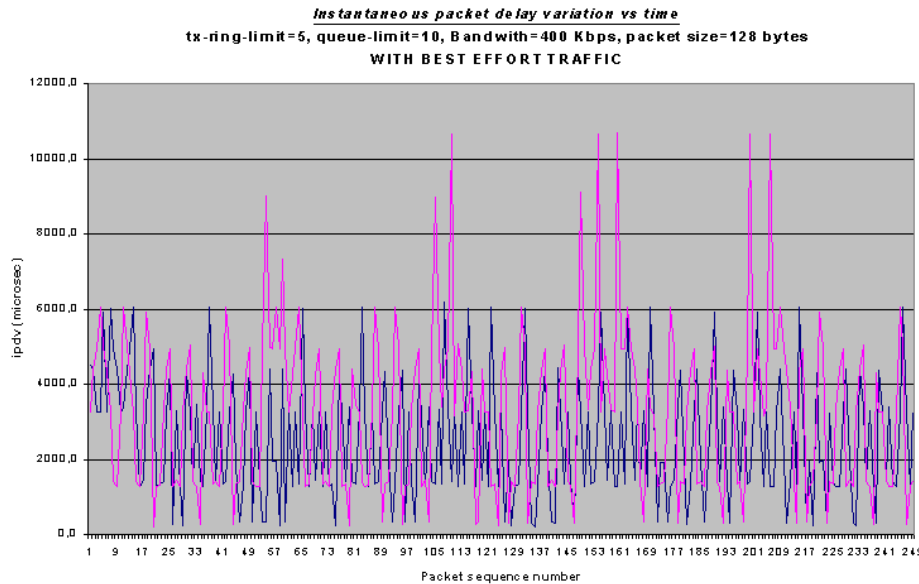
tx-ring-limit=5, limit-queue=10, EF service rate=300 Kbps, EF packet size=1024 bytes,
 WITH AND WITHOUT BEST EFFORT TRAFFIC



PQ: one-way delay (cont)

