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**Performance of TCP over ABR
on ATM Backbone and with
Various VBR Traffic Patterns**

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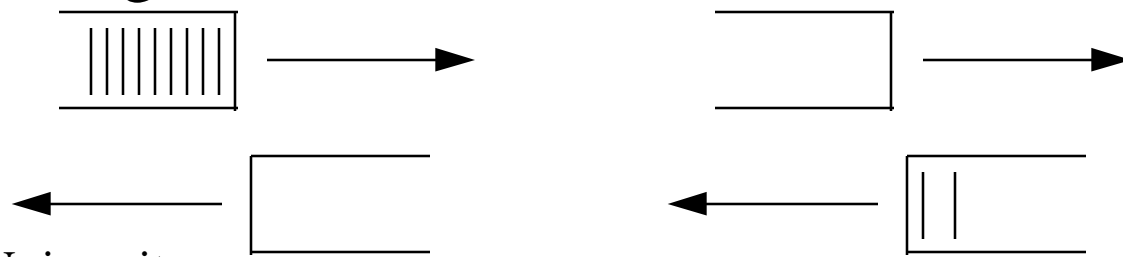
<http://www.cis.ohio-state.edu/~jain/>



- ❑ TCP over ABR on ATM backbone
- ❑ TCP over ABR with VBR background
⇒ High variance in demand and capacity
- ❑ Effect of VBR on-off times, feedback delay, switch scheme

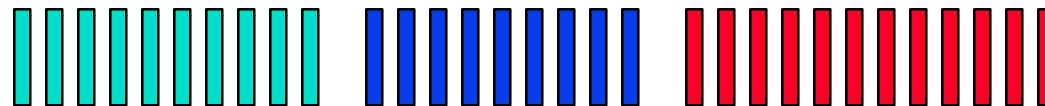
Out-Of Phase Effect

- ❑ Bursty load and backward RM cells are often out of phase.
- ❑ When there is load in the forward direction, there are no BRMs.
- ❑ By the time the switch sees BRMs, there is no load in the forward direction.
- ❑ The above effect disappears when the bursts become larger than RTT



Flocking Effect

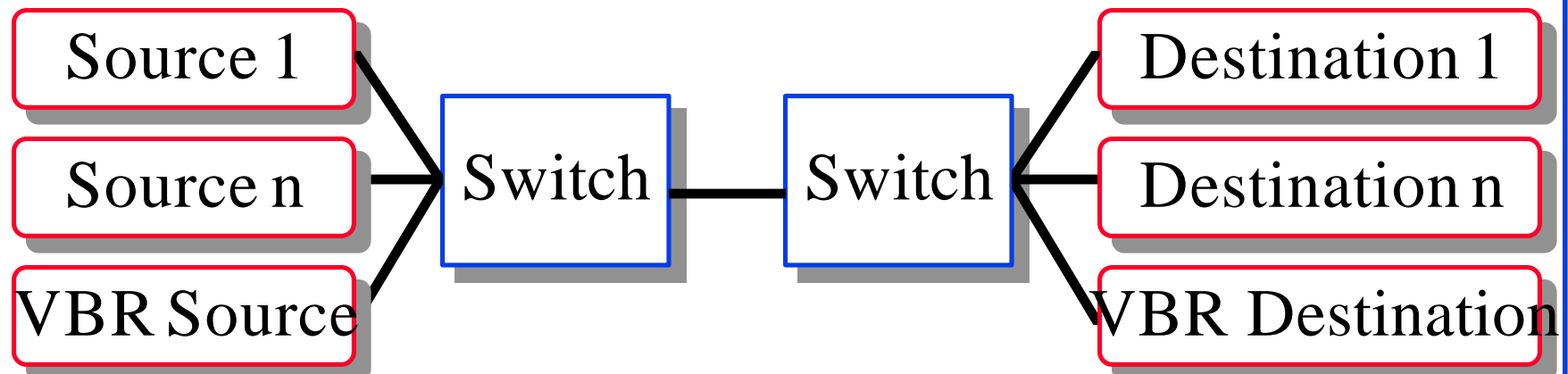
- ❑ All cells of a VC are often seen together.
- ❑ There is clustering of sources.
- ❑ Not all sources are seen all the time.
- ❑ TCP traffic is an example of "variable demand"
ABR traffic.



