Improving Utilization for Deterministic Real-time Service

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Synopsis

- What is the problem?
  - performance guarantees, bursty traffic, high average utilization
- What is the solution?
  - tighter delay bounding technique: deterministic fluid model analysis

Problem Specification

- Support new applications in packet networks
  - scientific visualization, medical imaging, video conferencing
- Alternative solutions:
  - traditional best-effort service
  - guaranteed service
  - predicted service

Considerations

- Environment: wide-area public packet-switching networks

	best-effort	predicted	guaranteed
protection	no	?	yes
QOS	bad	moderate	good
utilization	high	?	?
complexity	low	moderate	moderate

- Guaranteed service: utilization is the key consideration

Guaranteed Services

- Deterministic service: for the k^{th} packet on connection j

$$D_j^k \leq \overline{D}_j \quad \forall\ k$$

- Statistical service:

$$Prob(D_j^k \leq \overline{D}_j) \geq z_j$$

Providing Guaranteed Services

Two levels of control:

- Connection admission control: RCAP
  - reserves resources
- Service discipline: RTIP
  - allocates resources according to the reservation

Original Tenet Admission Control Test

- Limit the sum of peak rates to be less than link speed

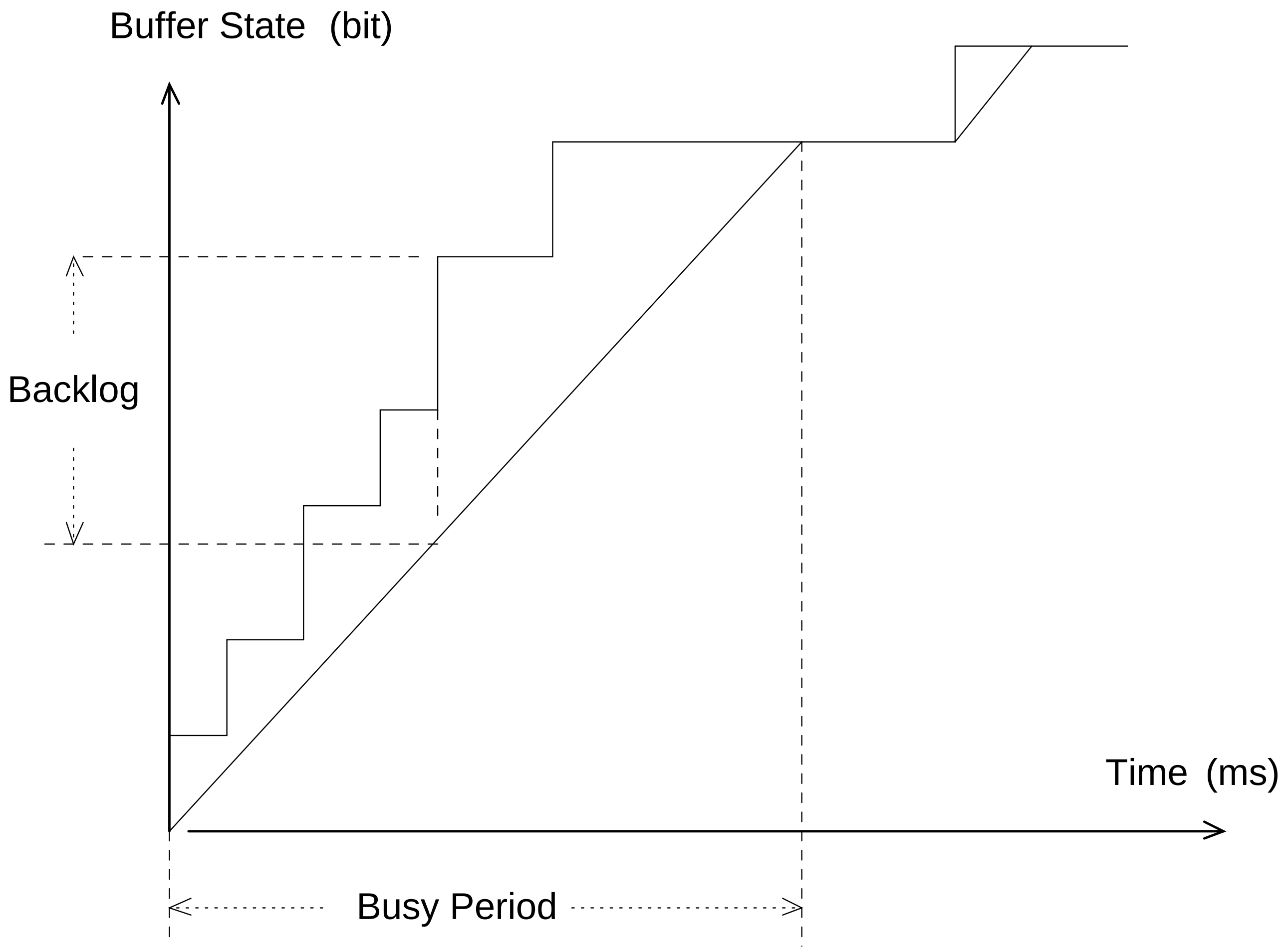
- Low average link utilization if peak-average ratio is high
  e.g. peak-average ratio 5 $\Longrightarrow$ link utilization $\leq$ 20%

