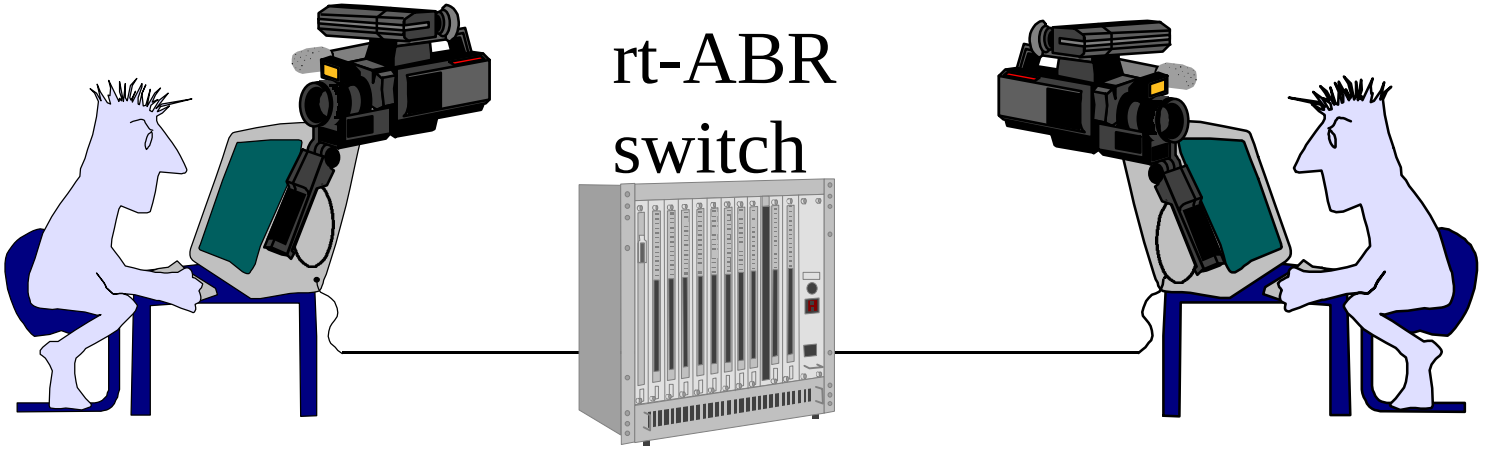
Real-Time ABR, MPEG2 Streams over VBR, and Virtual Source/Virtual Destination



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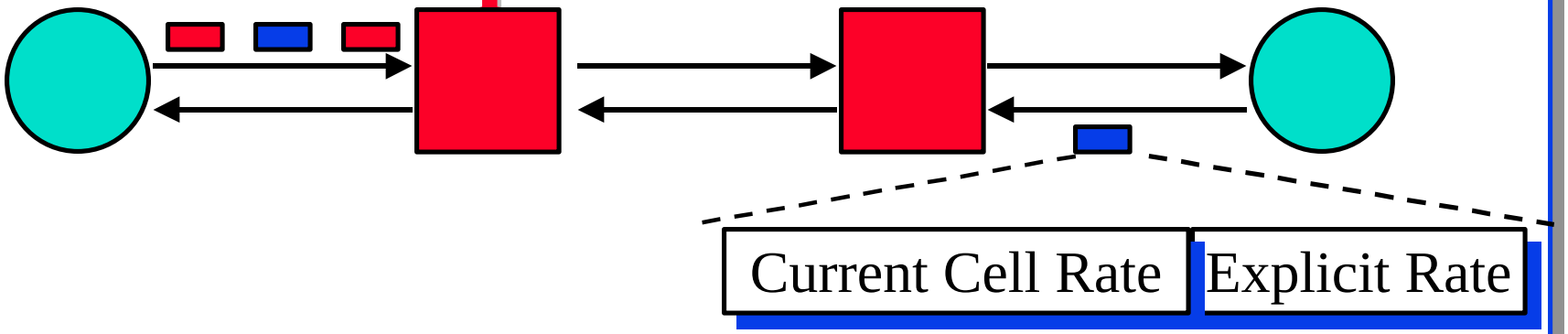
Overview

- Presentation at ATM Forum
- Modeling MPEG2 Transport Streams over VBR background
- Virtual Source/Virtual Destination Design Analysis

The Explicit Rate Scheme



- Sources send one RM cell every n cells
- The RM cells contain "Explicit rate"
- Destination returns the RM cell to the source
- The switches adjust the rate down
- Source adjusts to the specified rate

1. ATM Forum Presentation

- "Real-Time ABR: Proposal for a New Work Item," ATM Forum Contribution 96-1760, December 1996, ftp://netlab.ohio-state.edu/pub/jain/atm96-1760.txt
- Contribution co-sponsored by Samsung and Lucent Technologies
- AT&T seems to be working on it also
- Accepted as a work item for Traffic Management V5.0

Video over ABR: How?

- Compression parameters can be dynamically adjusted to match the available bandwidth
  $\Rightarrow$ real-time ABR or rt-ABR
- With proper switch algorithm,
  ABR queues in the switches are very small
  $\Rightarrow$ Negligible delay in the network
- Any switch algorithm with fast transient response and queue control can loosely guarantee low delay through the switch

