>BUSINESS MADE **SIMPLE**

T-Spec Examples for Audio-Video Bridging

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NORTEL

Source TSPEC for IP Intserv

> Five parameters describing the traffic, p, r, b, m, M.

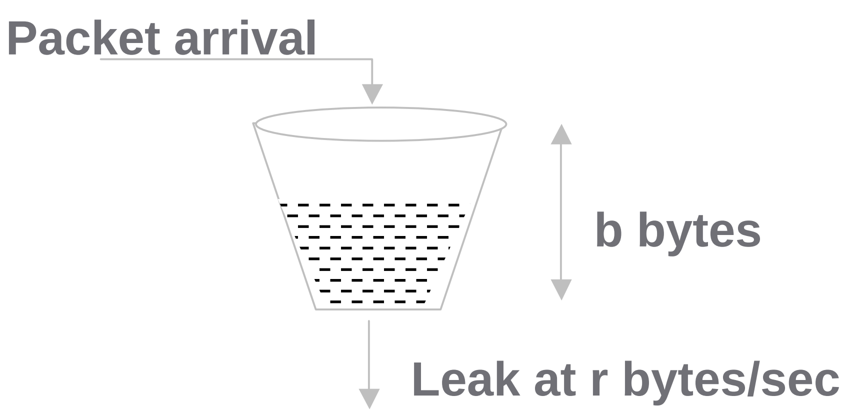
> Peak rate, p measured in bytes of IP datagram per second

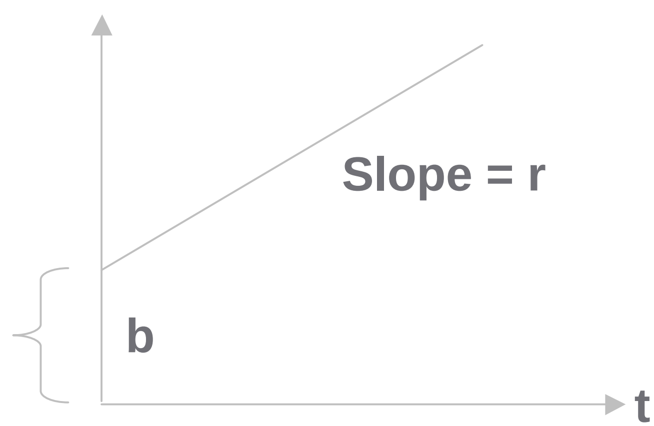
- At all time periods of length T, the amount of data sent cannot exceed (pT+M).

> Token bucket depth (b) and rate (r). b is measured in bytes and r is measured in bytes of IP datagram per second

- Packets not conforming to (r, b) leaky bucket (regulator) are treated as best effort
  - At any interval of length T, traffic is bounded by (b + rT) ← Arrival Curve

> Combining the two conditions together → at any interval of length T, traffic is bounded by min(M+pT, b+rT)





Source TSPEC for IP Intserv- continued

- m is the minimum policed unit
  - All IP datagram of size less than m will be counted when policed and tested for conformance as m
- M is the maximum datagram size
  - Flows requesting M greater than the link MTU must be rejected.

ATM Traffic Descriptor

> Peak cell rate (PCR) and cell delay variation tolerance (CDVT)
  - Specified for all ATM service categories

> Sustained cell rate (SCR), Maximum Burst Size (MBS), and CDVT
  - Specified for rt-VBR and nrt-VBR service categories

