97-0177
Performance of TCP over ABR with Long-Range Dependent VBR Background Traffic Over Terrestrial and Satellite ATM Networks

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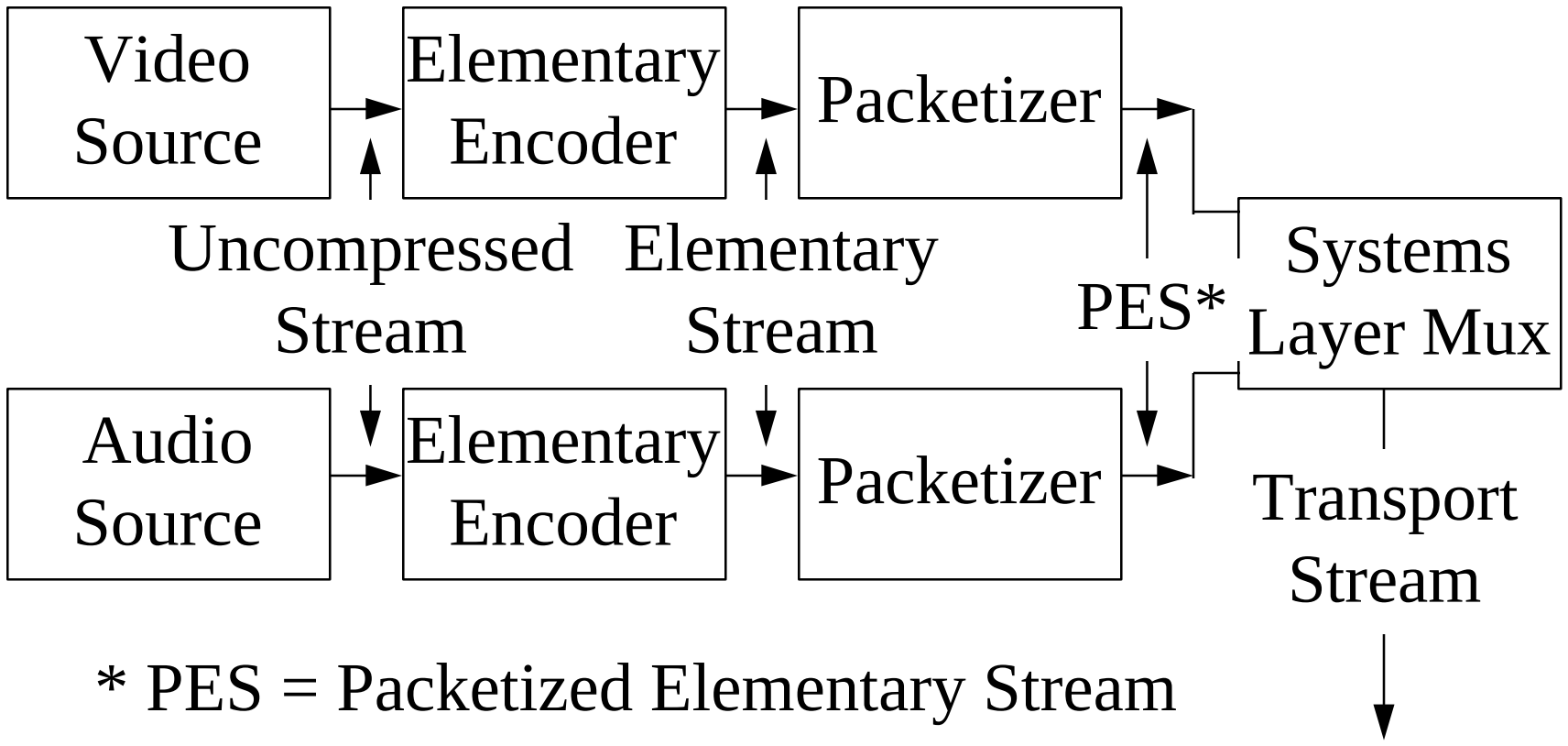
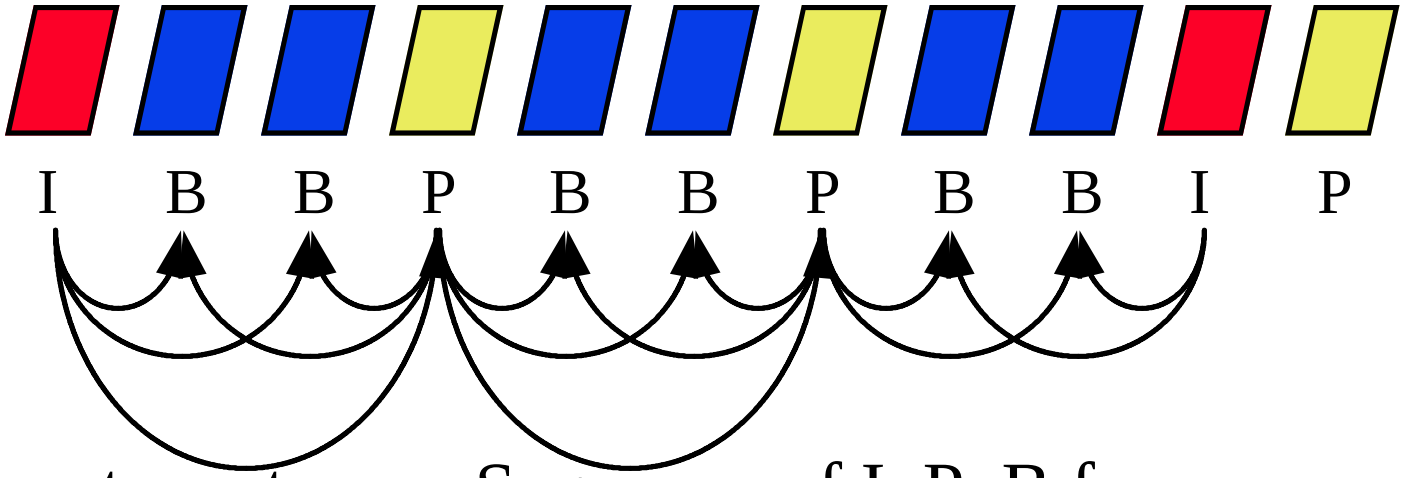
- MPEG2 over ATM Overview
- Modeling MPEG2 Transport Streams over VBR
- Simulation Results for Terrestrial Networks
- Simulation Results for Satellite Networks