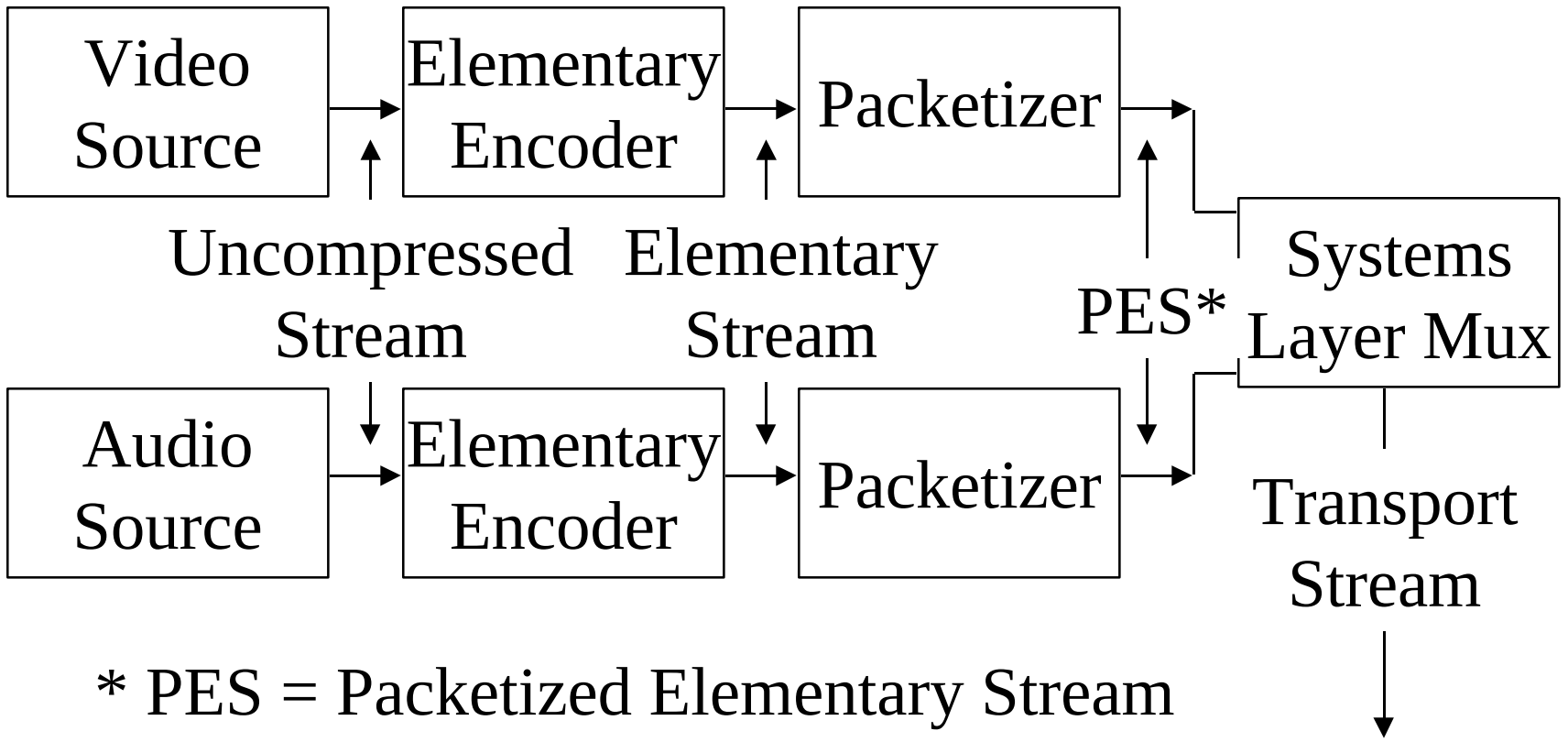
Scheduling and Buffering Issues

- Weighted max-min fairness: Allocate rates to flows in proportion to their weights
  ⇒ Higher rate sources are treated preferentially
- Buffering at the sources and acceptable loss
  ⇒ Equivalent bandwidth
  ⇒ MCR
  ⇒ Minimum acceptable quality is guaranteed
- Internet does not provide MCR. ABR does.
  rt-ABR video will be much better

2. MPEG2 Streams over VBR

- MPEG2 over ATM Overview
- Modeling MPEG2 Transport Streams over VBR
- Simulation Results for Terrestrial Networks
- Simulation Results for Satellite Networks
- Ref: "Performance of TCP over ABR with Long-Range Dependent VBR Background Traffic Over Terrestrial and Satellite ATM Networks," ATM Forum Contribution, 97-0177, February 1997, ftp://netlab.ohio-state.edu/pub/jain/atm97-0177.txt

MPEG-2 Over ATM



ATM cells 188-byte packets

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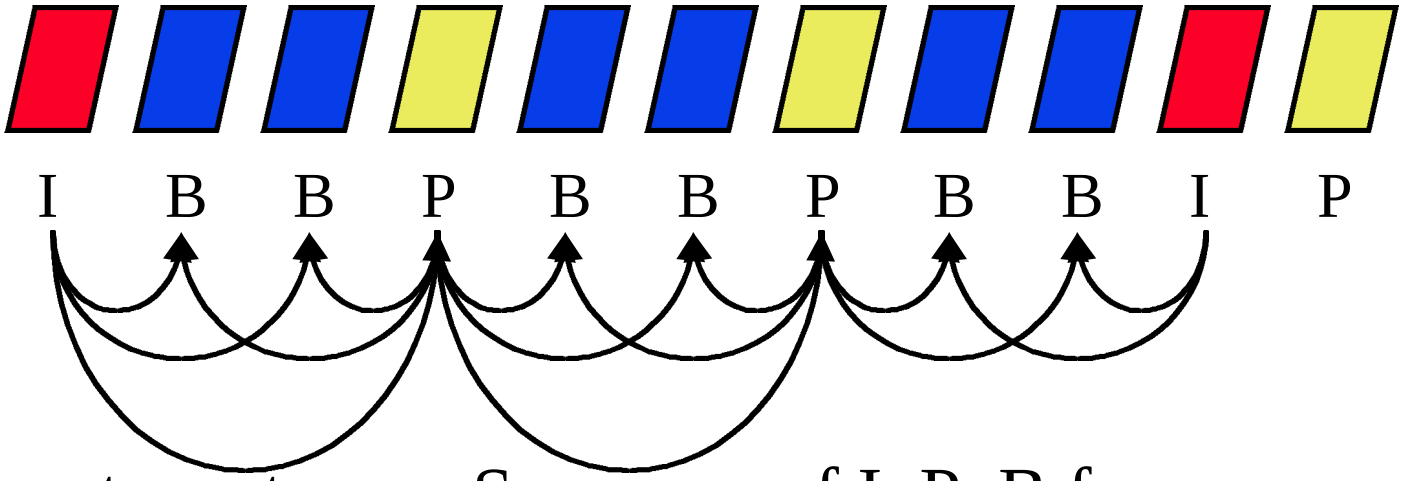
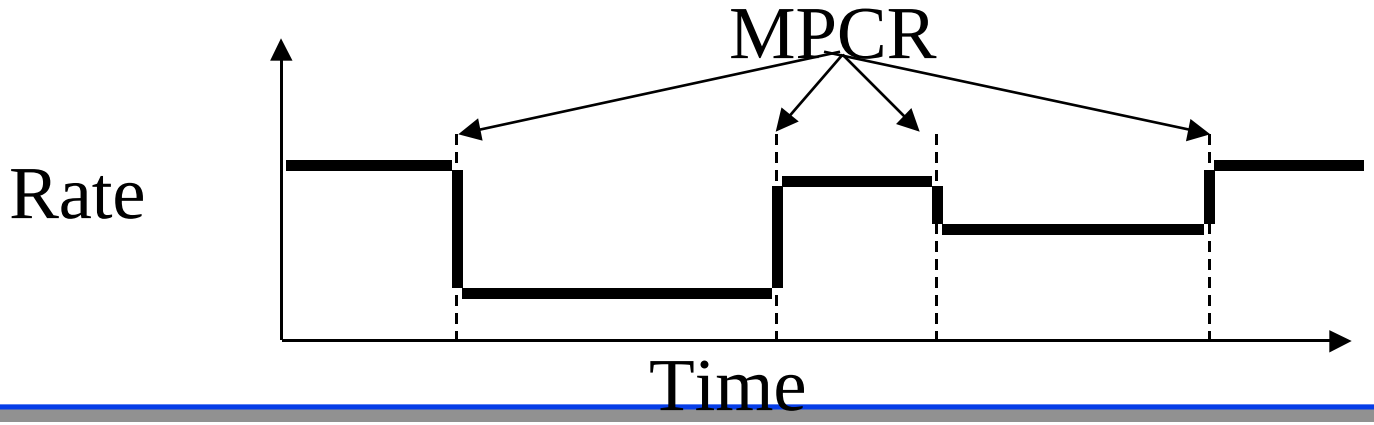
Elementary Stream



