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TCP/IP over ABR

[Was: TBE and TCP/IP Traffic]

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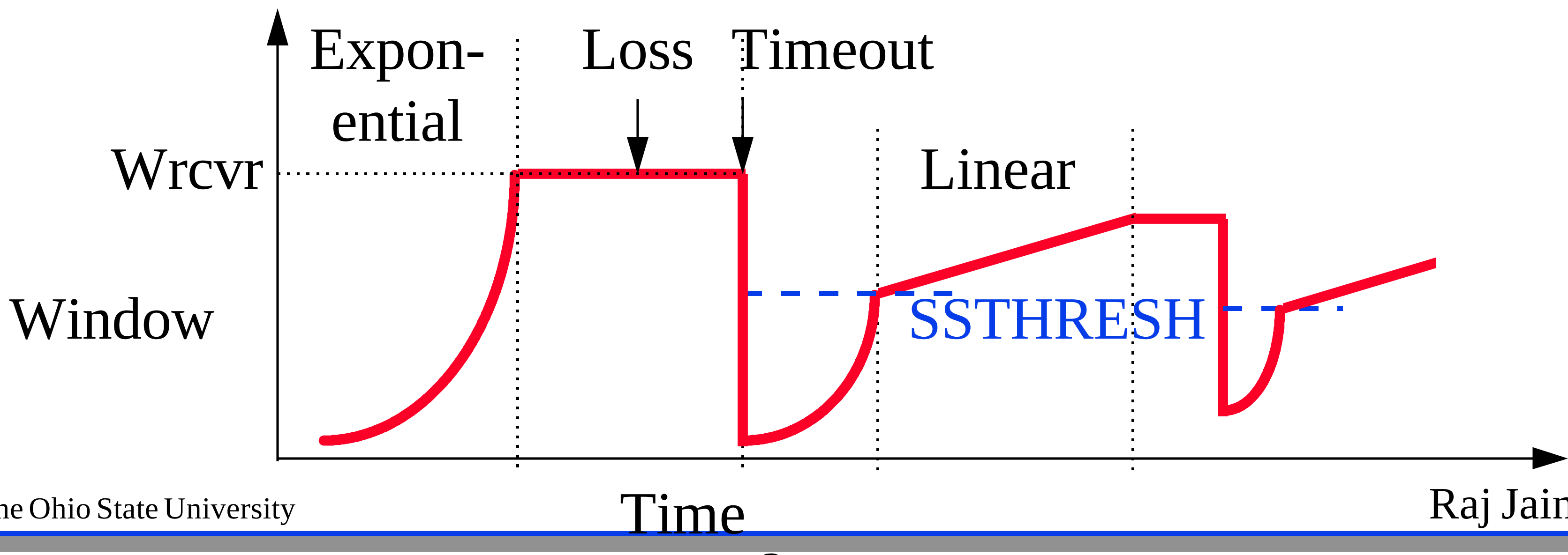
- TCP/IP's load control mechanisms
  Slow-start, Timeout, Retransmissions
- Simulation Results
  ABR + Finite buffers + 100 ms granularity + WAN
- Effect of TBE and finite buffers
- Effect of timer granularity, tail drop, VBR

