# 97-0617: Worst Case Buffer Requirements for TCP over ABR

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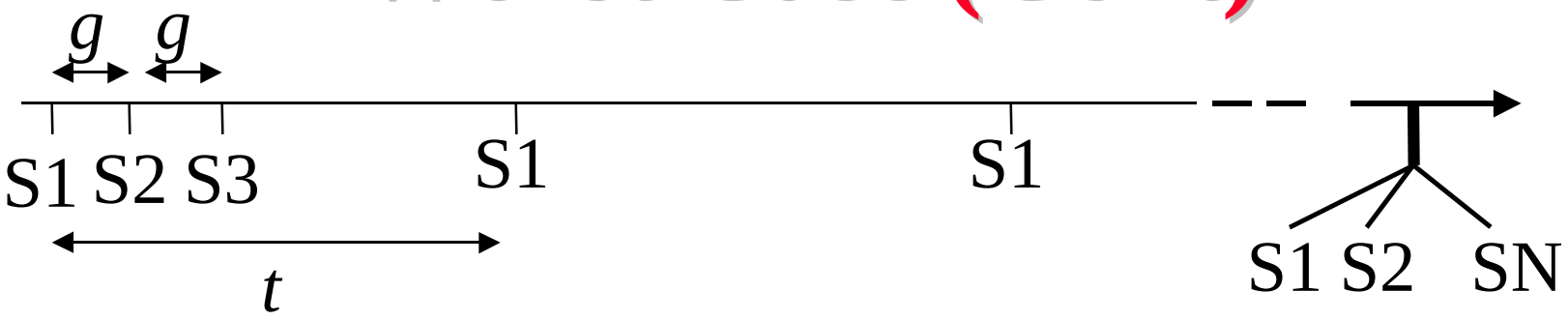
# Overview

- Generating Worst Case TCP Traffic
- Analytical Results
- Simulation Results
  - Effect of number of sources
  - Effect of RTT, MSS, and other parameters

# Worst Case TCP Traffic

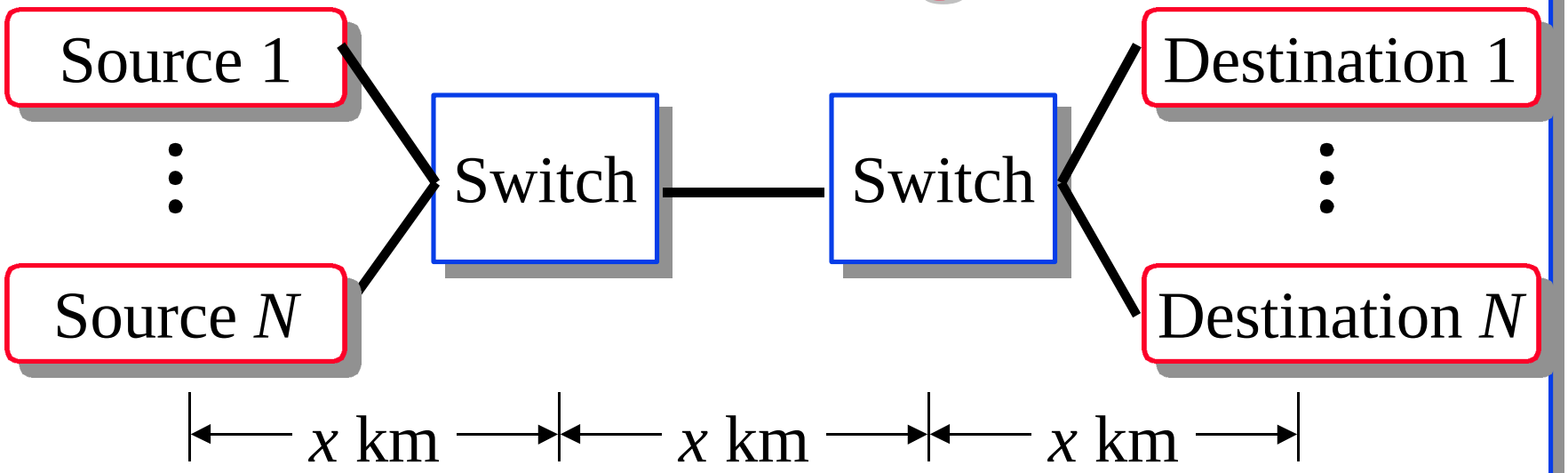
- Sources can retain high ACR, if they send packets within 500 ms.
- Many such sources with high ACR can dump a large amount of data
- Worst case is when all the sources dump the maximum window size