> Minimum Cell Rate (MCR)
  - Specified for ABR service category

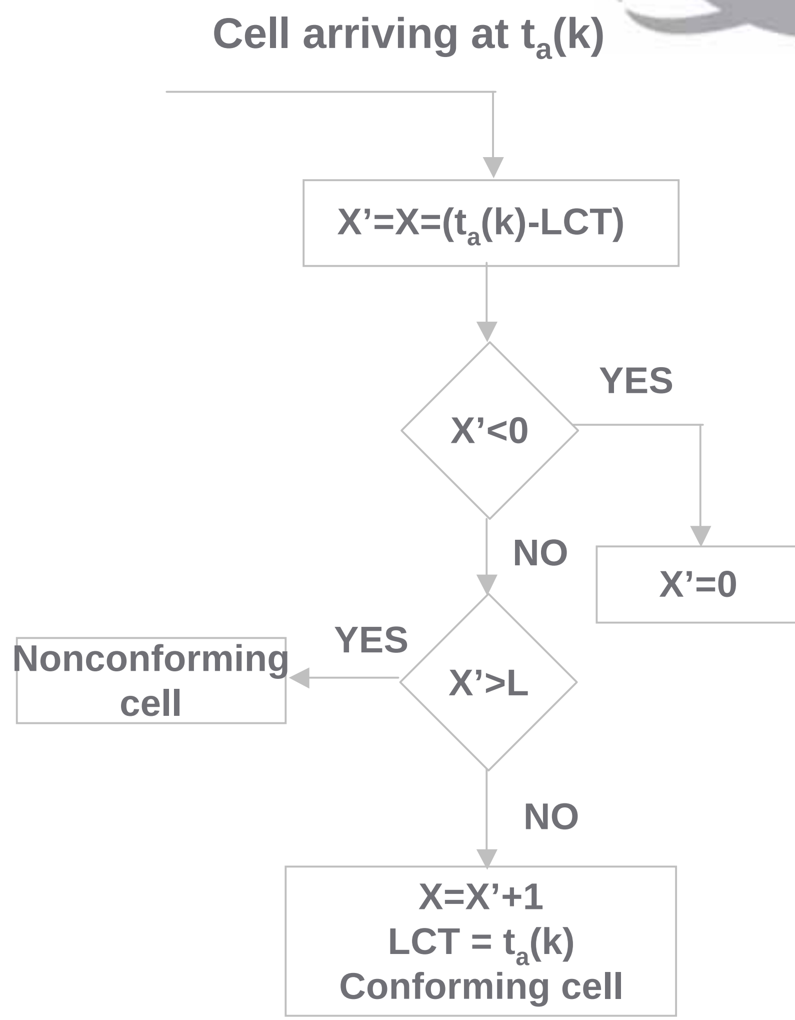
> Maximum Frame Size (MFS)
  - Specified for GFR service category

ATM Traffic Descriptors- Continued

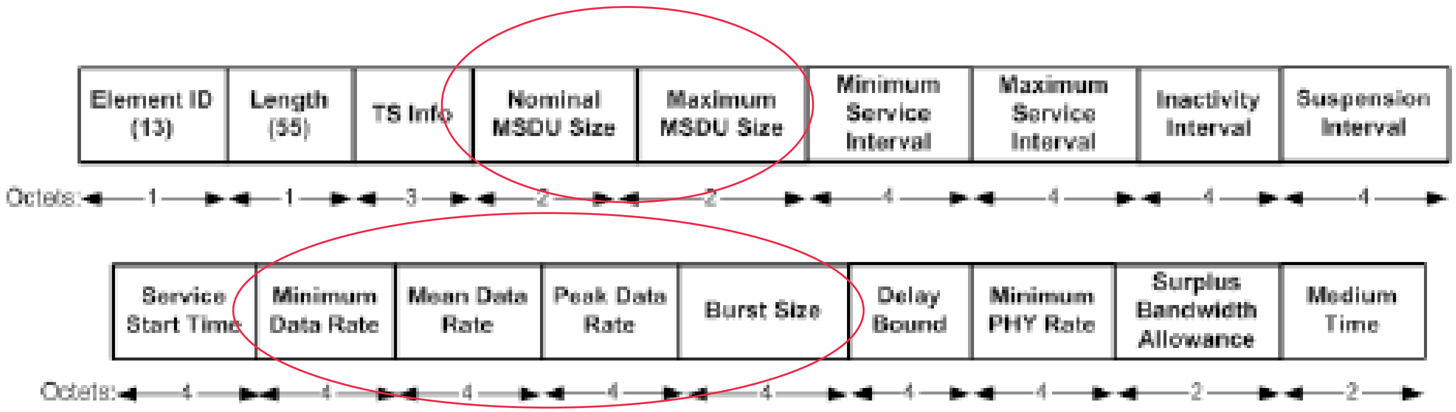
> Conformance testing is based on generic cell rate algorithm (GCRA) → yet another name for leaky bucket