- 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

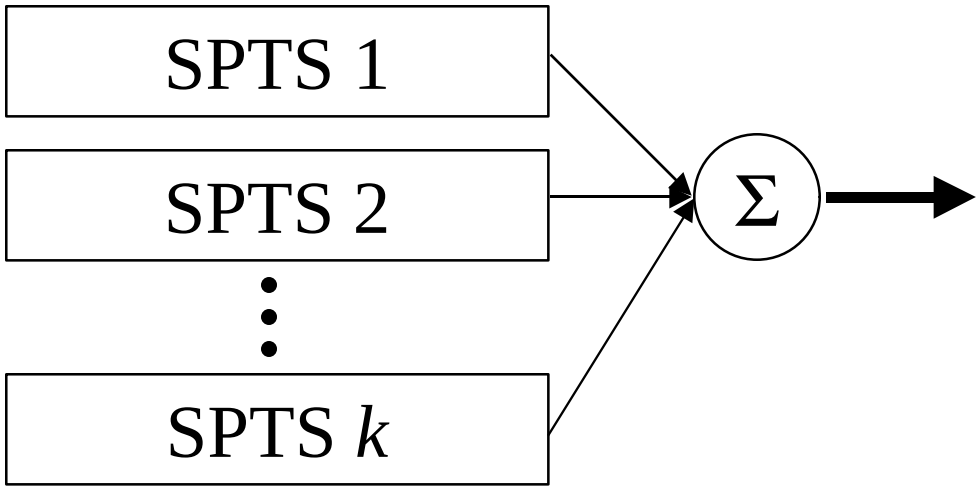
- Frames may contain a presentation timestamp.
- To synchronize the clocks, a sample of system clock is sent every 80μs to 100 ms
  MPEG2 Program Clock Reference (MPCR)
  We use MPCR instead of PCR (Peak Cell Rate)
- MPCRs are used by a phase lock loop
  ⇒ Rate between MPCRs must be constant



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

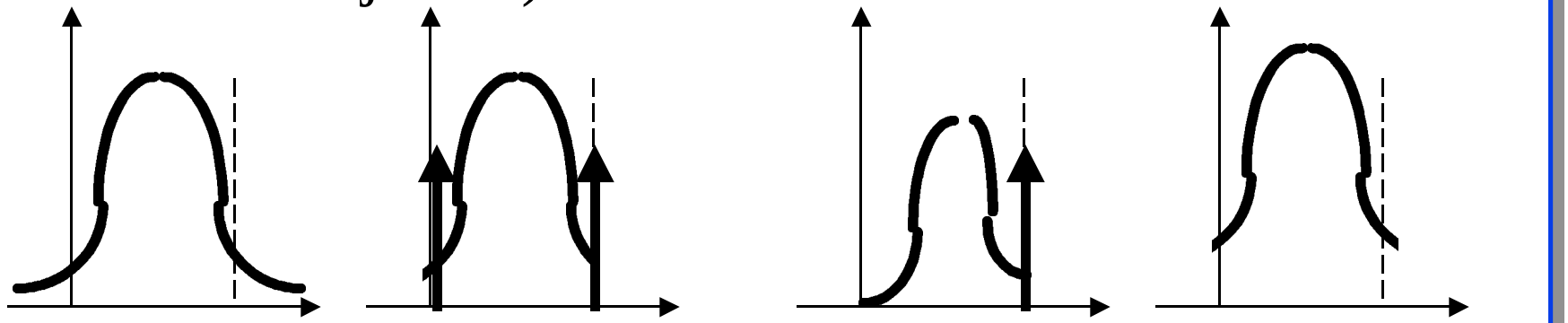
VBR Traffic Model



- 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)

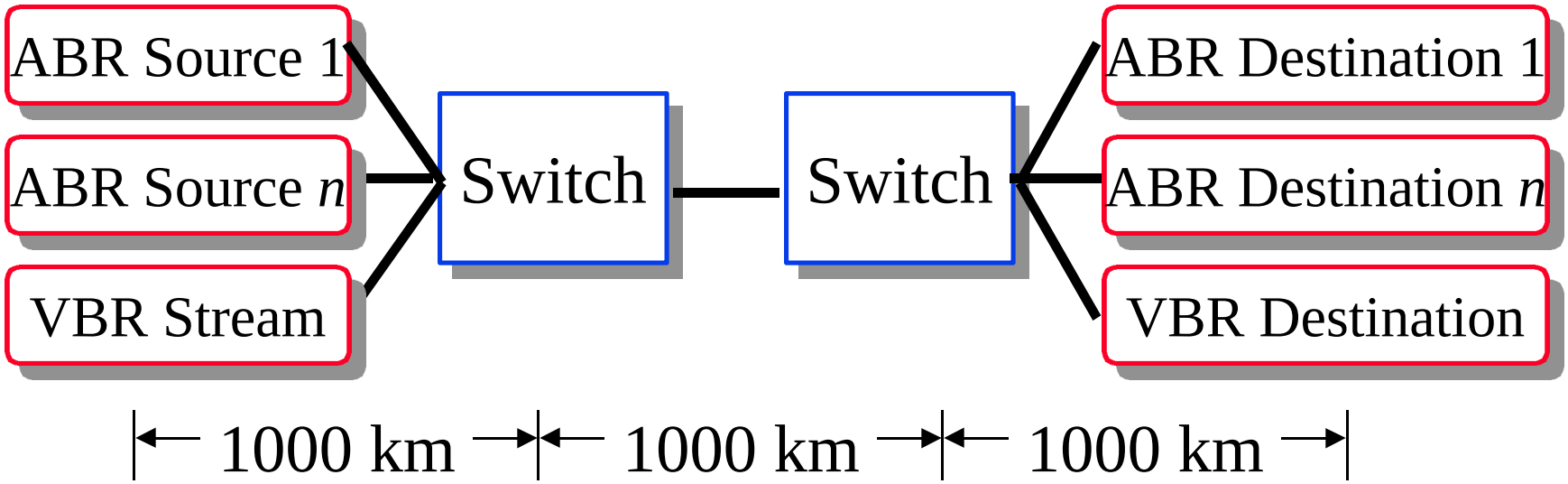
VBR Model (Cont)