# Worst Case (Cont)




- Each source sends one packet every '*t*' milliseconds. $t < 500$ ms.
- After several packets, the congestion window reaches the maximum for each source
- Sources synchronize and dump large burst at the same time.
- To avoid overload initially, the sources are uniformly spaced Þ *k*th source sends its first packet at '$k \times g$' µs.

# *N*-Source Configuration




- All links 149.76 Mbps. Lengths $x$ = 2000, 1000 km
- All traffic unidirectional. Worst case TCP traffic
- Parameters: # of sources={2, 3, 5, 10, 20, 30, …, 200} Infinite buffer size.

# Analytical results

- Buffer requirement is reflected in maximum switch queue size.
- Let cwnd_max = Max congestion window of TCP
- When $N \leq \lfloor t/g \rfloor$
  - Max Q length $\approx N \times$ cwnd_max/48 (formula 1)
- When $N > \lfloor t/g \rfloor$ ↑ 48 bytes/cell
  - Max Q length = N*PCR*t (formula 2)
    (PCR is peak cell rate)
- Queue length is given in terms of number of cells

# Analytical results (Cont)

- With few sources, switch does not get congested even when sources reach their maximum window, ACRs can be high. Formula 1 applies here.
- With many sources, switch detects congestion and gives feedback. ACRs are low. Formula 2 applies here.

