ATM ABR Traffic Management: Our Recent Research Results

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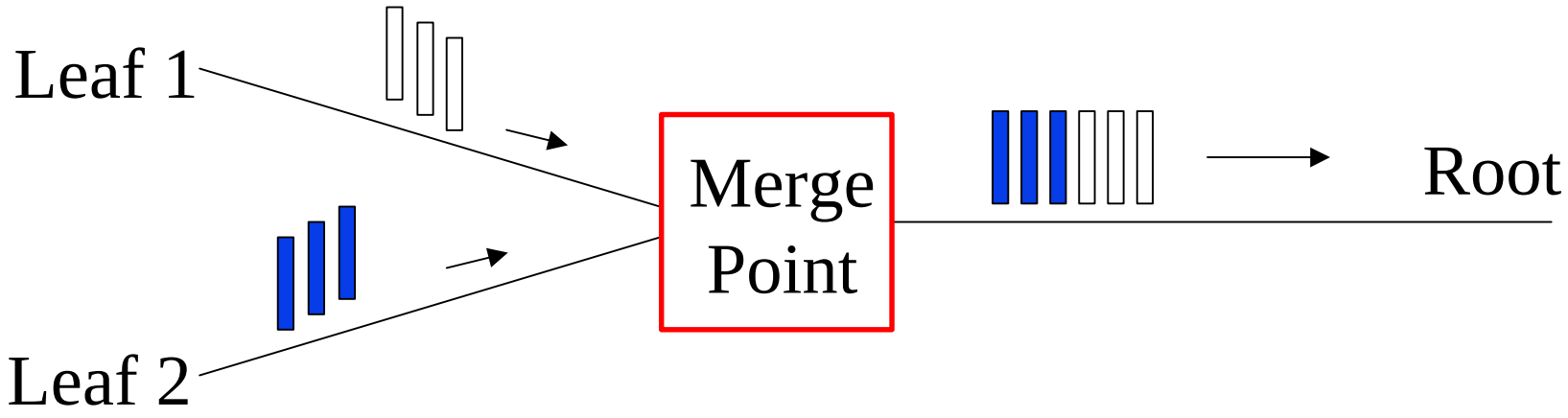
Overview

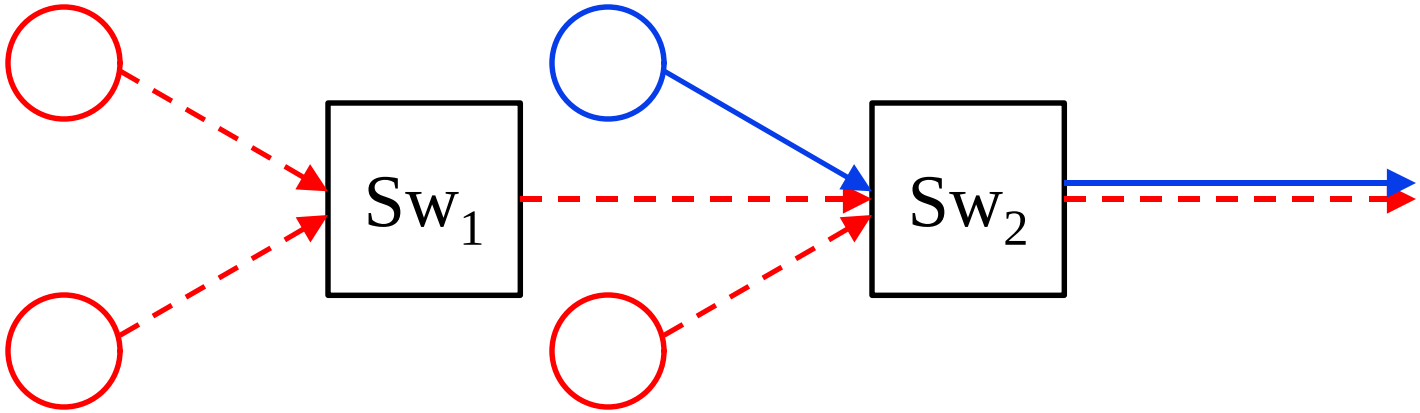
- Recent Achievements:
  1. Multipoint Communication
  2. Virtual Source/Virtual Destination
  3. Real-Time ABR: Generalized Fairness

1. Multipoint-to-Point VCs

- A multipoint-to-point VC can have more than one concurrent sender
- Traffic at root = Σ Traffic originating from leaves