- Can we bound delay when sum of peak rates is greater than link speed?

Bounding Techniques: Deterministic Fluid Model Analysis

- Pioneer work by R. Cruz, 1987
- More recent work:
  - Fixed Rate Servers, S. Low and P. Varaiya, 1991
  - General Processor Sharing, A. Parekh and R. Gallager, 1992
  - Hierarchical Round Robin, A. Banerjea and S. Keshav, 1992

Concepts: Delay, Backlog and Busy Period



Result

- First Come First Served and Static Priority solved

- Example: FCFS & homogeneous sources:

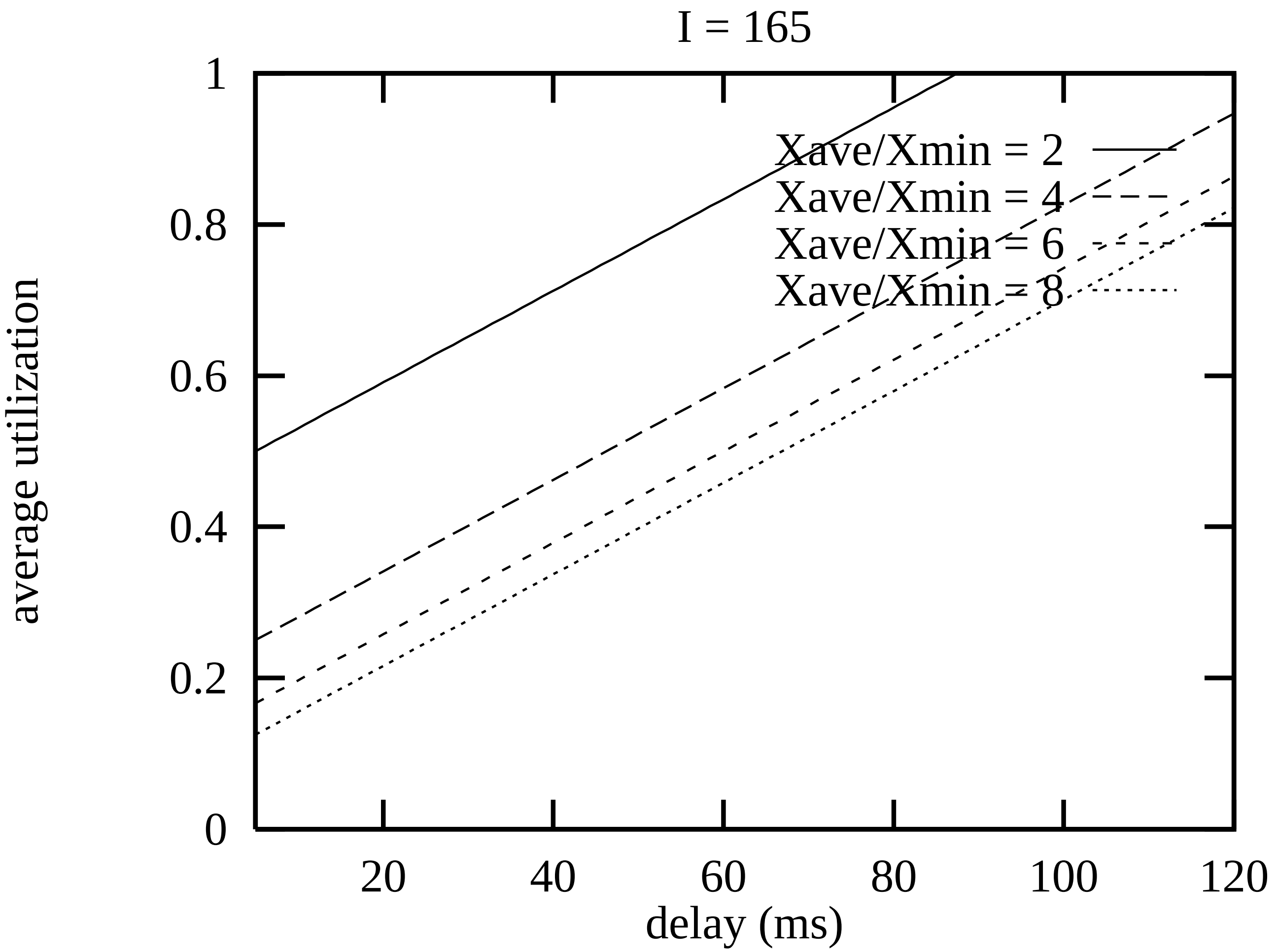
$$\overline{d} = Xmin + (\mu_{ave} - \frac{1}{burstRatio})I$$