TCP/IP Slow Start

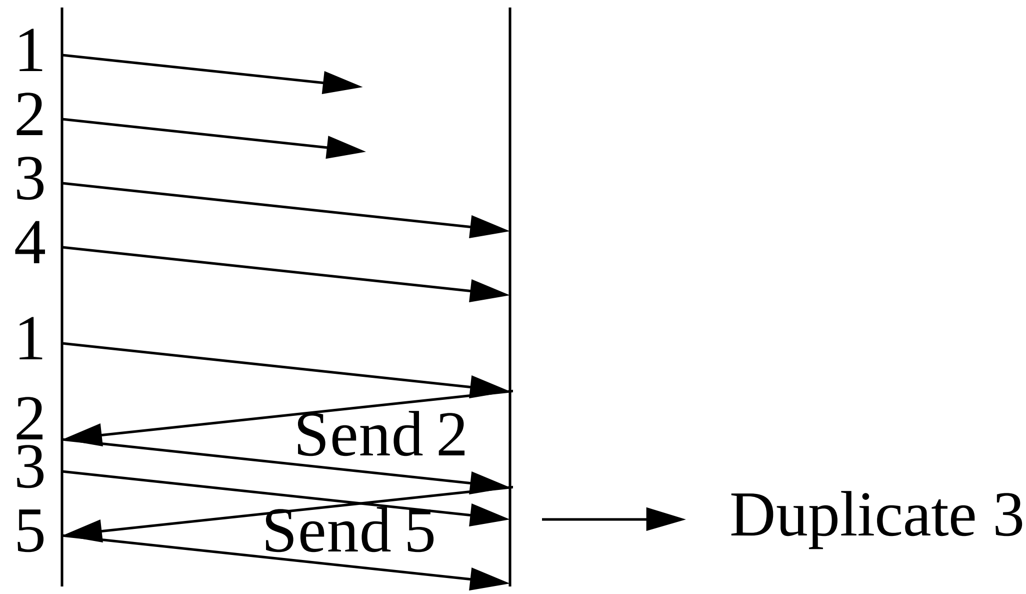
- Maximum Segment Size (MSS) = 512 bytes
- Congestion Window (CWND)
- Window W = Min{Wrcvr, CWND}
- Slow-Start Threshold = max{2,min{CWND/2,Wrcvr}}
- Exponential until SSTHRESH: W = W+1 for every ack
- Linear afterwards: W = W + 1/W for every ack until Wrcvr



Timeout and Timer Granularity

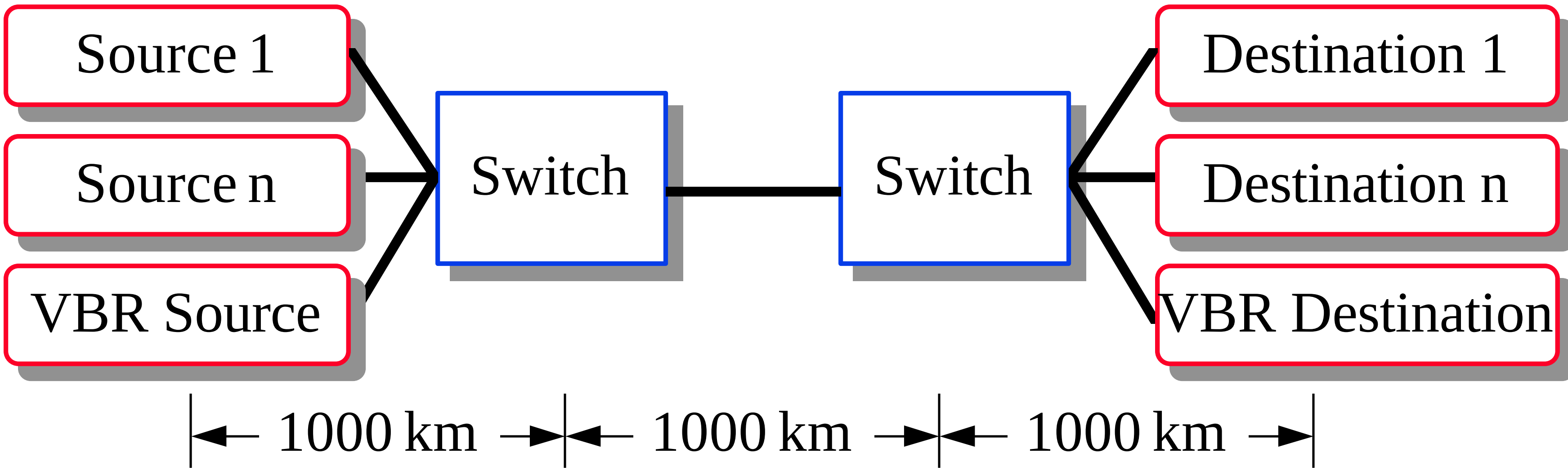
- Remember segment # and Send_time
- Upon acknowledgment: RTT = Now - Send_time
- Keep an exponential average of mean and std. dev. of RTT
- Retransmissions ⇒ Ignore the measured value
  Cumulative Ack ⇒ Use it as usual
- Timeout = Mean + 4 × Std. Dev.
- Only one packet is timed
- All times are measured using a granularity of 100 ms
  (500 ms in Solaris and all BSD implementations)
- RTT < 100 ms ⇒ RTT = 100 ms
- Upon retransmission: Timeout = 2 × Timeout until 128 ticks