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



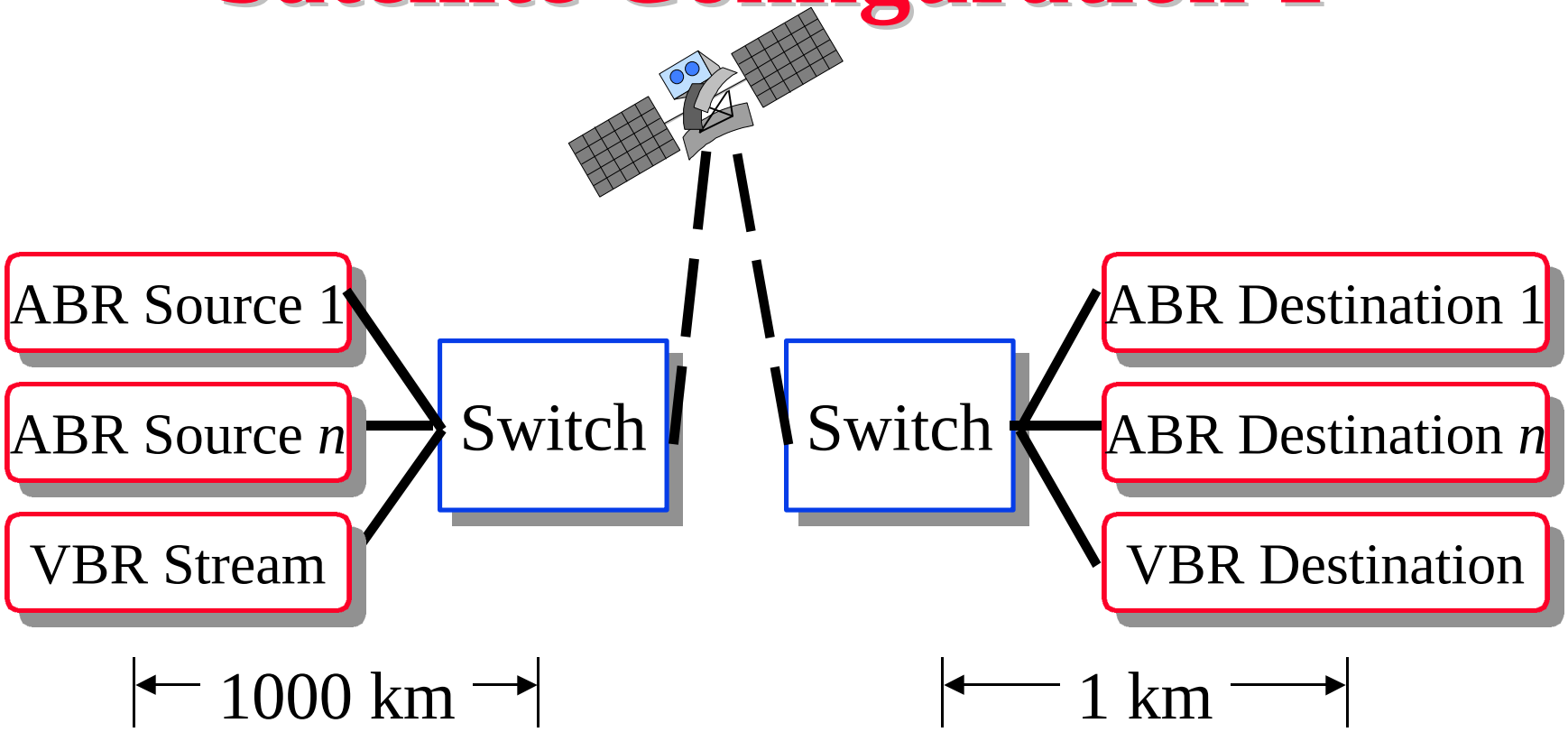
(a) Gaussian (b)Clipping Min{Max{0, x}, 15} (c) Exponentiation Min{2^x, *15}* (d) Pruning

n Source + VBR WAN Configuration



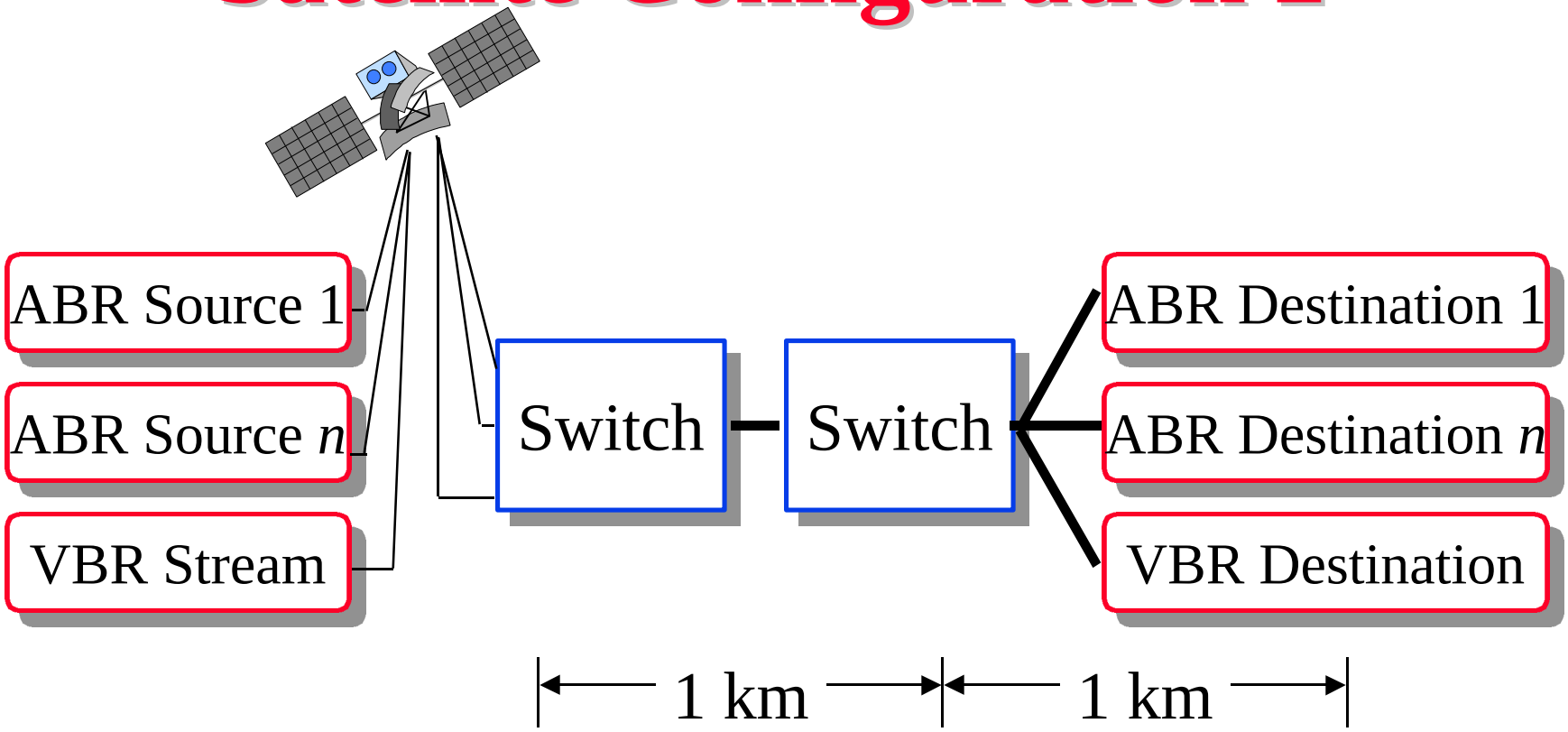
- All links 155 Mbps
- If VBR background , sum of *k* independent SPTSs
  Various mean and variances, H=0.8
- All traffic unidirectional; Large file transfer application
- 15 ABR sources, RTT =30 ms, Feedback Delay = 10 ms