> Note that L ≠ MBS. They are related by the relationship:

$$MBS = \frac{L}{1 - \frac{SCR}{PCR}}$$



IEEE 802.11 TSPEC



> "The mean data rate, the peak data rate, and the burst size are the parameters of the token bucket model which provides standard terminology for describing the behavior of traffic source"…RFC 2212

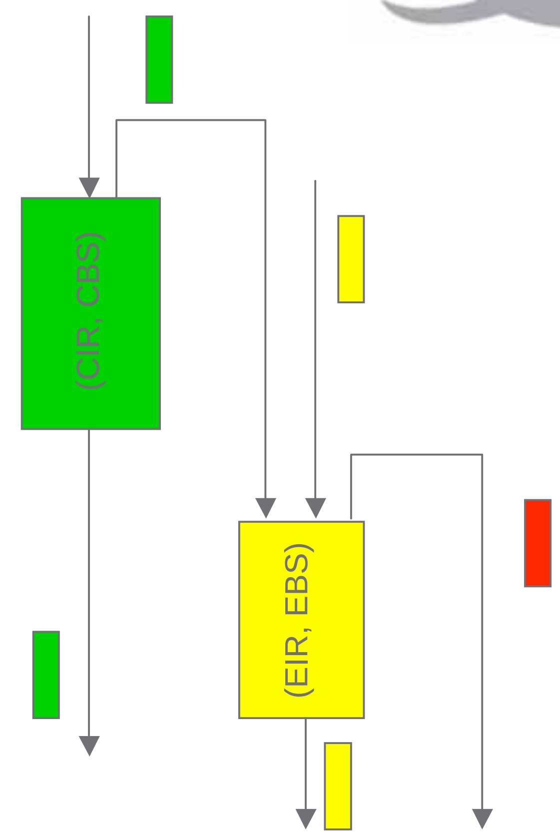
IEEE 802.11-2007

MEF Bandwidth Profile

RFC 4115

> Committed information rate (CIR) and Committed burst Size (CBS) → defined using leaky bucket algorithm

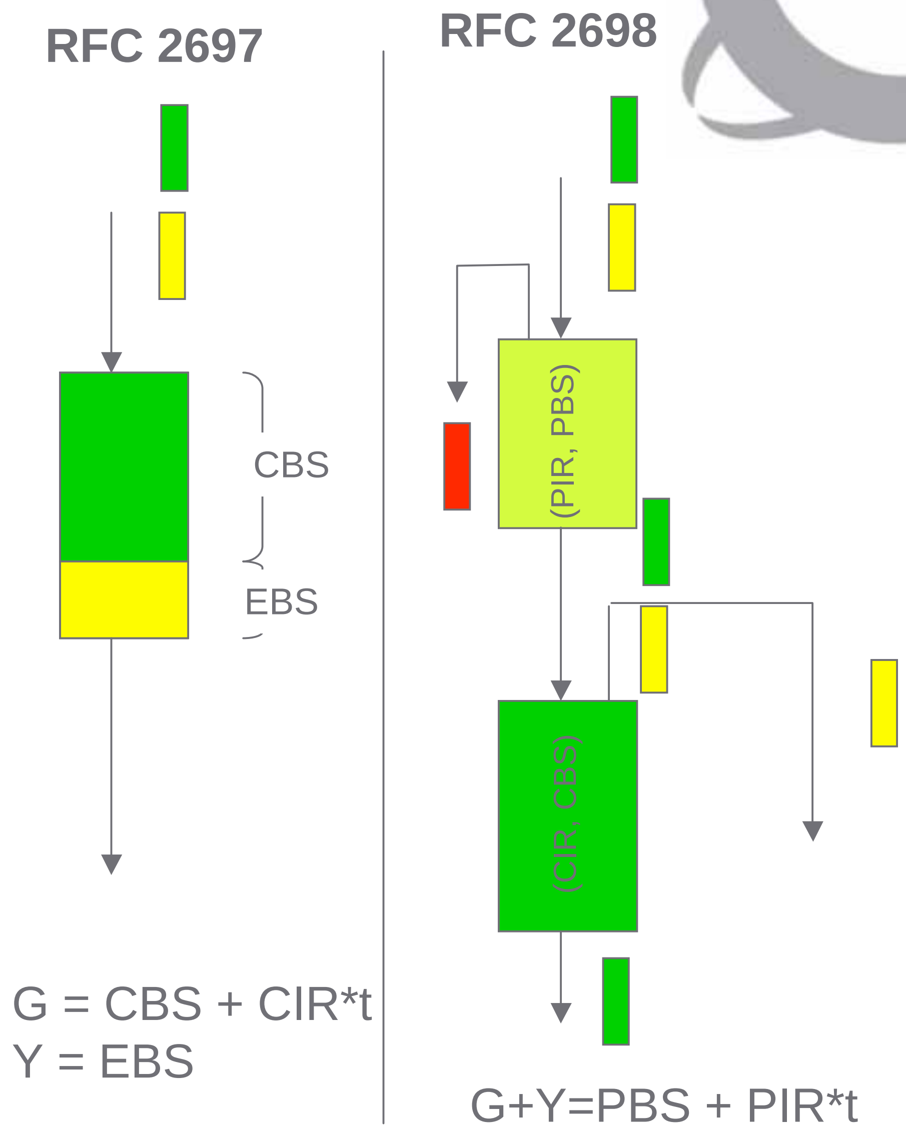
> Excess information rate (EIR) and Excess burst Size (EBS) → defined using leaky bucket algorithm