MPEG-2 Over ATM



ATM cells 188-byte packets

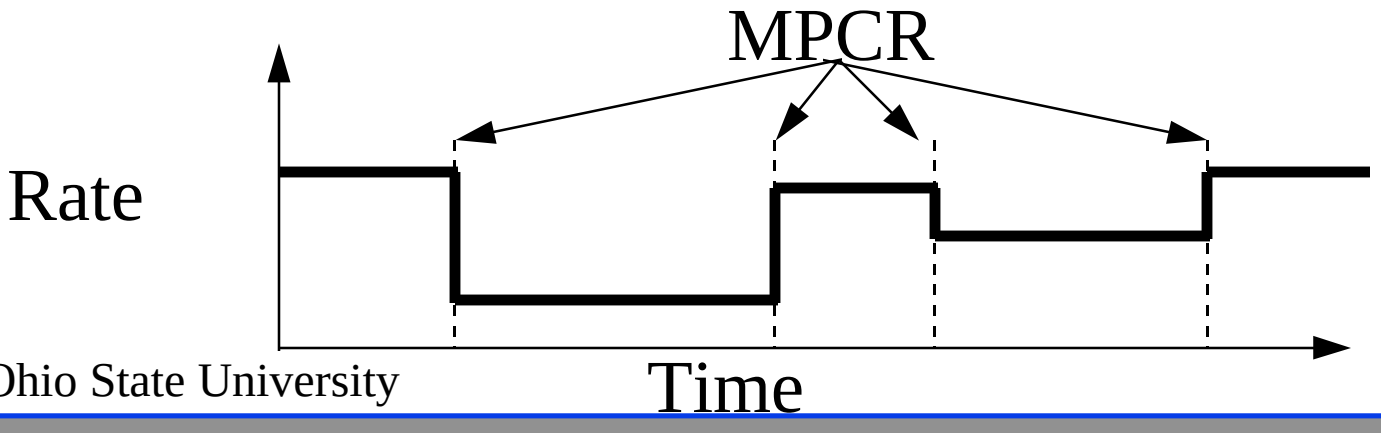
Elementary Stream



- Elementary stream: Sequence of I, P, B frames
  - Individually coded **I** frames - Large
    Transmission time = 4 to 5 frame display time
  - Predictively coded **P** frames - Medium
    Transmission time = 0.5-1 frame display time
  - Bidirectionally coded **B** frames - Small
    Transmission time = 0.2 frame display time