  - $Xmin$: minimum packet inter-arrival time
  - $Xave$: average packet inter-arrival time over an interval I
  - $burstRatio$: $\frac{Xave}{Xmin}$
  - μ_{ave}: average link utilization

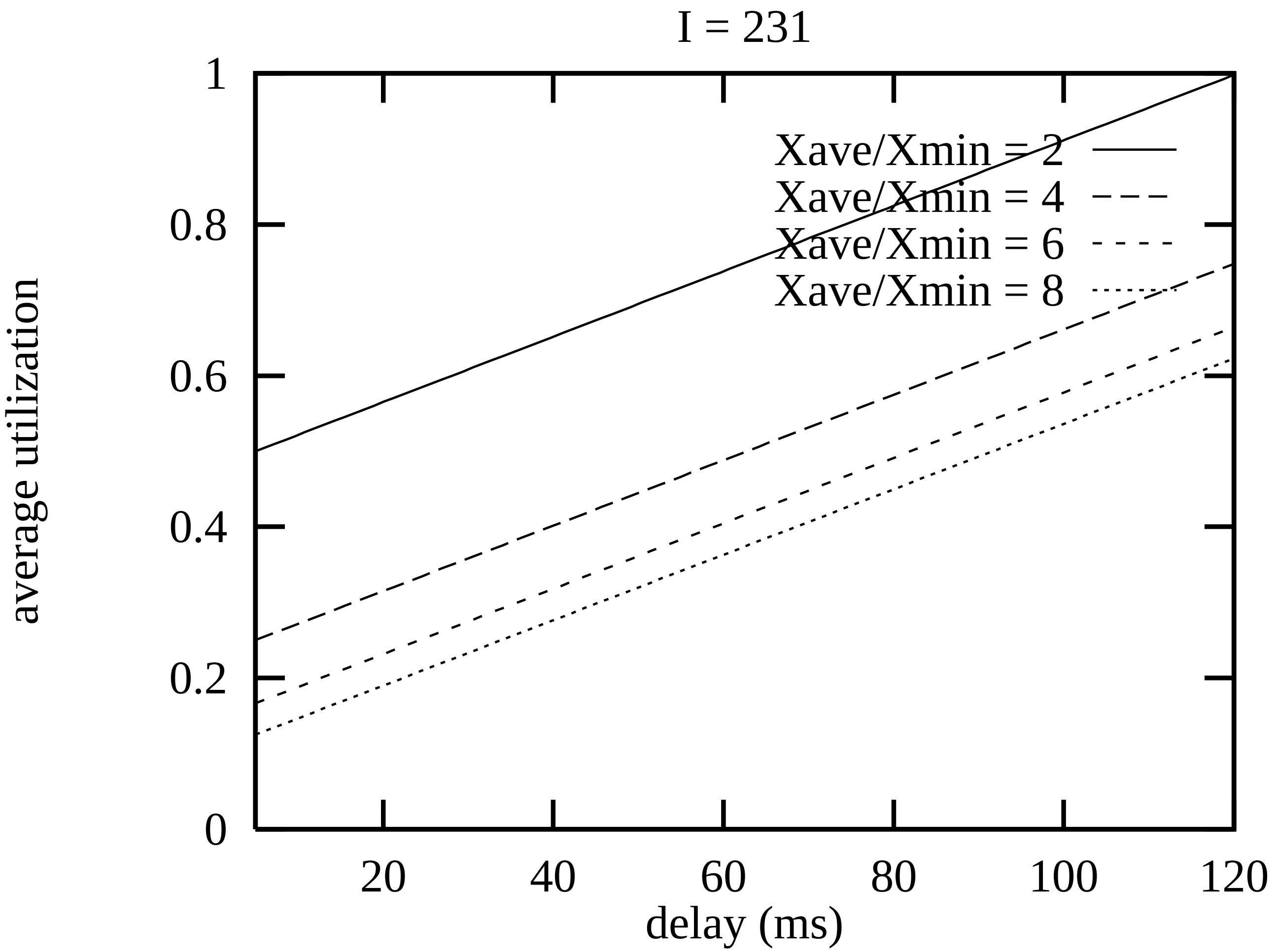
Numerical Examples

- Variable Bit Rate (VBR) video:
  - peak-to-average rate ratio $\sim 1.5 - 4$ [Kanakia 93], [Morgan 93]
  - averaging interval $\sim 3 - 7$ frame times