G = CBS + CIR * t
Y = EBS + EIR * t

RFC 2697 and RFC 2698

- RFC 2697: Committed information rate (CIR), Committed burst size (CBS), and excess burst size (EBS)
- RFC 2698: Peak information rate (PIR), Peak burst size (PBS). CIR and CBS.



TSPEC Summary

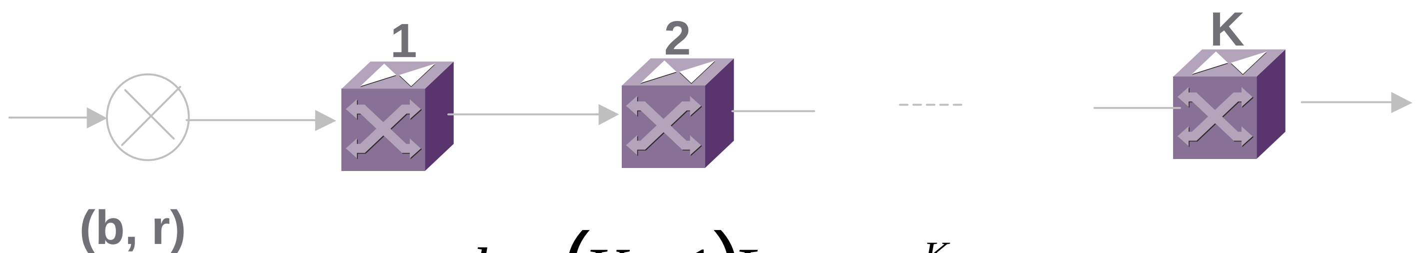
	IP Intserv	ATM	MEF (RFC 4115)	RFC 2697	RFC 2698
PIR	p	PCR	x	x	PIR
PBS	x	CDVT	x	x	PBS
CIR	r	SCR	CIR	CIR	CIR
CBS	b	MBS	CBS	CBS	CBS
EIR	x	x	EIR	x	x
EBS	x	x	EBS	EBS	x
m	m	N/A	x	x	x
M	M	N/A	x	x	x

Why TSPEC?

> When TSPEC parameters are enforced at the ingress they provide an upper bound (envelope) of the traffic

> Coupled with a guaranteed rate (GR) schedulers at the networks nodes, it is possible to develop an end-to-end delay bound

- GR Definition [1]: $d_{i+1} = \max\{A_{i+1}, d_i) + L_i/r$
    - A scheduling algorithm at the j^{th} node belongs to GR class if it guarantees that packet i will be transmitted by $d_i + \beta^j$ where β^j is a constant that depends on the scheduling algorithm at node j
- Delay bound for flows controlled by leaky bucket (b, r) and K switches on the path → assuming per flow queuing