# Simulation Parameters

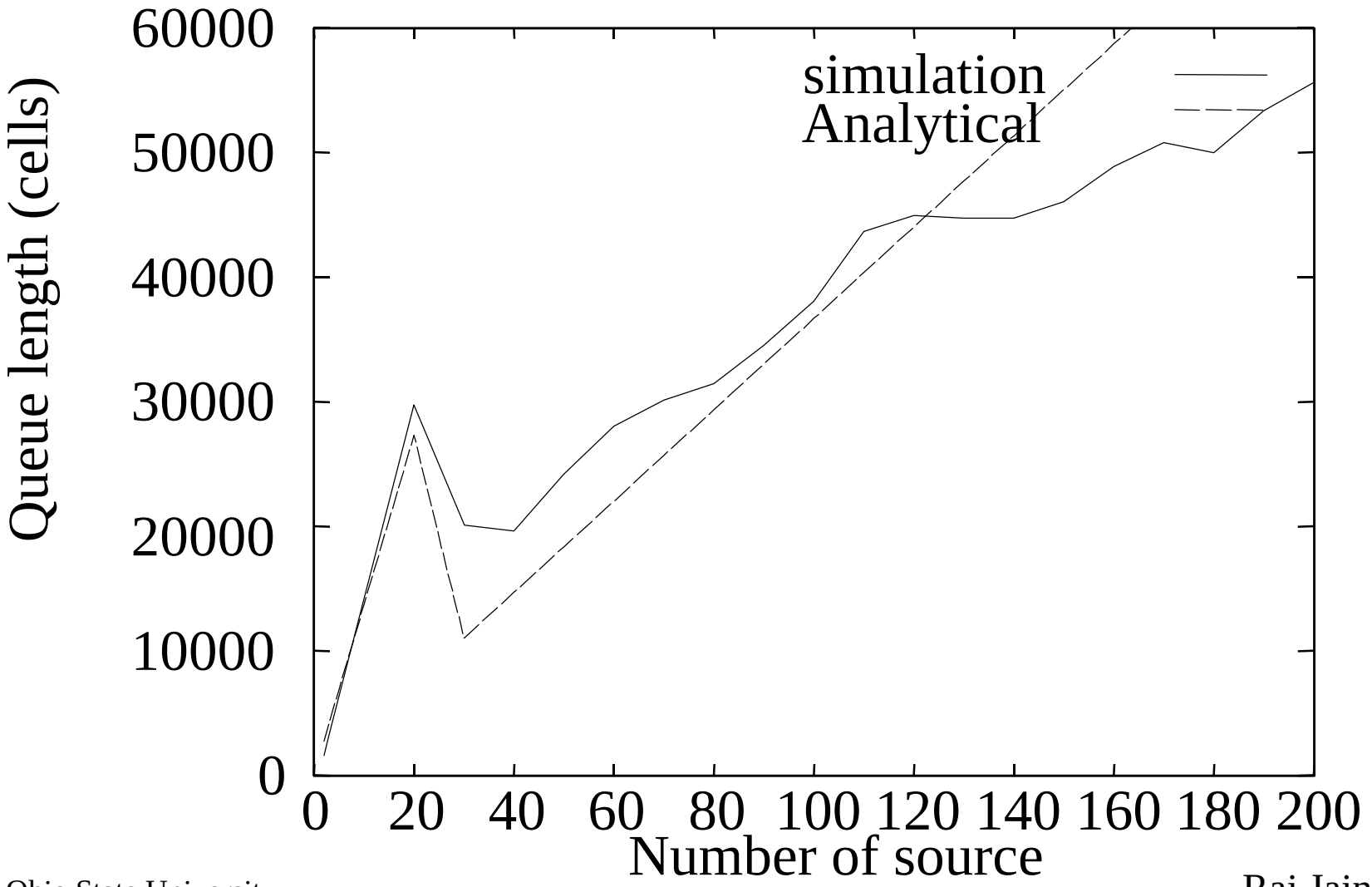
- Source: Parameters selected to maximize ACR
  TBE = 512
  CDF (XDF) = 0.5
  ICR = 10 Mbps
  CRM (Xrm)=⌈ TBE/Nrm ⌉
  ADTF = 0.5 sec
  PCR = 149.76 Mbps, MCR= 0, RIF (AIR) = 1,
  Nrm = 32, Mrm = 2, RDF = 1/512, Trm =100ms,
  TCR = 10 c/s
- Traffic: TCP/IP with worst case traffic
- Switch: ERICA+
  Averaging interval = min{100 cells, 1000 μs}

# Effect of Number of Sources

| # TCP Srcs | Q Size (Cells) | |
|---|---|---|
| | Simul. | Analyt. |
| 2 | 1575 | 2730 |
| 3 | 3149 | 4095 |
| 5 | 6297 | 6825 |
| 10 | 14131 | 13650 |
| 20 | 29751 | 27300 |
| 30 | 20068 | 11010 |
| 40 | 19619 | 14680 |
| 50 | 24162 | 18350 |
| 60 | 28006 | 22020 |

| # TCP Srcs | Q Size (Cells) | |
|---|---|---|
| | Simul. | Analyt. |
| 70 | 30109 | 25690 |
| 80 | 31439 | 29360 |
| 90 | 34530 | 33030 |
| 100 | 38088 | 36700 |
| 120 | 44939 | 44040 |
| 140 | 44744 | 51380 |
| 160 | 48880 | 58720 |
| 180 | 49961 | 66060 |
| 200 | 55618 | 73400 |

# Effect of # of Sources (Cont)



# Effect of # of Rources (Cont)

- Analytical results: For t = 1 ms, g = 50 μs, MSS = 512 bytes, cwnd_max = 64 kB
  - Q = N*1365 for N ≤ 20 (formula 1)
  - Q = N*367 for N > 20 (formula 2)
- The zig-zag shape is due to the two formulas
- The simulation agrees well with the analytical results for N ≤ 20.
- The maximum queues occurred at predicted times (details in the contribution)