n Source + VBR Satellite Configuration 1



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

n Source + VBR Satellite Configuration 2



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

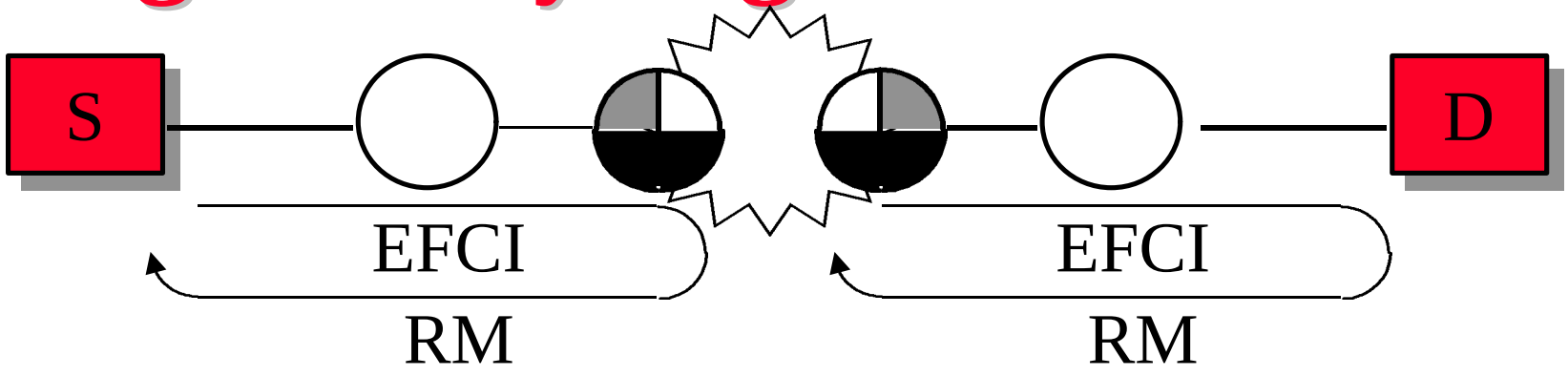
Summary of Results

- 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

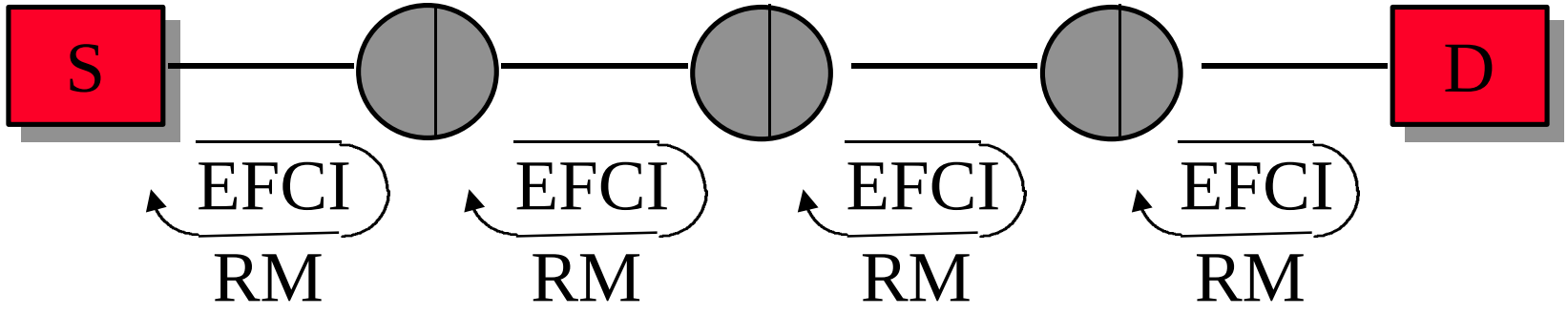
3. Virtual Source/Virtual Destination

- Overview of VS/VD
- Implementation Guidelines
- Simulation results
- Ref: "Virtual Source/Virtual Destination: Design Considerations," ATM Forum Contribution, 96-1759, December 1996, ftp://netlab.ohio-state.edu/pub/jain/atmf/atm96-1759.ps

Segment-by-Segment Control



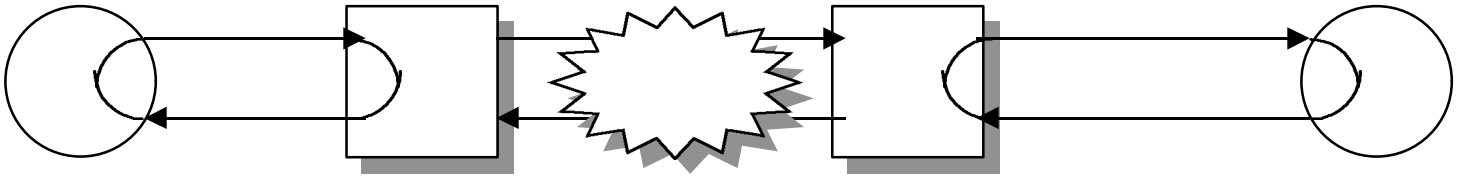
- Virtual source/virtual destinations (VS/VD) follow all notification/control rules
- Can be hop-by-hop



- Virtual dest/sources maintain per-VC queues.