Packets Dropped at Destination



- On every loss of n packets, time lost = Timeout + fn(n) RTT

n Source + VBR Configuration



- All links 155 Mbps
- If VBR background , 100 ms on, 100 ms off, start at t = 2ms
- All traffic unidirectional, Large file transfer application
- Parameters: # sources={2, 5}
  Buffer size = TBE × # sources × {1, 2, or 4}

Simulation Parameters

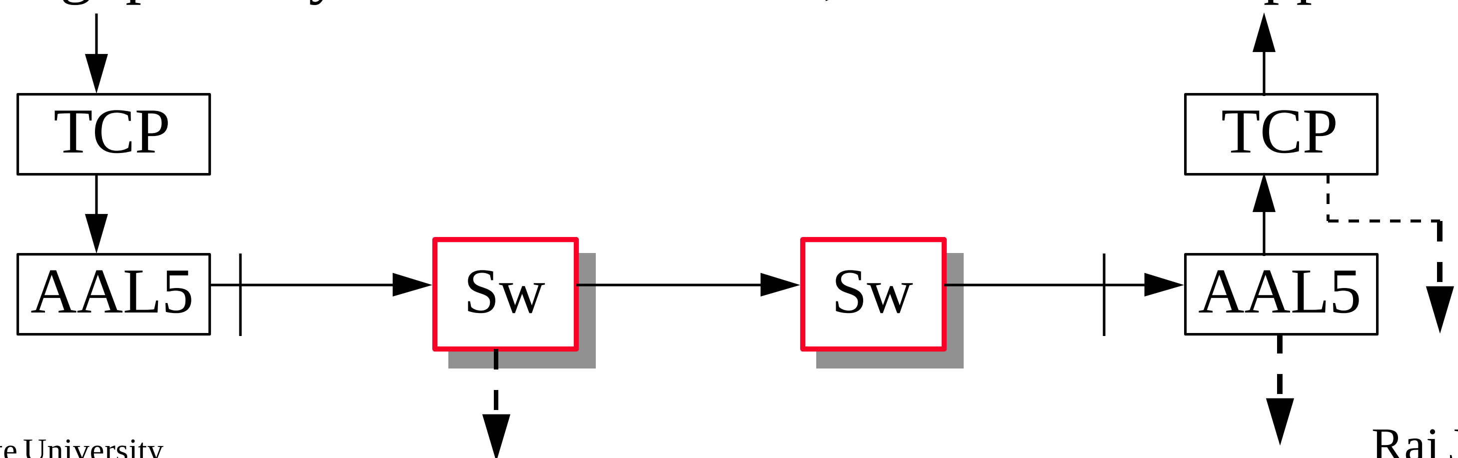
- Source: Parameters selected to maximize ACR
  TBE = 128, 512
  CDF (XDF) = 0.5
  ICR = 10 Mbps
  CRM (Xrm)= ⌈ TBE/Nrm ⌉
  ADTF = 0.5 sec
  PCR = 155.52 Mbps, MCR= 0, RIF (AIR) = 1,
  Nrm = 32, Mrm = 2, RDF = 1/512, Trm =100ms, TCR = 10 c/s
- Traffic: TCP/IP with Infinite source application
- Switch: ERICA modified
  Target Utilization = 90%
  Averaging interval = min{100 cells, 1000 μs}

TCP/IP Parameters

- Maximum Segment Size = 512 bytes
- Timer granularity = 100 ms
- Fast retransmit/recovery not completely experimented
- Early packet drop (EPD) not yet experimented
- No TCP processing time
- Max window = 16×64 kB,
  One-way delay = 15 ms = 145 kB
- No ack delay timer

Performance Metrics

- Sequence numbers at the source, Congestion window
- ACR, Link utilization, Queue length in the switch
- Bytes sent = Sent once + Retransmitted
  = Bytes delivered to application
  + data bytes dropped in the switch + bytes in the path
  + Partial packet bytes dropped at the destination AAL5
  + duplicate packet bytes dropped at the destination TCP
- Throughput = Bytes delivered/Time, CLR = Cells dropped/sent



Infinite Buffers & Fixed Capacity

- Buffer size = 4096, TBE = 512
- CLR = 0
- Maximum TCP throughput = 103.32 Mbps
- Throughput = 155 Mbps
  × 0.9 for ERICA Target Utilization
  × 48/53 for ATM payload
  × 512/568 for protocol headers
  (20 TCP + 20 IP + 8 RFC1577 + 8 AAL5 = 56 bytes)
  × 31/32 for ABR RM cell overhead
  × 0.9 TCP window startup period
- Fair
- ABR Rate limited

Finite Buffers & Fixed Capacity

- Buffer size = 2048, TBE =512
- CLR = 0.18%
- TCP throughput = 34.16 + 31.70 = 65.86 Mbps
  = 64% of Max
- 0.18% of CLR but 36% throughput loss
- Window limited
- Time lost in retransmissions
- With TCP, you don't loose cells but you loose time.