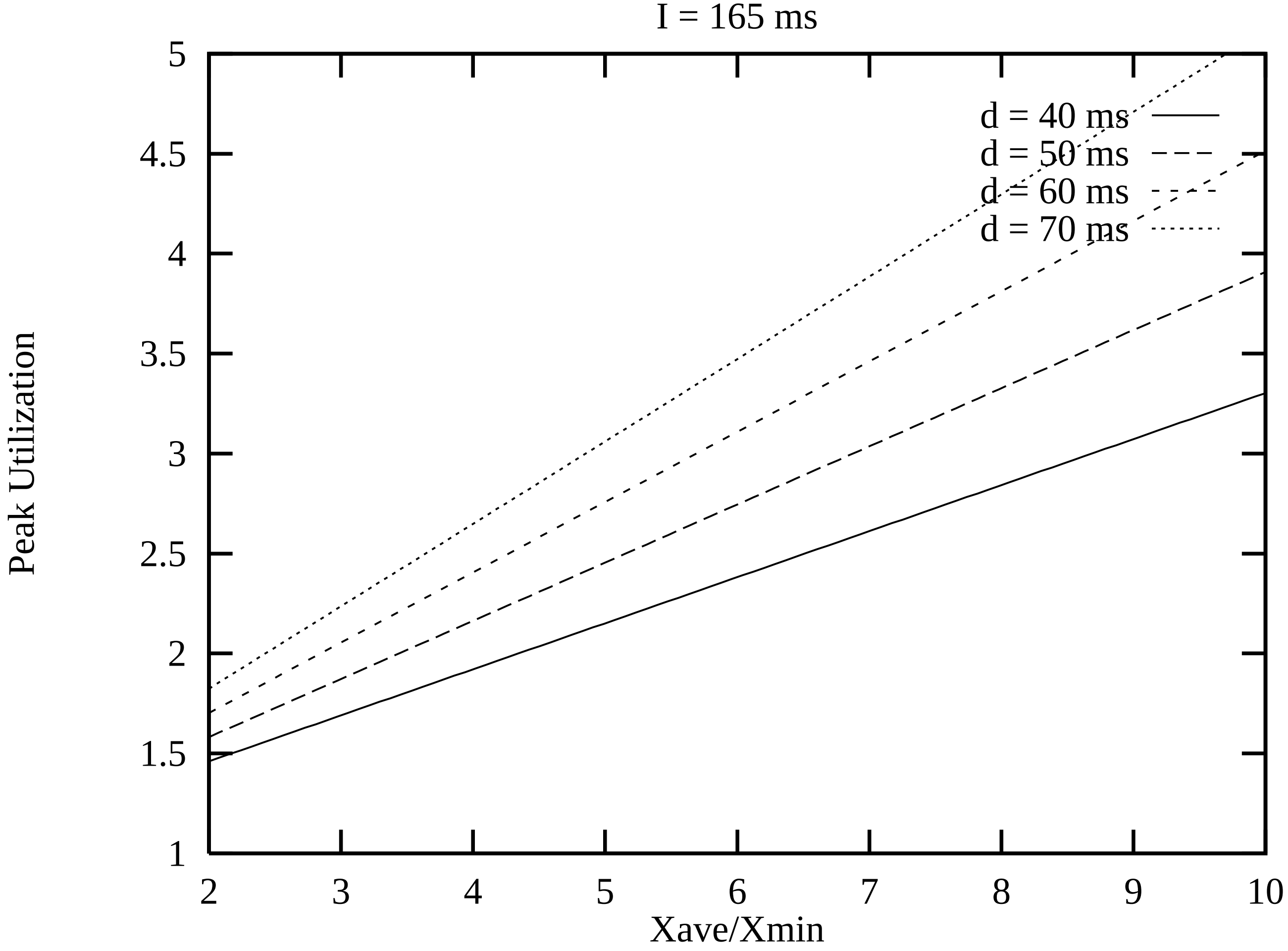
Average utilization vs. $\overline{d}$: I = 165 ms