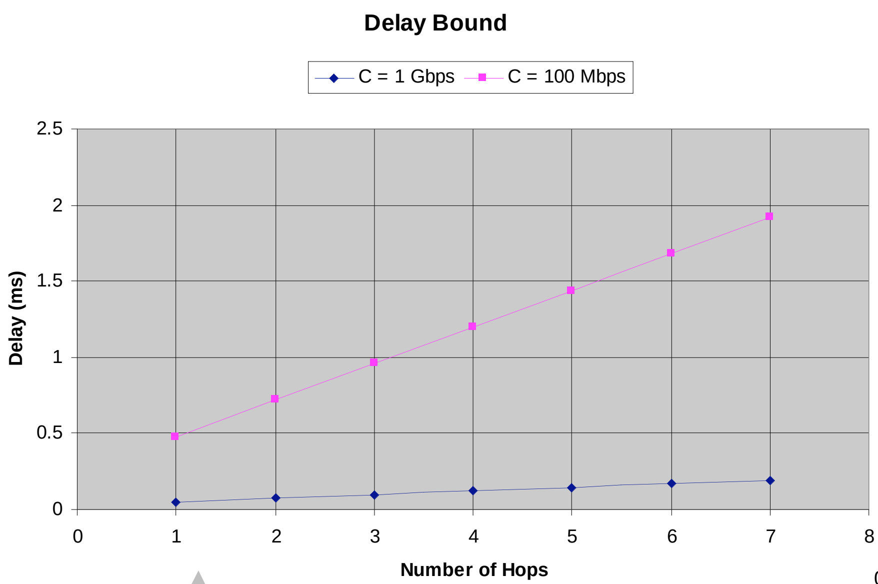


$$T \le \frac{b + (K-1)L_{\max}}{r} + \sum_{n=1}^{K} \left(\beta^n + \tau^n\right)$$

Some Observations

- GR scheduler are work conserving → server is busy as long as there is unfinished work in the system
  - A shaper by contrast is non work conserving
- No shaping is required by network nodes
  - Work conserving and work non-conserving schedulers are reviewed in [2]
  - Indeed shaping comes for free → it doesn't affect the end-to-end delay bound
    - It also doesn't improve it either.
- A non-preemptive absolute priority scheduler is a GR scheduler relative only to the highest priority with $\beta=L_{max}/C$
- Burst parameter, b is accounted for only once.
- Similar to the results in [3] the delay upper bound is linear in K. However the bound does not depend on the switch architecture (number of ports) nor it requires CBR traffic assumption.