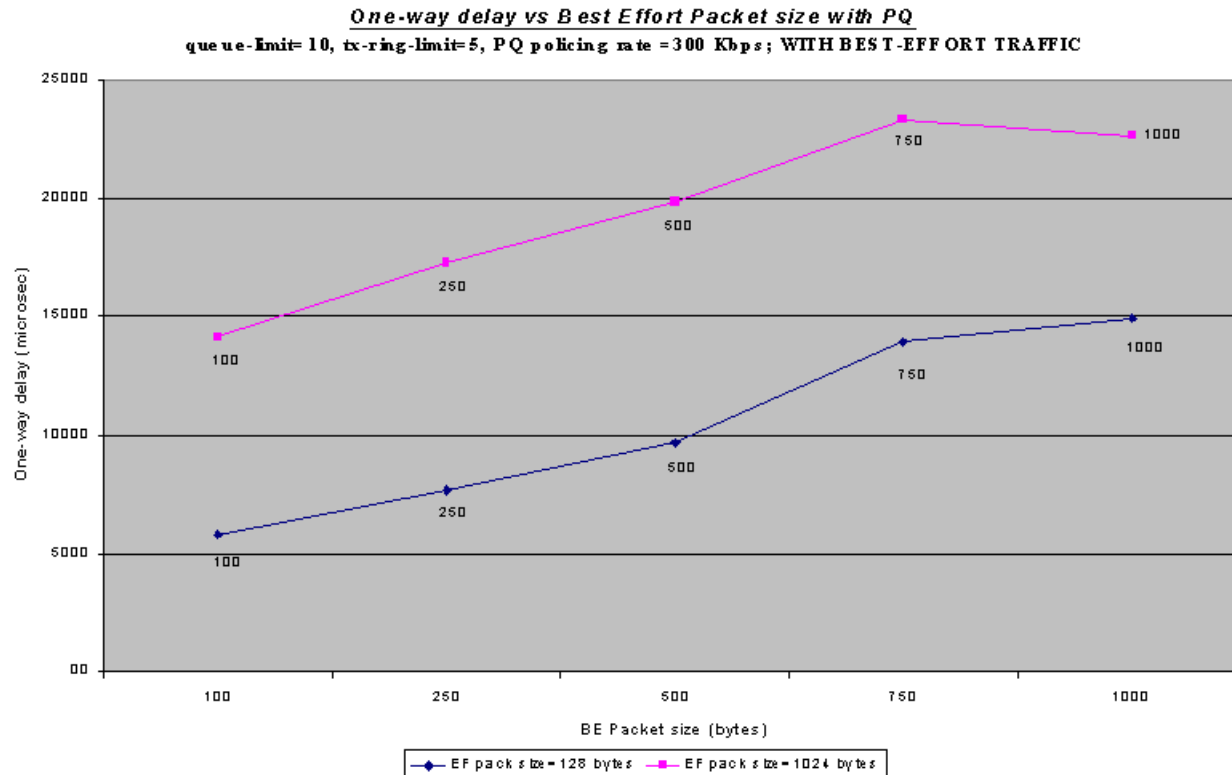


WFQ vs PQ: ipdv



- the gain in ipdv depends on the average EF pack size
- 128 by: higher peaks with PQ
- 1500 by: same peak height (tx time of 1 BE packet), but peak frequency is higher with WFQ