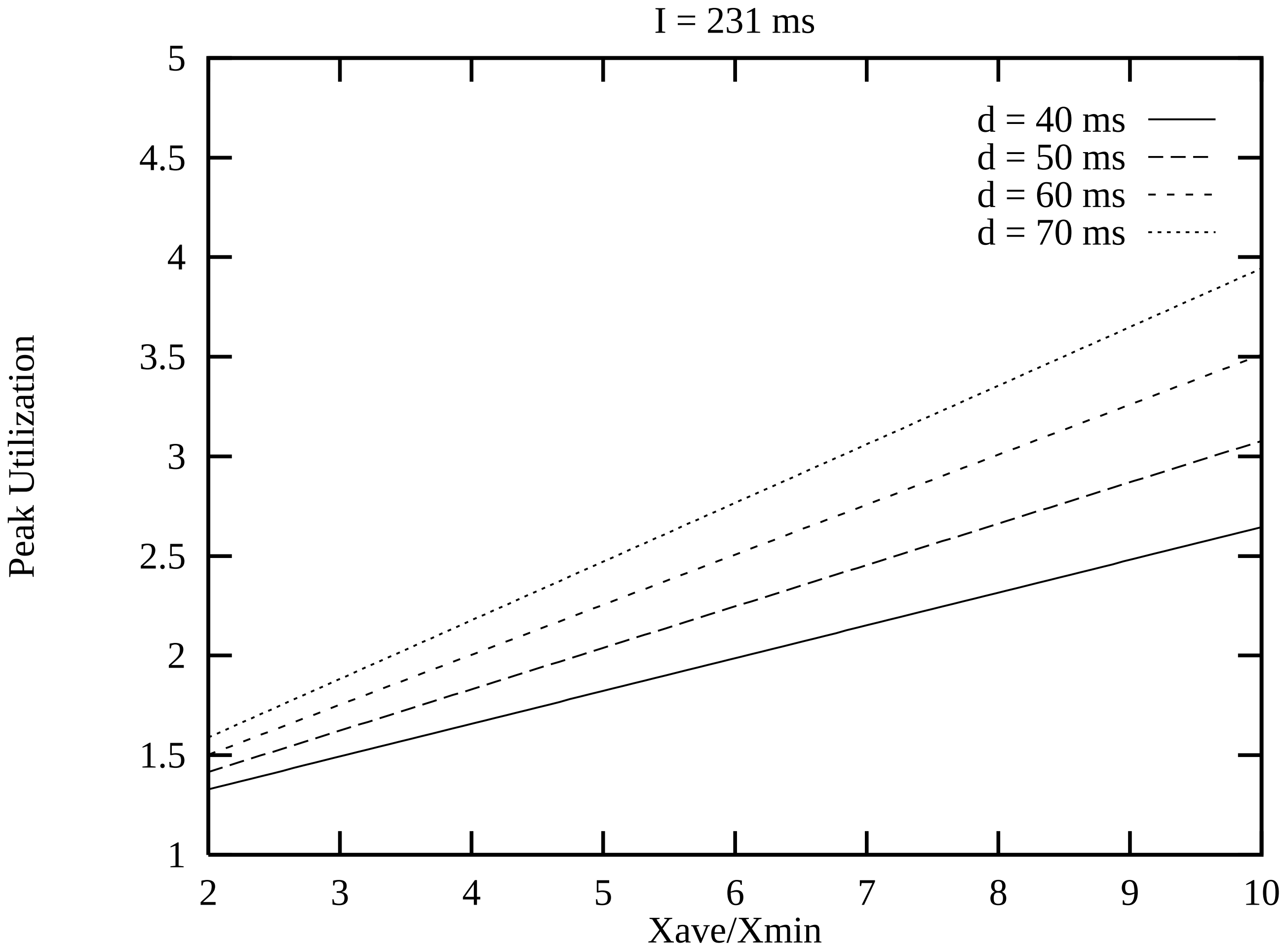
Average utilization vs. $\overline{d}$: I = 231 ms



Improvements: I = 165 ms



Improvements: I = 231 ms



Improvements

- Example: VBR video with peak rate 3 Mbps over T3 (45Mbps) link
- Old Admission Control: maximum 15 connections
- New Admission Control:

I	d	Burst Ratio	# Connection	Factor
165	40	3	25	1.69
165	50	4	32	2.16
165	60	5	41	2.76
231	50	4	27	1.83
231	60	5	33	2.26

Summary

- Biggest concern for guaranteed service: network under-utilized
- We can achieve high average utilization for bursty traffic even for deterministic service
- Higher utilization can be achieved by
  - statistical service: Ed Knightly's talk
- Why not guaranteed services, or Tenet protocols?