Delay Results

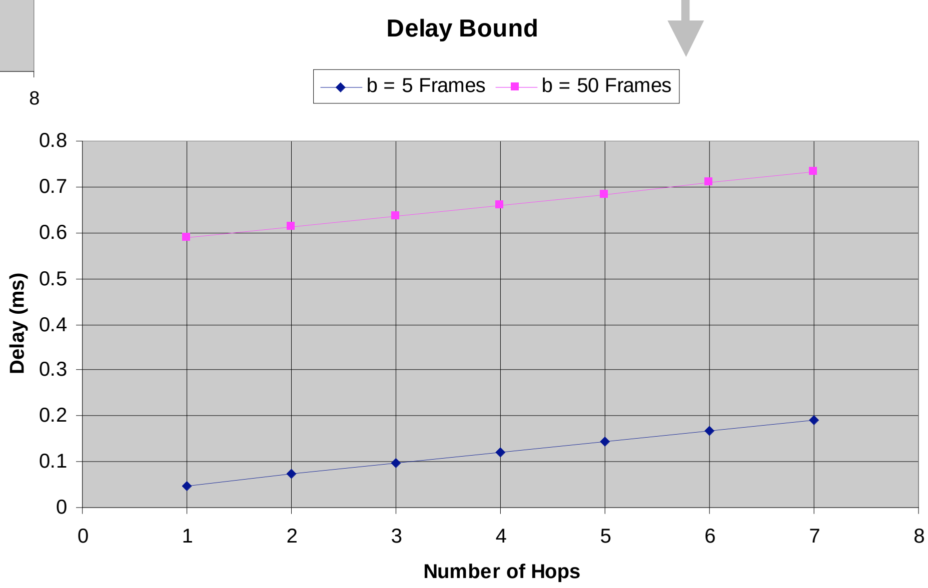


b = 5 Frames = 60 Kbits

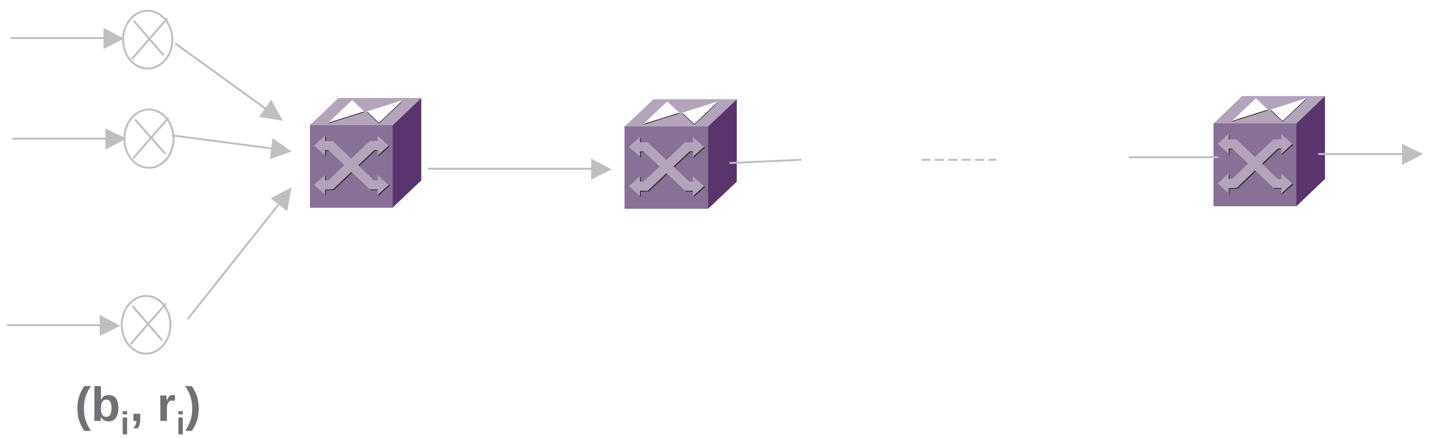
L_{max} = 1500 bytes

C = 1 Gbps

L_{max} = 1500 bytes



Extension to Aggregate Flow



> Delay bound can be extended to aggregate flow if we notice $b = \Sigma b_i$ and $r = \Sigma r_i$

> Other delay bounds are also available in the context of IP EF PHB [4, 5], assuming GR scheduler

$$T \leq \frac{\beta + \tau}{1 - (K-1)\rho}$$

Open Issues

> Which TSPEC to use for AVB?

- Most (if not all) of the existing TSPEC agree on peak rate, sustained (or committed) rate, and on leaky bucket representation of the rates, rate and burst length
- IP Intserv TSPEC parameters seem to be a good choice. It also facilitates interworking with IP Intserv and Diffserv.

> Is shaping inside the switch fabric a necessity?

- There is no data to support the switch fabric shaping as a necessary element for delay guarantees.
- On the other hand simple scheduler algorithms, e.g. absolute priority in particular and GR scheduler in general, may provide the required delay bounds for priority 5.

> What will be the real delay performance?

- Delay bounds are known to be based on worst case analysis. They are not tight enough to provide good efficiency
- Simulation is needed with some traffic models and real-time traces.

References:

[1] Goyal, P; Lam, S; and Vin, H. Deterministic End-to-End Delay Bounds In Heterogeneous Networks, Proceedings of the 5th International Workshop on Operating Systems Support for Digital Audio and Video, 1995

[2] Zhang, H. "Service Discipline for Guaranteed Performance Services in Packet-Switching Network", Proceedings of the IEEEE, Vol. 83, October 1995

[3] Azarov, M. "Approach to a Latency-Bound Ethernet", IEEE 802.1 AVB Group, April 2006

[4] Firoiu,, V; Le Boudec, JY; Towsley, D. "Theories and Models for Internet Quality of Service", Proceedings of the IEEE, Vol. 90, September 2002

[5] Le Boudec, J. and Thiran, P. Network Calculus: A Theory of Deterministic Queueing Systems for the Internet. On-Line Version of Springer Verlag LNC 2050, May 2004 Available at: http://ica1www.epfl.ch/PS_files/netCalBookv4.pdf