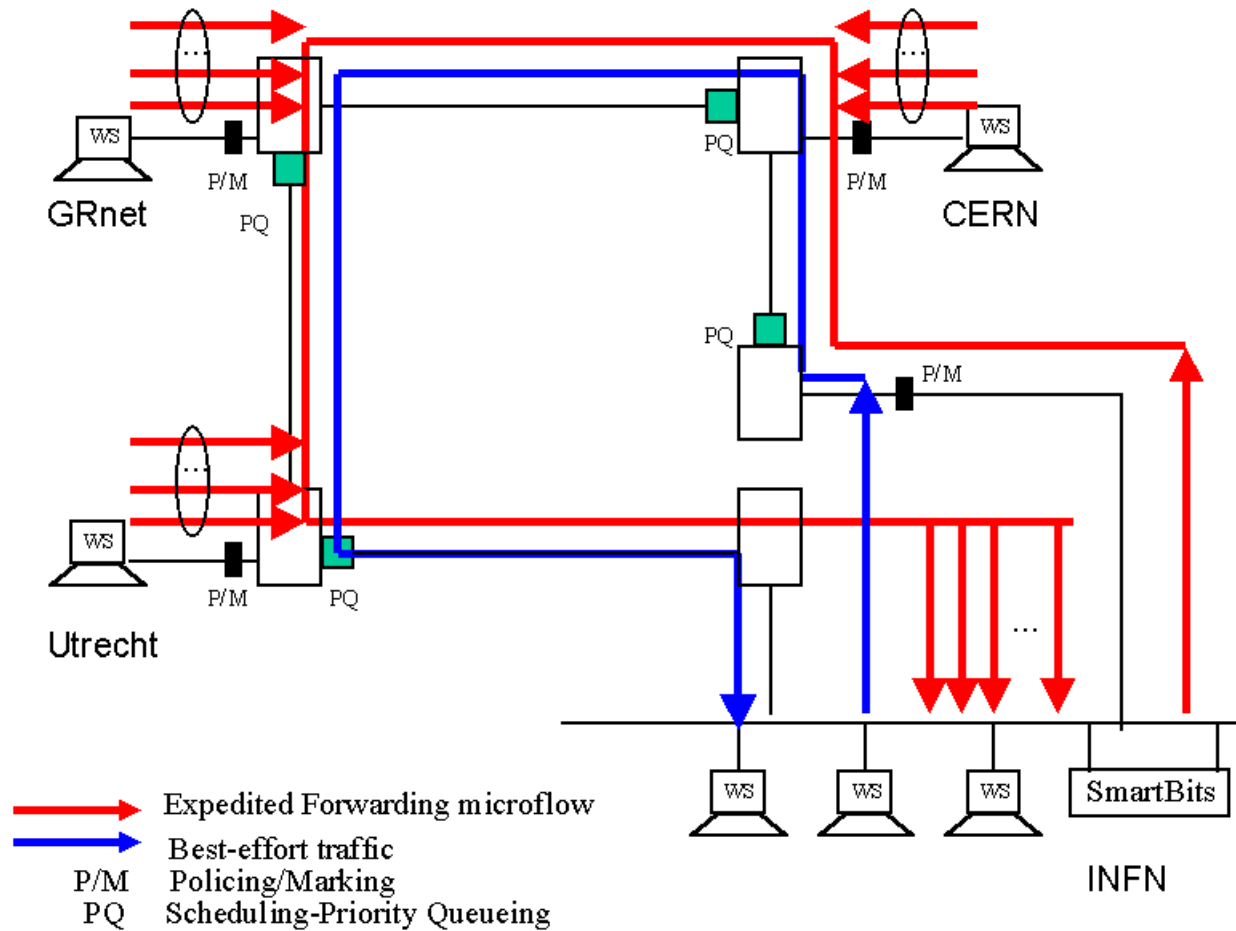
PQ: one-way delay



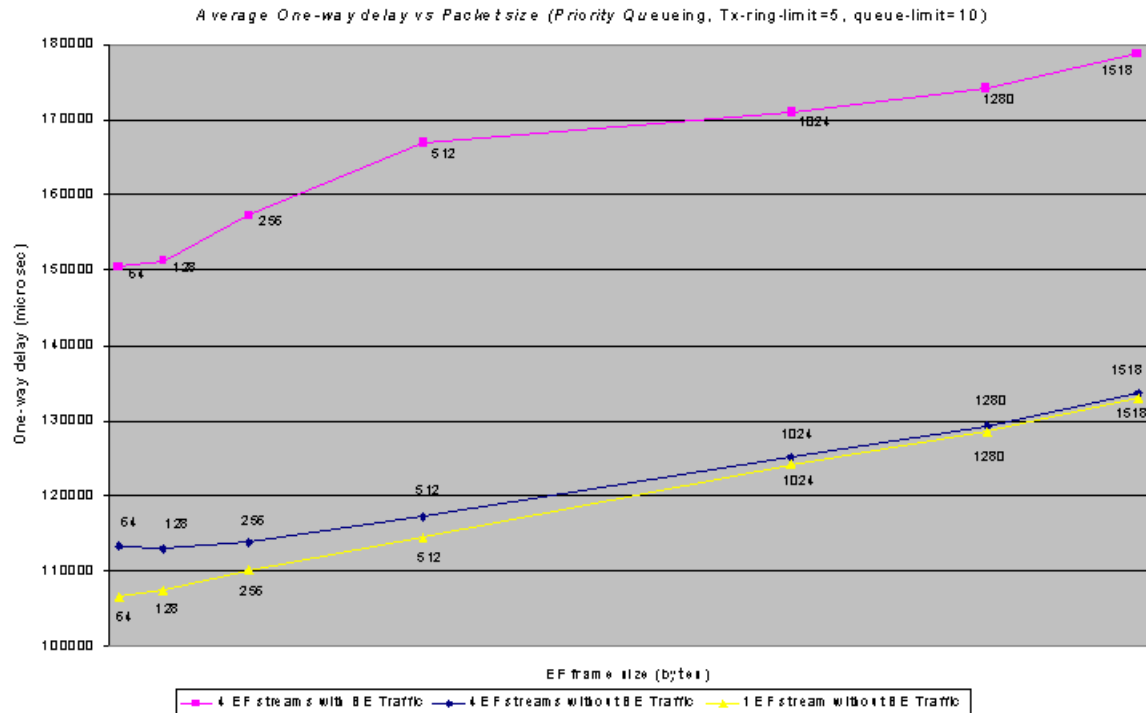
1-way delay depends:

- * on the BE average packet size (the queuing time introduced by the tx queue varies)
- * on the average EF packet size (the transmission time of the pack increases)