TCP over ABR: Buffering

- ❑ Buffering depends heavily upon switch scheme.
- ❑ For the ERICA scheme and the traffic loads considered:
 - ❑ W/o VBR, $3 \times \text{RTT}$ buffers will do for any number of TCP sources
 - ❑ In general, $Q_{\max} = a \times \text{RTT} + b \times \text{Averaging Interval} + c \times \text{Feedback delay} + d \times \text{fn}(\text{VBR})$
- ❑ After TCP sources are rate-limited:
Switch queues become zero, source queues build up

n Source + VBR Configuration



← 1000 km → ← 1000 km → ← 1000 km →

- ❑ All links 155 Mbps
- ❑ If VBR background , y ms on, y ms off, start at $t = 2$ ms
All traffic unidirectional; Large file transfer application
- ❑ # sources = 15, FRTT = 30 ms, Feedback Delay = 10 ms
- ❑ Source buffer size = 100, 1000, 10000, 100000, ∞ cells.

Simulation Parameters

- Source: Parameters selected to maximize ACR

TBE = 512

CDF = 0.5

ICR = 10 Mbps

ADTF = 0.5 sec

PCR = 155.52 Mbps, MCR = 0, RIF (AIR) = 1,

Nrm = 32, Mrm = 2, RDF = 1/512

Traffic: TCP/IP with Infinite source application

- Switch: ERICA+

Averaging interval = $\min\{100 \text{ cells}, 100\mu\text{s}\}$ and other values

TCP/IP Parameters

- ❑ Maximum Segment Size = 512 bytes
- ❑ Timer granularity = 100 ms
- ❑ No TCP processing time
- ❑ Max window = $16 \times 64 \text{ kB} = 24576 \text{ cells}$
One-way delay = 15 ms = 291 kB
- ❑ No delay ack timer
- ❑ Fast retransmit/recovery or Early packet drop (EPD) have no impact when there is no loss.

TCP over ABR on ATM Backbone with no VBR

Source Buffer (cells/VC)	Max Source Q (cells/VC)	Max Switch Q (total cells)	Total Throughput (Mbps)
100 ($< \text{Win}$)	> 100 (overflow)	8624 ($0.78 * \text{RTT}$)	73.27
1000 ($< \text{Win}$)	> 1000 (overflow)	17171 ($1.56 * \text{RTT}$)	83.79
10000 ($< \text{Win}$)	> 10000 (overflow)	17171 ($1.56 * \text{RTT}$)	95.48
100000 ($> \text{Win}$)	23901 ($0.97 * \text{Win}$)	17171 ($1.56 * \text{RTT}$)	110.90

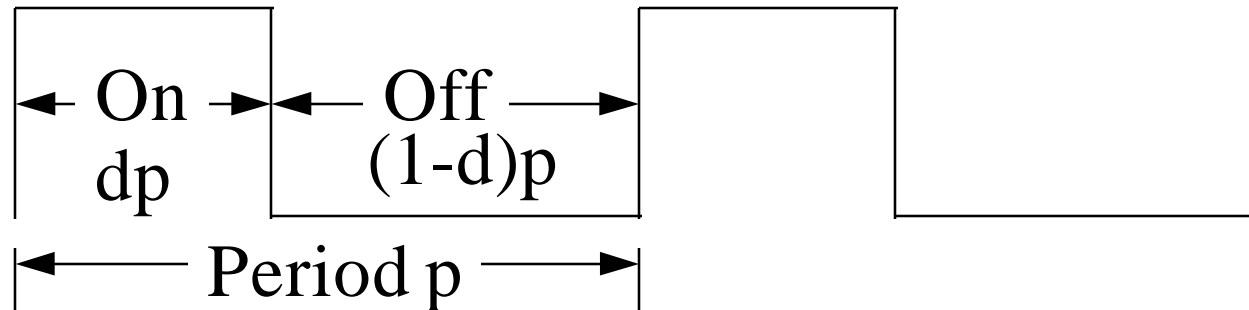
ATM Backbone (Cont)

- ❑ Source buffering = Receiver window per VC
- VC's data in network
- ❑ Total source buffering
= Edge router buffering
= Sum of receiver windows
= UBR switch buffering
- ❑ Switches reach maximum queue given minimum source buffering.