# Effect of # of Sources (Cont)

- Buffer size increases linearly as number of sources increase
- As N increases, load increases
  $\Rightarrow$ ERICA+ controls the queue lengths $\Rightarrow$ Less than analytical queue lengths

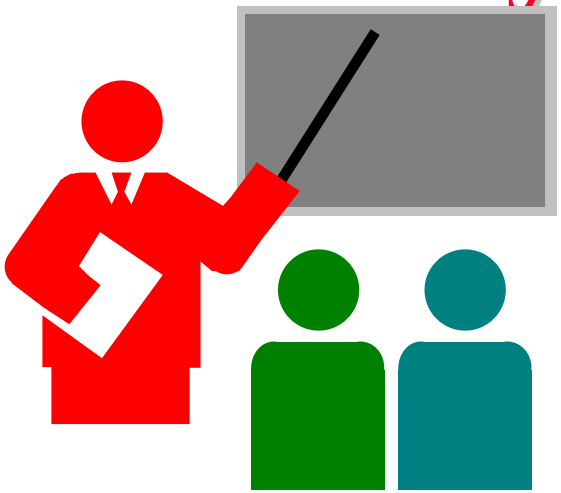
# Sensitivity Analysis

| # | mss/g/t/d | N=3 | N=10 | N=30 | N=40 | N=50 | N=100 |
|---|---|---|---|---|---|---|---|
| 1 | 512/50/1/1000 | 3171 | 14273 | 20068 | 19619 | 24162 | 35687 |
| 2 | 512/50/1/2000 | 3171 | 14273 | 19906 | 27567 | 30872 | 75083 |
| 3 | 512/50/10/1000 | 3172 | 14274 | 45994 | 61854 | 77714 | 150453 |
| 4 | 512/50/10/2000 | 3172 | 14274 | 45994 | 61854 | 77714 | 150458 |
| 5 | 512/100/1/1000 | 3171 | 14273 | 19283 | 20080 | 24164 | NA |
| 6 | 512/100/1/2000 | 3171 | 14273 | 21241 | 32314 | 35961 | NA |
| 7 | 512/100/10/1000 | 3172 | 14274 | 45994 | 61854 | 77714 | NA |
| 8 | 512/100/10/2000 | 3172 | 14274 | 45994 | 61854 | 77714 | NA |
| 9 | 1024/50/1/1000 | 3040 | 13680 | 18650 | 18824 | 23542 | NA |
| 10 | 1024/50/1/2000 | 1542 | 5612 | 19131 | 22934 | 29163 | NA |
| 11 | 1024/50/10/1000 | 3040 | 13680 | 44080 | 59280 | 74480 | NA |
| 12 | 1024/50/10/2000 | 3041 | 13681 | 44081 | 59281 | 74481 | NA |
| 13 | 1024/100/1/1000 | 3040 | 13680 | 18591 | 19600 | 24314 | NA |
| 14 | 1024/100/1/2000 | 1403 | 5556 | 17471 | 24412 | 30533 | NA |
| 15 | 1024/100/10/1000 | 3040 | 13680 | 44080 | 59280 | 74480 | NA |
| 16 | 1024/100/10/2000 | 3041 | 13681 | 44081 | 59281 | 74481 | NA |

# Sensitivity Analysis: Results

- MSS = 512, 1024 bytes, t = 1, 10 ms, g = 50, 100 μs, Link distance = 1000, 2000 km
  Two values for each of the 4 parameters ⇒ 16 experiments.
- Segment size does not affect queue sizes
- If the network is not overloaded then round trip time has no effect (Expt. 3 and 4)
- If the network is overloaded then a larger round trip gives larger queue lengths (Expt. 1, 2 for N = 30, 40, 50)

# Summary



- In worst case, the buffer requirements depend on the number of sources, network congestion status (overloaded or underloaded) and round trip time
- It is not affected by maximum segment size.