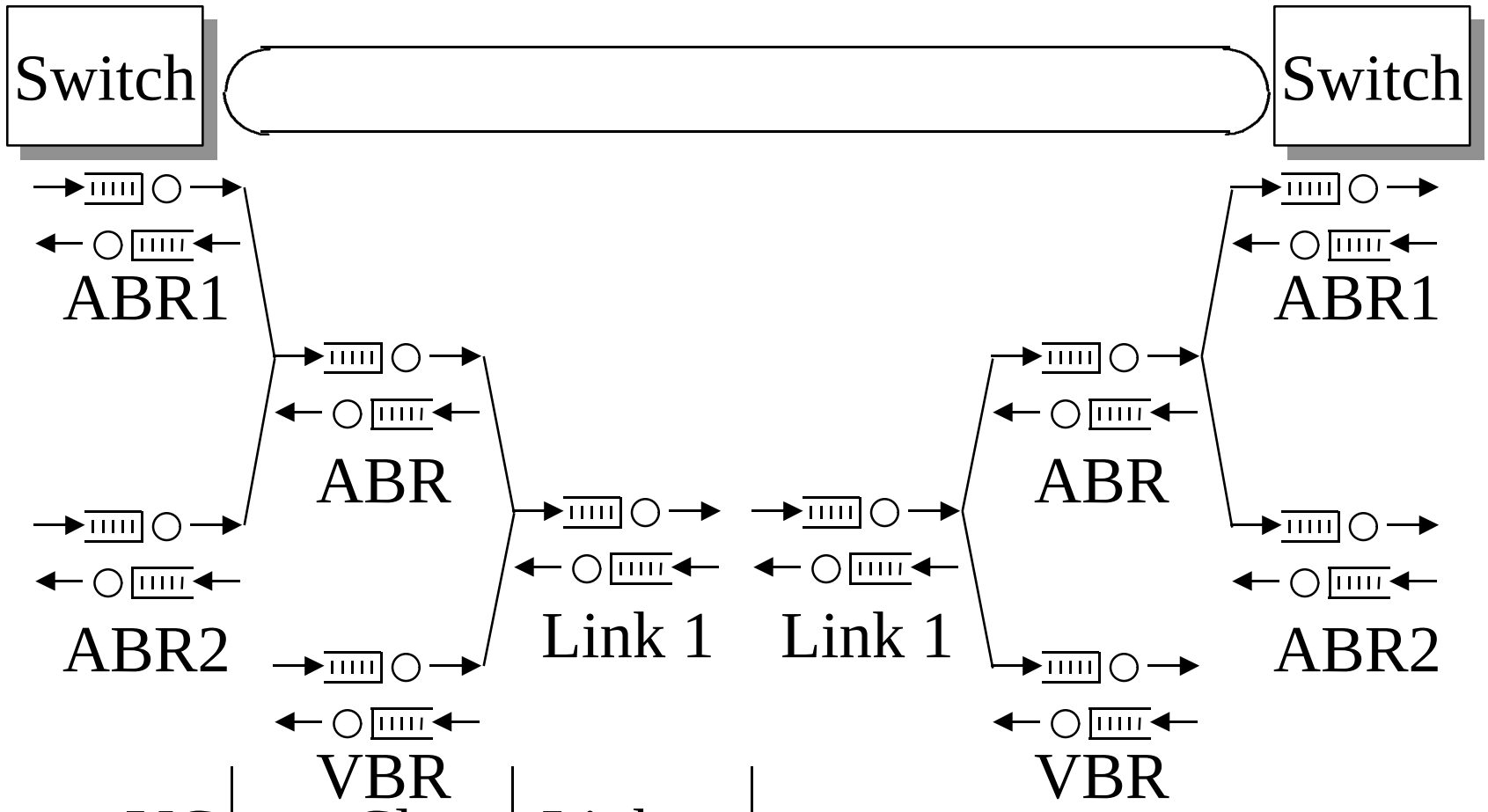
Why Implement VS/VD?

- Isolates users from the network
  Or, isolates different networks
- Allows proprietary protocol in the intermediate cloud
- Shorter control loops improve performance



- Little cost to implement VS/VD if per-VC queueing and scheduling is already in the switch. (Queues shared by multiple VCs aren't sufficient.)

Switch Queue Structure (Logical)



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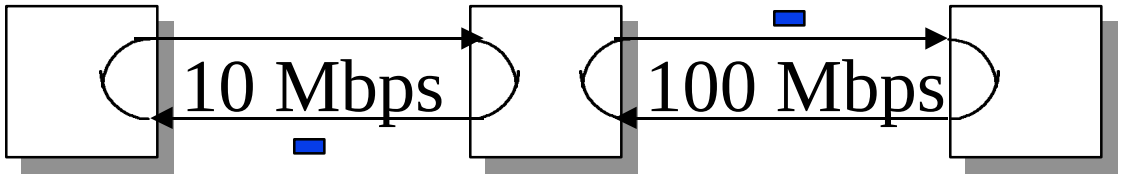
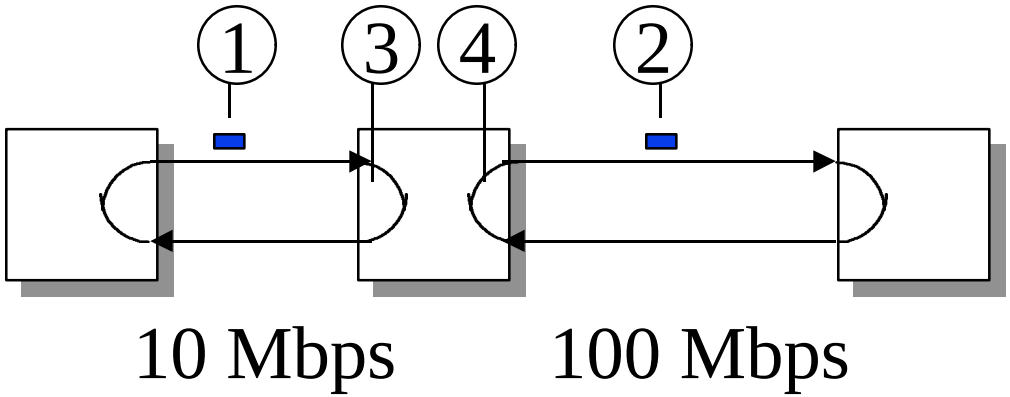
Design Decisions

- What is the VC's rate?
- What is the input rate?
- Does a link affect current loop or previous loop?
- When to calculate the VAL?



What is the VC's Rate?

1. CCR in FRM1
2. CCR in FRM2 = ACR_2
3. Measured source rate in the previous loop
   =VC's input rate to per-VC queue (Not yet analyzed)
4. Measured source rate in the next loop
   =VC's input rate to per-class queue