EF: dependency to aggregation, congestion and load



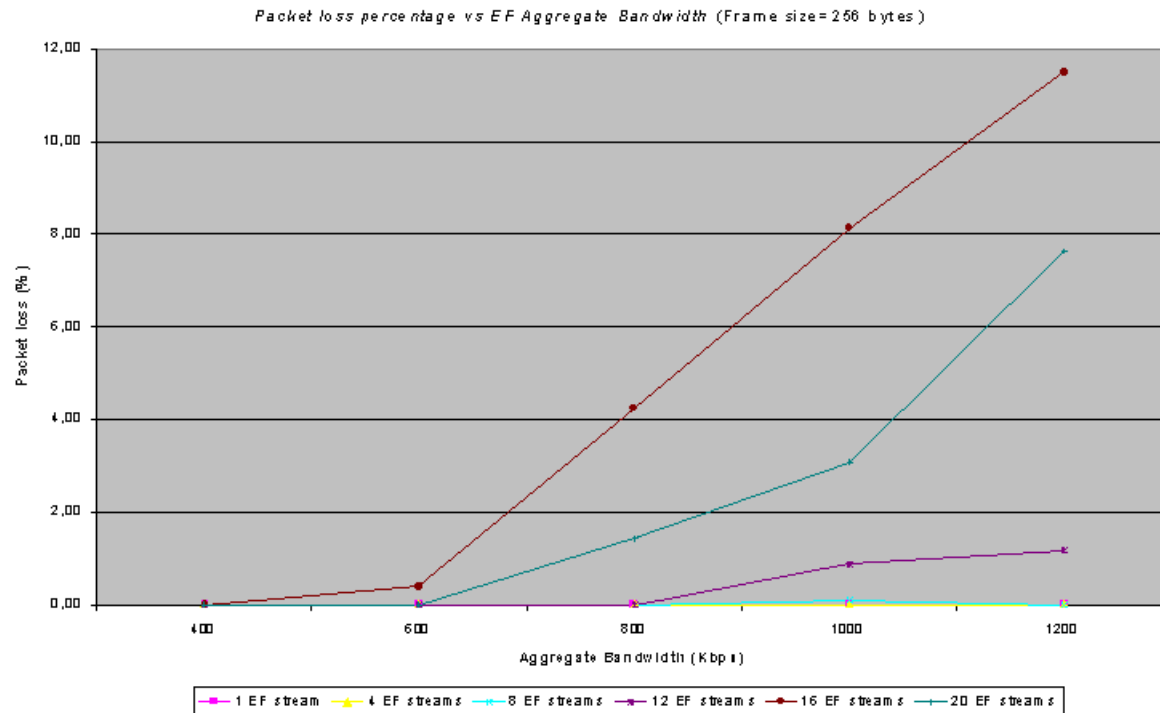
Aggregation and congestion (PQ): one-way delay



- the smaller the average EF pack size, the higher is the contribution of aggregation to 1-way delay (for an overall EF constant load, the pb that EF packs get clustered increases)
- considerable contribution to 1-way delay in case of congestion: queuing delay contribution from the tx queue in **each** congestion point:

$$\Delta D = \Delta D_1 + \Delta D_2 + \dots + \Delta D_n$$
 where n is the num of congestion points

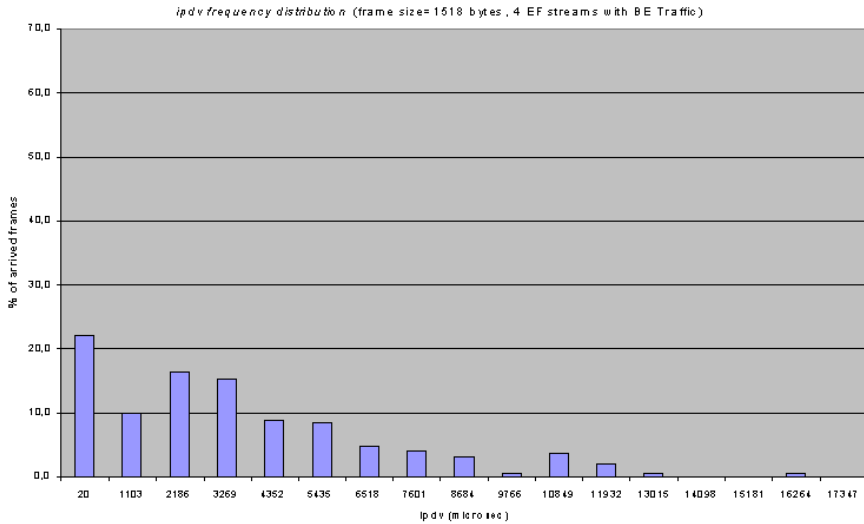
EF load and aggregation (PQ): packet clustering