Timestamps in MPEG2

- Frames may contain a presentation timestamp.
- To synchronize the clocks, a sample of system clock is sent every 80μs to 100 ms
  MPEG2 Program Clock Reference (MPCR)
  We use MPCR instead of PCR (Peak Cell Rate)
- MPCRs are used by a phase lock loop
  ⇒ Rate between MPCRs must be constant



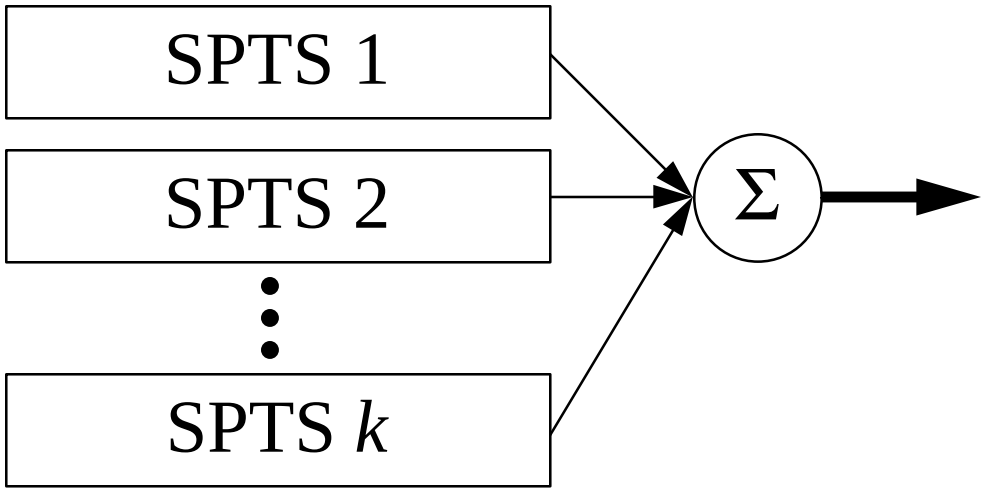
Program vs Transport Streams

- Program stream = One program, e.g., one movie.
  Designed for MPEG1 compatibility.
  Mostly for local video.
- Transport stream = Multiple programs, e.g., a cable.
  Designed for remote video.
- For networking applications, only transport streams are of interest.
- We model each video source as a "Single Program Transport Stream (SPTS)"

MPEG2 Traffic Characteristics

- Single Program Transport Stream
- Piecewise CBR
- Rate changes only at MPCRs
- Inter-MPCR interval is random
  Standard allows 80μs to 100 ms interval
  Most implementations change only 20 to 100 ms
- Rate values have a long-range dependence