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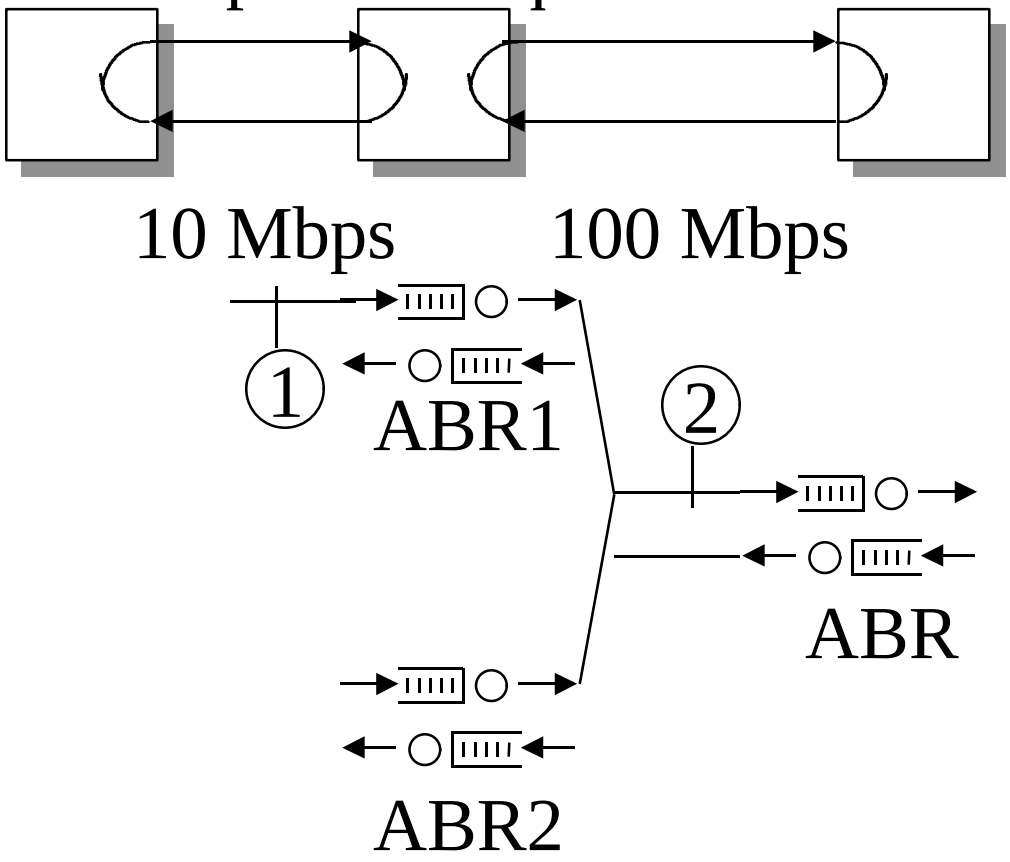
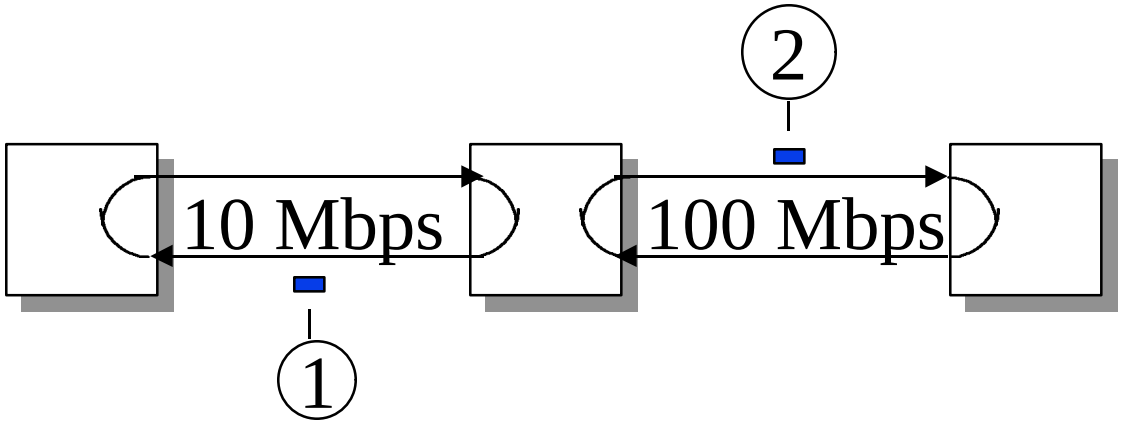
What is the Input Rate?

1. Σ Input rates to per-VC queues
2. Input rate to per-class queue



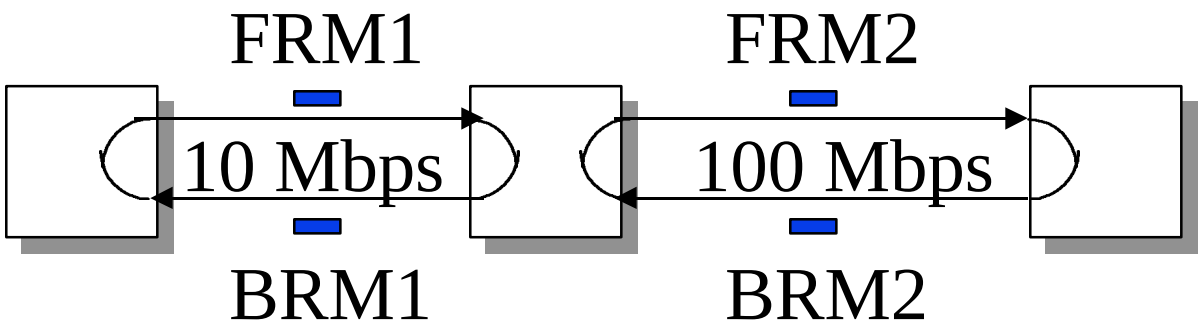
Effect of link congestion

- Which link affects which loop?
  E.g., Effect of Link 2 congestion:
  1. Change $ER_1 \Rightarrow$ Previous loop only
  2. Change $ACR_2 \Rightarrow$ Next loop only
  3. Change ER_1 and $ACR_2 \Rightarrow$ Both loops



Allocated Rate Update Frequency

- When should the rate allocated to a VC be calculated? (Applies only to the previous loop)
  This is normally done on receiving a BRM in a switch or on turning around an FRM in a destination
  1. On receiving BRM2
  2. On turning around FRM1
  3. Both