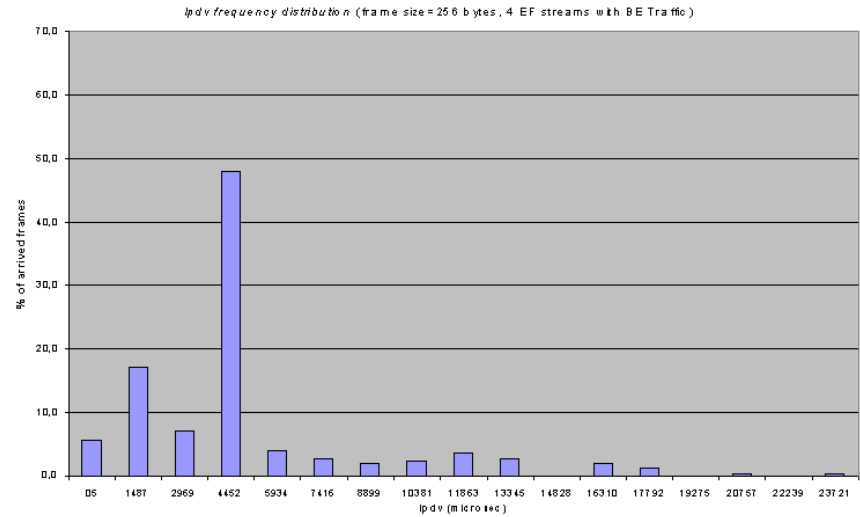
- EF pack loss: up to 12% for EF load = 60% of line rate, 20 EF streams
- EF pack loss negligible if the number of EF streams decreases (up to 8)
→ EF load irrelevant
- EF aggregation can cause EF packet clustering, i.e. EF burstiness.
EF packets are dropped by the policer associated to the PQ queue

EF packet size and ipdv (with aggregation and congestion)