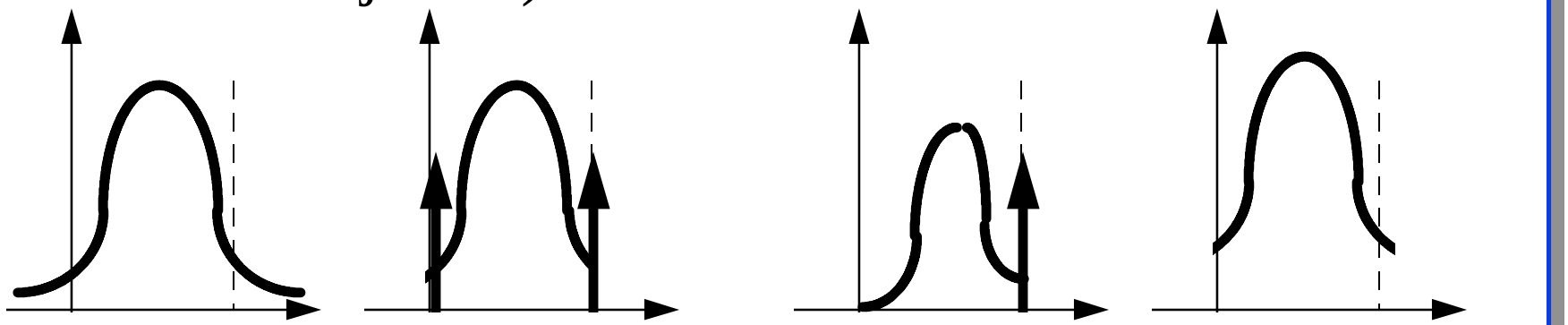
VBR Traffic Model



- VBR background = Sum of *k* transport streams
- Each transport stream has
  - a random inter-MPCR interval = Uniform(20,100)
  - a random long-range dependent rates (Fractional Gaussian Noise)

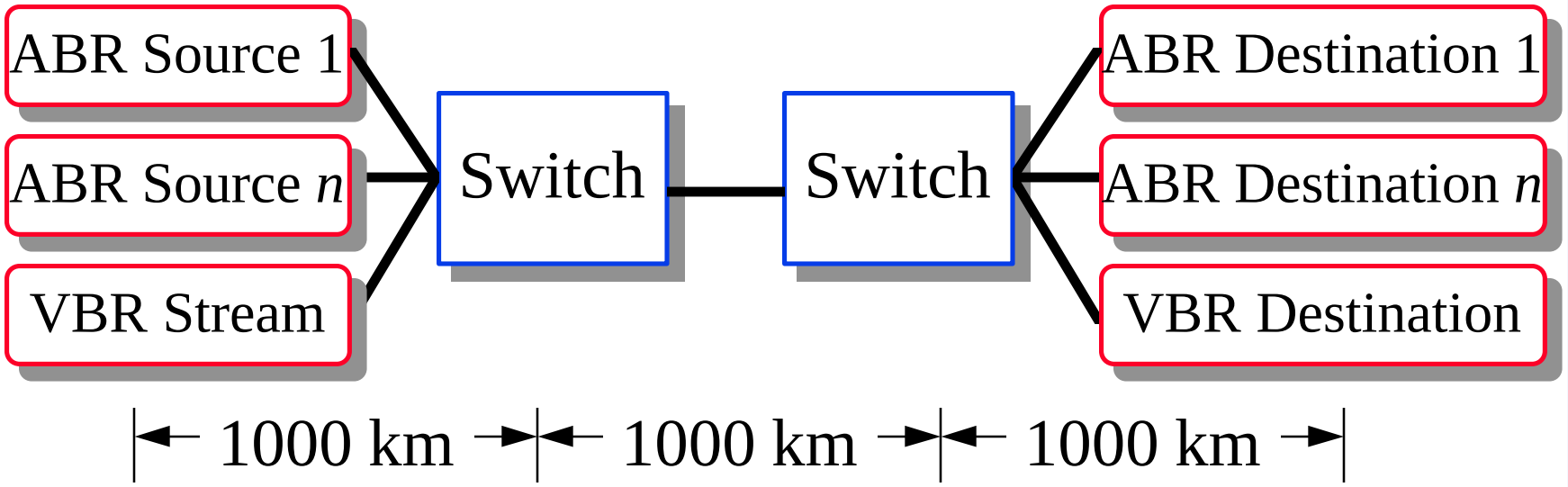
VBR Model (Cont)

- Maximum bandwidth demand = 15 Mbps
  Minimum bandwidth demand = 0 Mbps
  ⇒ Random numbers below 0 or above 15 are ignored (Pruning)
  (Alternative choices: clipping or exponentiation were rejected).