Simulation Results: Summary

# srcs	TBE	Buffer Size	T1	T2	T3	T4	T5	Throughput	% of Max	CLR.
2	128	256	3.1	3.1				6.2	10.6	1.2
2	128	1024	10.5	4.1				14.6	24.9	2.0
2	512	1024	5.7	5.9				11.6	19.8	2.7
2	512	2048	8.0	8.0				16.0	27.4	1.0
5	128	640	1.5	1.4	3.0	1.6	1.6	9.1	15.6	4.8
5	128	1280	2.7	2.4	2.6	2.5	2.6	12.8	21.8	1.0
5	512	2560	4.0	4.0	4.0	3.9	4.1	19.9	34.1	0.3
5	512	5720	11.7	11.8	11.6	11.8	11.6	58.4	100.0	0.0

- CLR has high variance
- CLR does not reflect performance. Higher CLR does not necessarily mean lower throughput
- CLR and throughput are one order of magnitude apart
- Bursty losses are less damaging than scattered losses

Observations I

- TCP's slow-start does reduce network load
  Most of the queues are at the source
  Not much queue in the switch
- CLR in the switch is low
  But, throughput is also low
  - TCP does not use all the available bandwidth
  - Many packets are dropped at the destination
  - Much time is lost due to timer granularity
- Lower CLR does not mean higher throughput

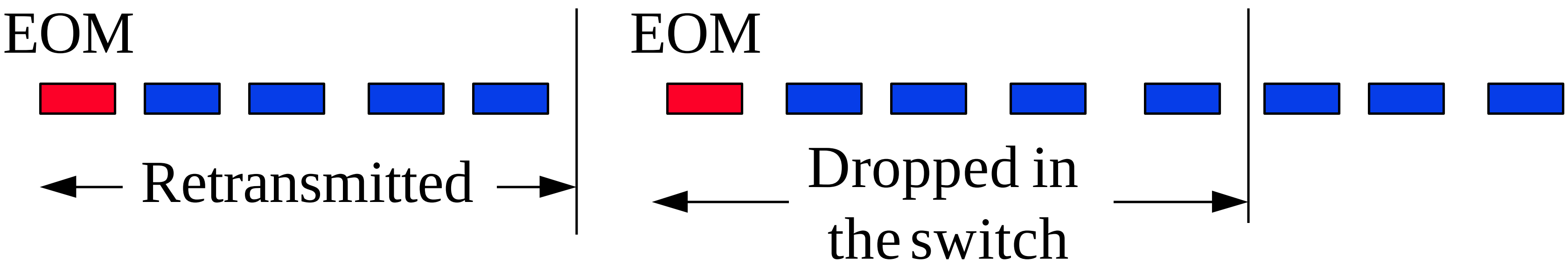
Observations II

- Larger buffer size ⇒ Higher throughput
- Effect of buffers on CLR is mixed.
  Larger buffer ⇒ CLR may be lower
  or may be higher (if loss occurs at a higher window)
- TBE's effect on throughput is mixed
  Lower TBE ⇒ Rule 6 ⇒ Less CLR ⇒ Higher throughput
  Lower TBE ⇒ Rule 6 ⇒ Rate limited ⇒ Lower throughput
- Only very low values of TBE's produce different result.
- In general, TBE of 512 or higher has no effect in this configuration

Observations III

- As the number of sources is increased, generally the total throughput increases
- TCP sources are generally window limited.
  Five sources with small windows pump more data than two sources with small windows
- Interaction among: TBE, buffer size, and number of sources