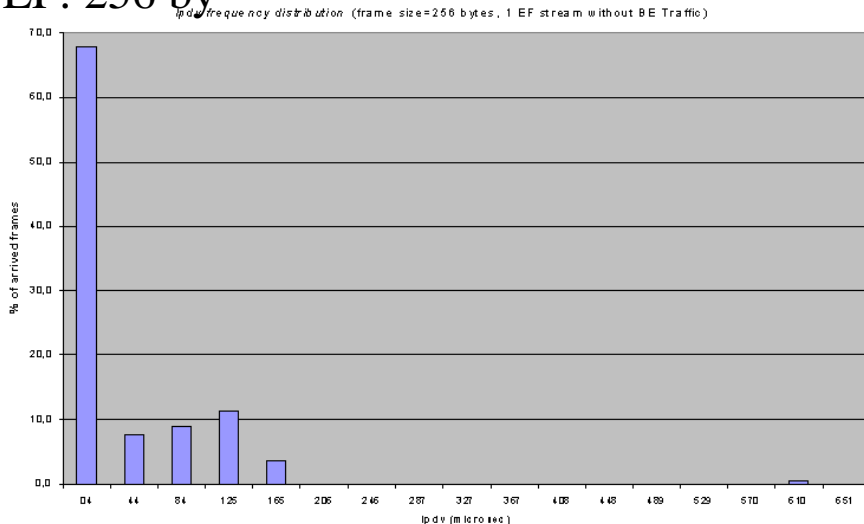
EF: 1518 by



EF: 256 by

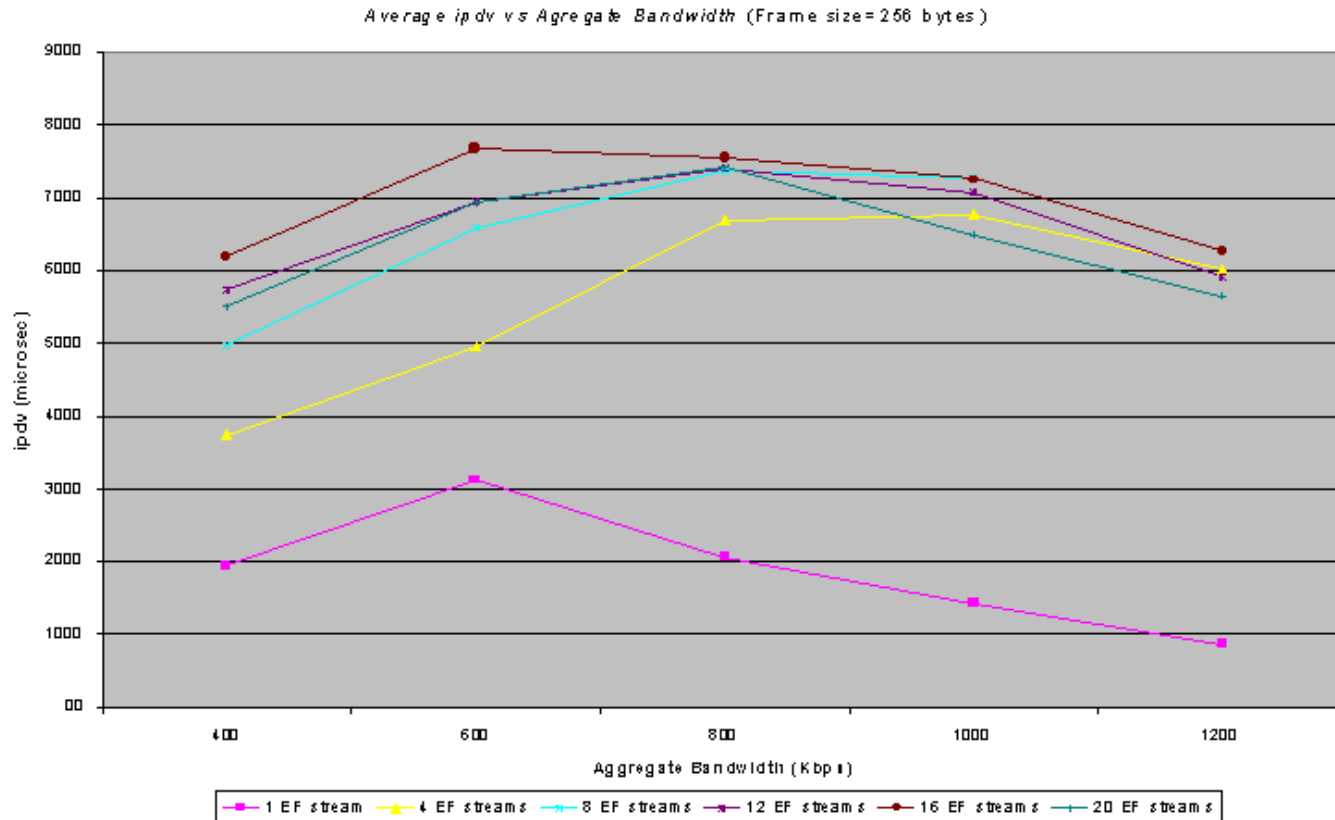


EF: 256 by



- for any EF pack, the standard deviation increases as an effect of both aggregation and congestion
- a few packets experience high ipdv independently of the EF pack size

EF aggregation and load: effect on ipdv



- effect of EF aggregation on avg ipdv (load = 600 Kbps) :

for **1 EF stream** and congestion, avg ipdv = $2.5 * \text{tx time EF pack}$

for **20 EF streams** and congestion, avg ipdv = $6 * \text{tx time EF pack}$

References

- Diffserv test programme, reports and interim test results:
<http://www.cnaf.infn.it/~ferrari/tnfg/ds/>
- QoS measurement test programme, reports and interim test results:
<http://www.cnaf.infn.it/~ferrari/tnfg/qosmon/>
- Activities of the TF-TANT task force:
<http://www.dante.net/tf-tant>
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