(a) Gaussian (b)Clipping Min{Max{0, x}, 15} (c) Exponentiation Min{2^x, *15}* (d) Pruning

n Source + VBR WAN Configuration



- All links 155 Mbps
- If VBR background , sum of *k* independent SPTSs
  Various mean and variances, H=0.8
- All traffic unidirectional; Large file transfer application
- 15 ABR sources, RTT =30 ms, Feedback Delay = 10 ms

TCP over ABR

- 512 Bytes of data:
  = 512 B (data) + 20 B (TCP header)
  + 20 B (IP header) + 8 B (LLC/SNAP)
  + 8 B (AAL5 trailer)
  = 568 B = 12 Cells
  = 53 × 12 B × (32/31) = 656.5 B on wire
- Maximum TCP data throughput on 155.52 Mbps
  = (512/656.5) × 155.52 Mbps = 121.3 Mbps = 78%

Simulation Parameters

- Source: Parameters selected to maximize ACR
  TBE = 512
  CDF = 0 (Rule 6 disabled)
  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{500 cells, 5000 μs}
  Target queueing delay T0 = 0.5 ms, QDLF = 0.5
  ERICA+ curves: Hyperbolic with a=1.15, b=1.00

TCP/IP Parameters

- Maximum Segment Size = 512 bytes
- Timer granularity = 100 ms
- No TCP processing time
- Max window on WAN = 16 × 65,536 B
  = 10,485,760 B > 30 ms at 121.3 Mbps = 454,875 B
- Max window on Satellites = 256 × 34,000 B
  = 8,704,000 B > 550 ms at 121.3 Mbps = 8,339,375 B
- No delay ack timer
- Fast retransmit/recovery or Early packet drop (EPD) have no impact when there is no loss.

Performance Metrics

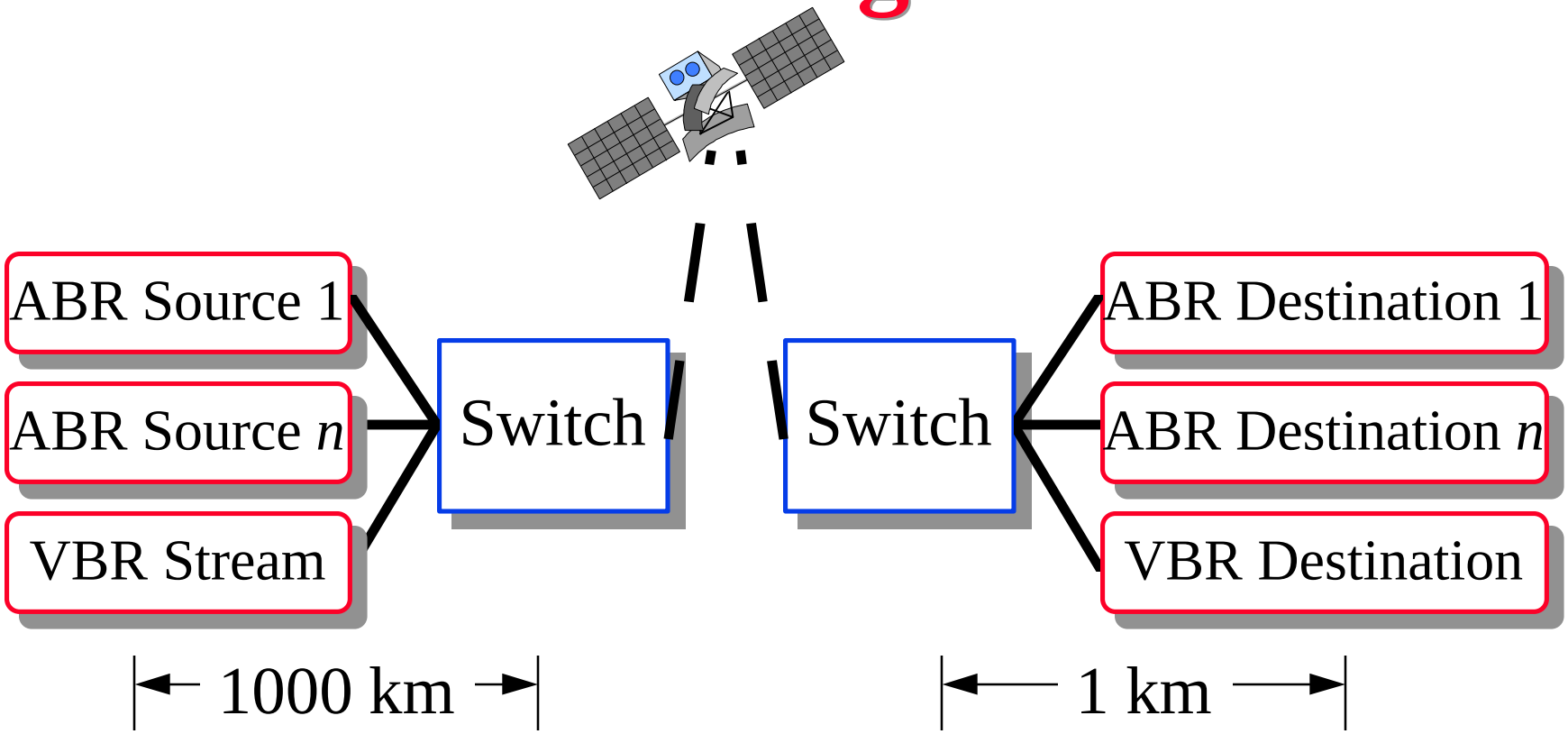
- ABR Capacity
  = Link Bandwidth - VBR mean rate
  Note 100% link bandwidth can be used in ERICA+.
  Not 90% as in ERICA.
- Max Possible TCP Throughput
  = 0.78 × ABR Capacity
- Efficiency
  = TCP Throughput/ Max Possible TCP Throughput
- Maximum queue length