Tail Drop

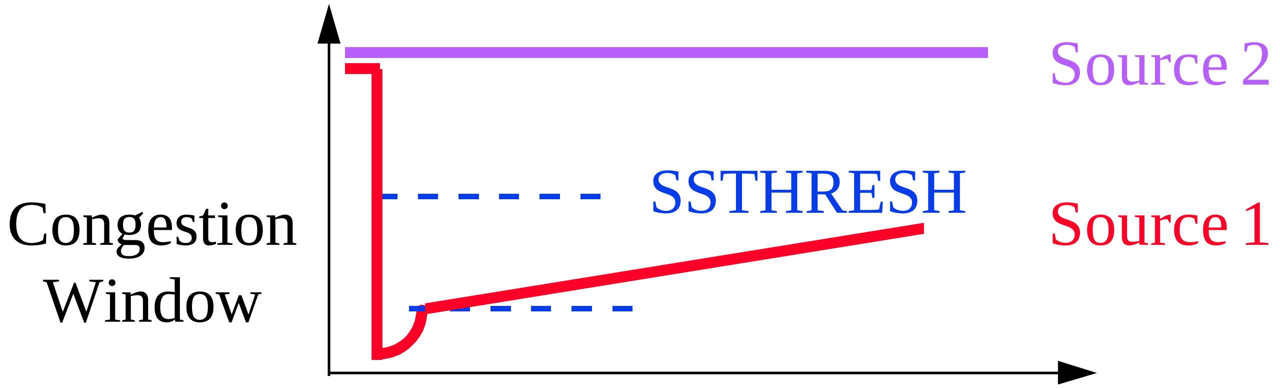


- AAL5 marks the last cell by End-of-Message (EOM)
- If EOM is dropped
  Retransmitted packet gets merged with previous partial packet.
  Fails CRC and is dropped at the destination by AAL5

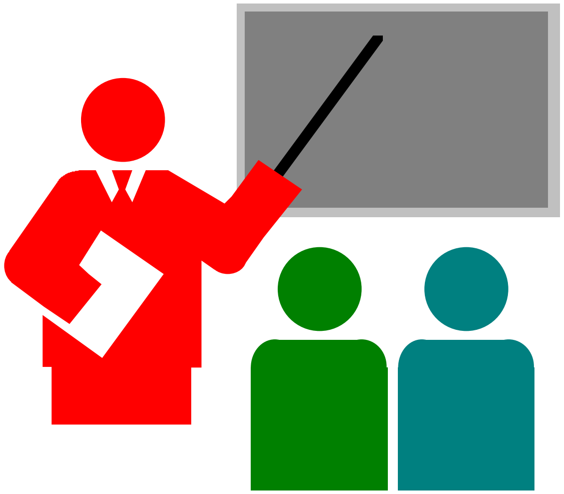
⇒ Two retransmissions in a row

Tail Drop (Cont)

- Two retransmissions in a row
  - On 1st Retransmission: SSTHRESH = W/2; W = 1
  - On 2nd Retransmission: SSTHRESH = 2, W = 1
    ⇒ Window is increased linearly
    ⇒ Very low throughput
    ⇒ Unfairness
- Intelligent Tail Drop: Do not drop EOM ⇒ Improved fairness



Summary



- TCP's slow-start + ABR's Load Control = Overcontrol
- With TCP, you may not lose cells but you lose time
  ⇒ Lower CLR but also lower throughput
- Time lost depends upon timer granularity.
- Buffers help. TBE and number of sources interact.
- Indiscriminate cell drop may cause unnecessary retransmissions and unfairness ⇒ Try not to drop EOM cells

Fast Retransmit and Recovery

- Idea: Don't wait for time-outs. Duplicate Acks indicate loss.
- Upon 3 duplicate acks, assume loss:
  - Set SSTHRESH = max{2, min{CWND/2, Wrcvr}}
  - Retransmit one packet
  - Set CWND = SSTHRESH + 3
  - For every duplicate ack: CWND = CWND + 1
  - At new ack: CWND = SSTHRESH
    This results in a sudden burst
- Reset duplicate ack count on piggybacked acks
  Intermingled duplicate and piggybacked acks $\Rightarrow$ No action

Effect of Fast Retransmit

- Fast retransmit helps only if occasional losses
  Mild congestion or errors
- With n packet loss, SSTHRESH is reduced to half after each retransmission. Window enters the linear-increase zone even when the window is small $\Rightarrow$ Low throughput.
- Even with fast retransmits, there are time-outs when the losses are bursty. These time-outs are more damaging than if there is no fast retransmit since SSTHRESH is low.

	Bursty Loss	Scattered Loss
With Fast-Retransmit Fast-Recovery	×	√
Without Fast-Retransmit Fast-Recovery	√	×