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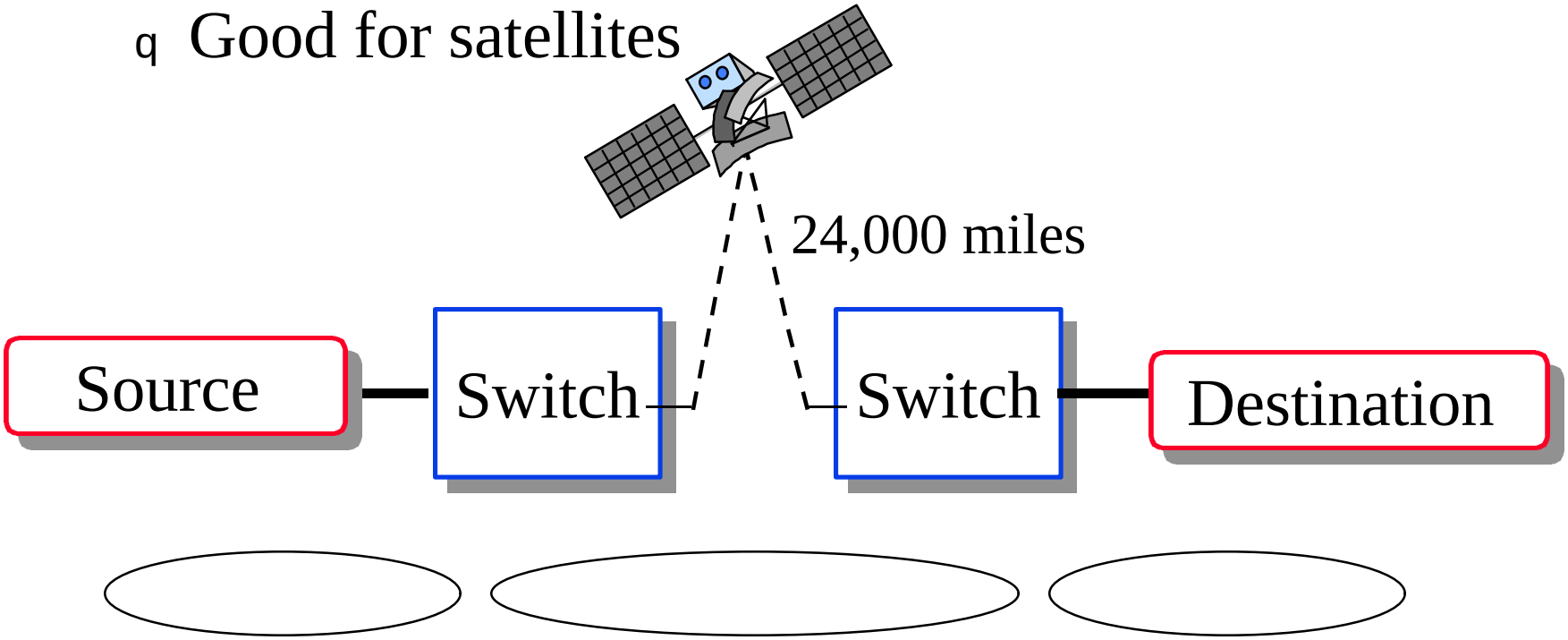
Design Decisions: Summary

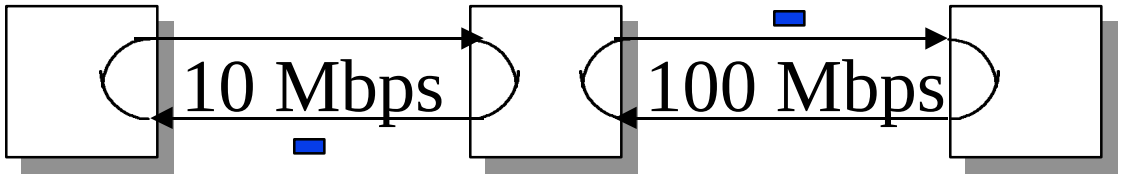
- Four Decisions:
  1. What is the VC's rate: 4 alternatives
  2. What is the input rate: 2 alternatives
  3. Effect of link congestion: 3 alternatives
  4. Allocated rate update frequency: 3 alternatives
- Total $4 \times 2 \times 3 \times 3 = 72$ combinations
- Some of these combinations do not work
- Recommendation: Measured VC rate from per-Class Queue, per-class input rate, Control both loops, VC's allocation updated at FRM_1 and at BRM_2

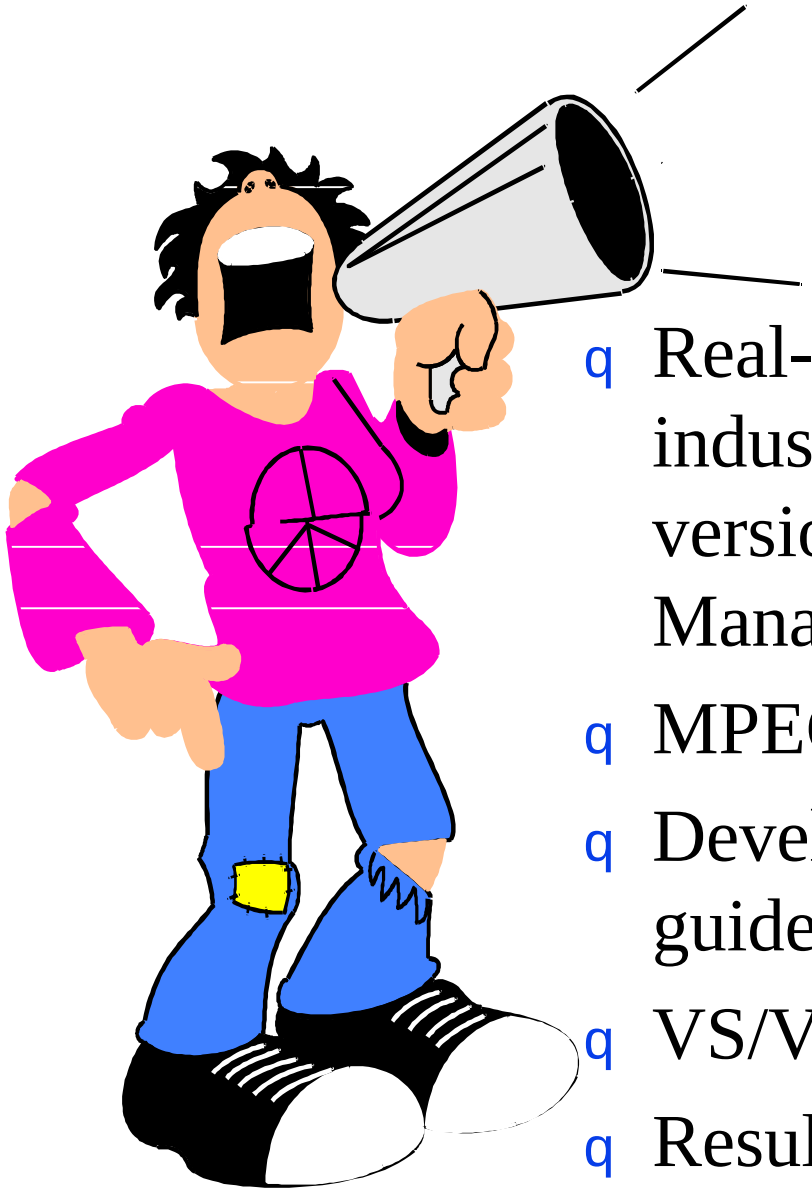
Summary of Results

- Virtual Source/Virtual destination:
  - Reduces response time during first round-trip
  - Good for satellites



- VS/VD does improve the stability of the network. Some cases that diverged with basic ERICA converge with VS/VD.
- VS/VD increases throughput slightly due to reduced response time and reduced convergence time.
- The effect of VS/VD depends upon the switch algorithm.
- In VS/VD situations, ACR and actual rates are very different. Cannot rely on CCR field.
  Must measure VC's rate.





Summary

- Real-time ABR accepted by the industry as a work-item for the next version of ATM Forum Traffic Management
- MPEG2 Video is piece-wise CBR
- Developed VS/VD implementation guidelines
- VS/VD may help in satellite paths.
- Results are quickly being communicated to industry.