WAN Simulation Results

Per-video Source		ABR Performance		
Mean Rate (Mbps)	Standard Deviation (Mbps)	Max Switch Queue (Cells)	TCP Throughput (Mbps)	Efficiency
5	5	11634 = 3.18 × F/b delay	76.77	95.2%
7.5	7	8175 = 2.22 × F/b delay	66.30	93.8%
10	5	3884 = 1.05 × F/b delay	56.52	91.8%

- Efficiency > 90% = Very close to maximum possible
- Maximum switch queue = 3 × Feedback delay or 1 × RTT
- Lower VBR Usage ⇒ Higher ABR capacity
  ⇒ ABR errors ⇒ Higher ABR queues

n Source + VBR Satellite Configuration 1



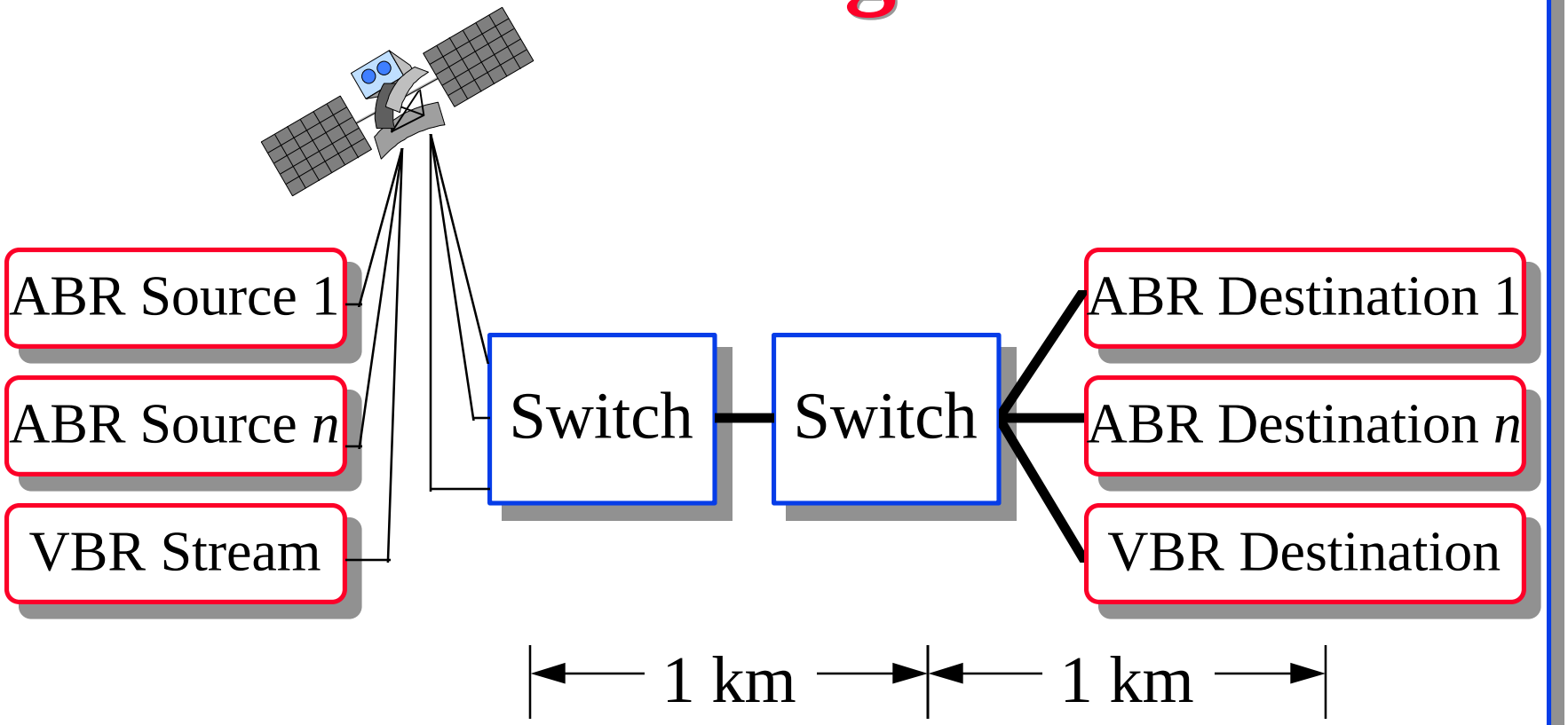
- 15 ABR sources, RTT =550 ms, Feedback Delay = 10 ms