Implications for Edge Routers

- ❑ ABR pushes the TCP queues to the edge of the ATM network
- ❑ To avoid cell loss, edge routers need one window of buffering per TCP connection
- ❑ If limited buffers and edge routers cannot flow control TCP sources, performance degradation is same irrespective of whether the loss occurs at the ATM source or the switch
- ❑ ATM network buffering less for ABR
⇒ Benefit for ABR service providers
Low queues ⇒ Low delay in the network

Parameters



- ❑ Number of sources = 15
- ❑ Infinite source and switch buffer size
- ❑ VBR: Duty cycle $d = 0.9, 0.8, 0.7$
- ❑ Period $p = 1, 10, 100$ ms
- ❑ On time = $d \cdot p$, Off time = $(1-d) \cdot p$
- ❑ All traffic unidirectional, large file transfer application

Effect of VBR On-Off Times

#	Duty Cycle(d)	Period (p)	Max Switch Q
		(ms)	(cells)
1.	0.95	100	2588 (0.23*RTT)
2.	0.80	100	5217 (0.47*RTT)
3.	0.70	100	5688 (0.52*RTT)
4.	0.95	10	2709 (0.25*RTT)
5.	0.80	10	Diverges
6.	0.70	10	Diverges
7.	0.95	1	2589 (0.23*RTT)
8.	0.80	1	4077 (0.37*RTT)
9.	0.70	1	2928 (0.26*RTT)

Effect of VBR On-Off Times

- ❑ Queues small for large or small on-off times.
- ❑ Queues unbounded for some medium on-off time cases.
- ❑ Off-times Effect: High rate feedback vs queue drain
- ❑ Unbounded queues if high rate feedback dominates

Effect of Feedback Delay

Feedback Delay	RTT	Duty Cycle (d)	Period (p)	Max Switch Q
1 ms	3 ms	0.8	10 ms	4176 cells (0.4*RTT)
5 ms	15 ms	0.8	10 ms	Diverges
10 ms	30 ms	0.8	10 ms	Diverges

- ❑ Queues may be bounded for small feedback delays, but unbounded for large feedback delays.
- ❑ Time to allocate high rate
= MIN (Off Time, Feedback delay)
- ❑ Time to control overload = $c * \text{Feedback delay}$

Effect of Switch Scheme

- ❑ Switch scheme needs to overcome effects of variance
- ❑ TCP: variance in ABR demand
- ❑ VBR: variance in ABR capacity
- ❑ Variance \Rightarrow Errors in measurement
 \Rightarrow Errors in feedback \Rightarrow Queues

Enhancements to ERICA

- ❑ ERICA+ uses queueing delay as an additional metric
- ❑ Longer averaging interval:
 - Averages with less variance
 - Trades off stability for responsiveness
- ❑ Averaging of number of active sources
- ❑ Averaging of overload factor
- ❑ Boundary Conditions: zero load, no sources seen

Effect of Switch Scheme: Results

Avg Interval	Averaging of Na?	Averaging of z?	Duty Cycle d	Period p(ms)	Switch Queue
(n cells, T ms)	($A_n = 0.9$)	($A_z = 0.2$)			(cells)
(100, 1)	Yes	Yes	0.7	20	5223
(500, 5)	Yes	No	0.7	20	5637

- ❑ All cases, we studied, have small bounded queues.
- ❑ Averaging of number of sources required.
- ❑ Averaging of overload is approximately equivalent to using a larger interval
- ❑ Longer averaging interval \Rightarrow lesser processing cost.

Summary

- ❑ ABR pushes TCP queues to the edge of the network.
- ❑ Edge routers require buffers equal to the sum of TCP receiver windows for zero loss over ABR.
- ❑ TCP and VBR produce a variable demand and variable capacity workload
⇒ Unbounded queues with simple ABR schemes.
- ❑ VBR on-off time and feedback delay are important factors.
- ❑ ERICA+ enhancements help convergence of queues:
Averaging of N and overload factor, longer averaging intervals, and boundary conditions