Results: Satellite Configuration 1

Per-video Source		ABR Performance
Mean Rate (Mbps)	Standard Dev. (Mbps)	Max Switch Queue (Cells)
5	5	6824 = 1.86 × F/b delay
7.5	7	5313 = 1.45 × F/b delay
10	5	6062 = 1.65 × F/b delay

- Switch queues depend upon the feedback delay
- Switch queues are below 3 times the feedback delay regardless of the variance.

n Source + VBR Satellite Configuration 2



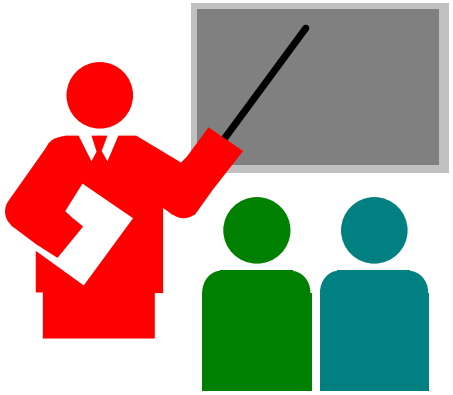
- 15 ABR sources, RTT =550 ms, Feedback Delay = 550 ms

Results: Satellite Configuration 2

Per-video Source		ABR Performance
Mean Rate (Mbps)	Standard Dev. (Mbps)	Max Switch Queue (Cells)
5	5	212520 = 1.05 × F/b delay
7.5	7	229599 = 1.14 × F/b delay
10	5	165681 = 0.82 × F/b delay

- Same results as in Satellite 1:
  - Switch queues depend upon the feedback delay
  - Switch queues are below 3 times the feedback delay regardless of the variance.

Summary



- MPEG2 compressed video = piecewise CBR, long-range dependent rate, random inter-MPCR intervals
- ABR with appropriate switch algorithm can handle the randomness in ABR capacity
- With ERICA+ and Infinite TCP Traffic:
  - Queue lengths < 3 × Feedback delay
  - Efficiency close to the maximum possible.
  - Queues are similar to those with deterministic VBR

Key References

- All of our previous contributions and papers are at: http://www.cis.ohio-state.edu/~jain/
- Mathew Goldman, "Variable bit rate MPEG2 over ATM: Definitions and Recommendations," AF-TM 96-1433, October 1996.
- Vern Paxson, "Fast approximation of self-similar network traffic," LBL report LBL-36750, April 1995.
- Christos Tryfonas, "MPEG-2 Transport over ATM Networks," MS Thesis, UC Santa Cruz, Sept 1996.