Sources, VCs, and Flows



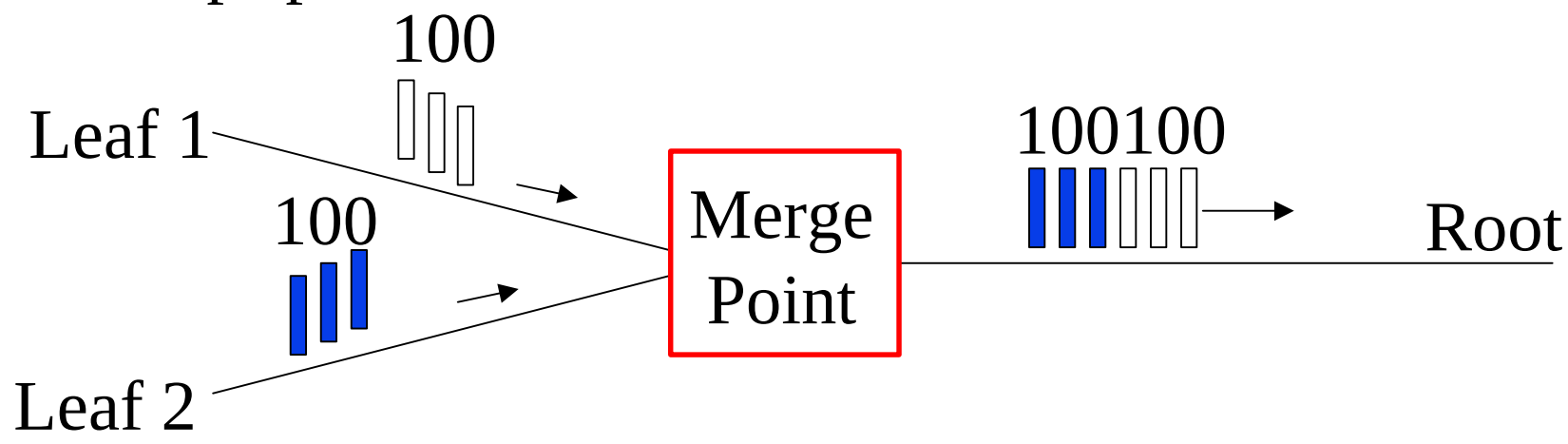
- Sw_2 has to deal with
  - Two VCs: Red and Blue
  - Four sources: Three red sources and one blue source
  - Three flows: Two red flows and one blue

Fairness Definitions

- Source-based: N-to-one connection = N one-to-one connections ⇒ Use max-min fairness among sources
- VC/Source-based:
  1. Allocate bandwidth fairly among VCs
  2. For each VC, allocate fairly among its sources
- Flow-based: Flow = VC coming on an input link. Switch can easily distinguish flows.
- VC/Flow-based:
  1. Allocate bandwidth fairly among VCs
  2. For each VC, allocate fairly among its flows

Mpt-pt Issues

- Cells of senders in the same multipoint-to-point VC cannot be distinguished
- Question: Can we achieve source-based fairness? Answer: Yes!
- We extended ERICA to achieve source based fairness for mpt-pt VCs



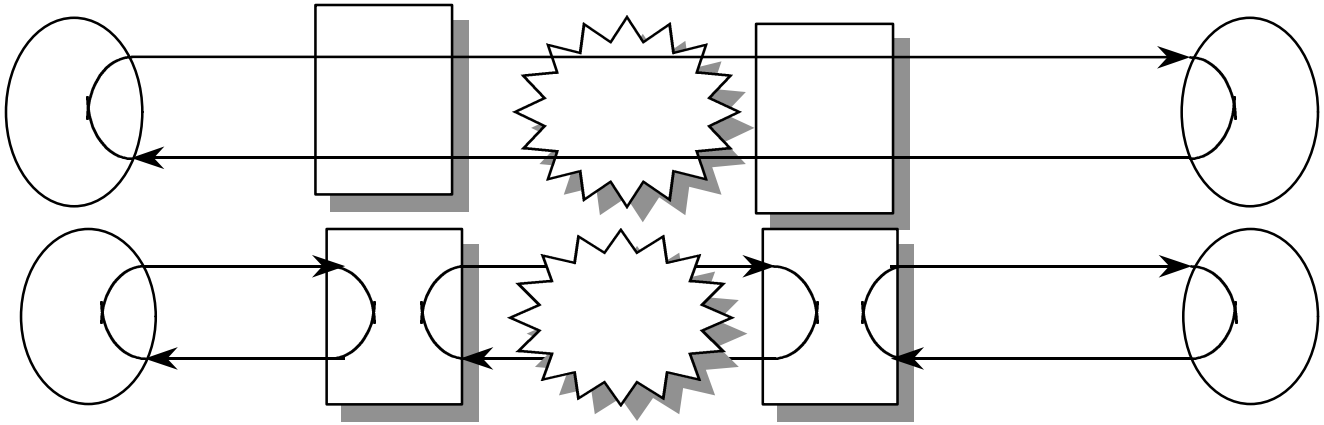
Lessons Learnt

- Avoid determining the effective number of active sources
- Avoid estimation of rates of sources, or determining if a source is bottlenecked at this link
- Use only aggregate measurements
- Do not use CCR values from BRM cells
- CCR from FRM cells can be used
- Using the maximum CCR in an interval, and exponentially averaging the maximum ER in the previous interval can improve performance
- Do not turn around RM cells at merging point

Impact I

- A new item was added to the TM living list describing the issues in Mpt-to-pt ABR
- A sample merge point algorithm, which applies to mpt-to-mpt also, was added to the living list
- Our fairness definitions were moved to this same living list item

2. Virtual Source / Virtual Destination (VS / VD)

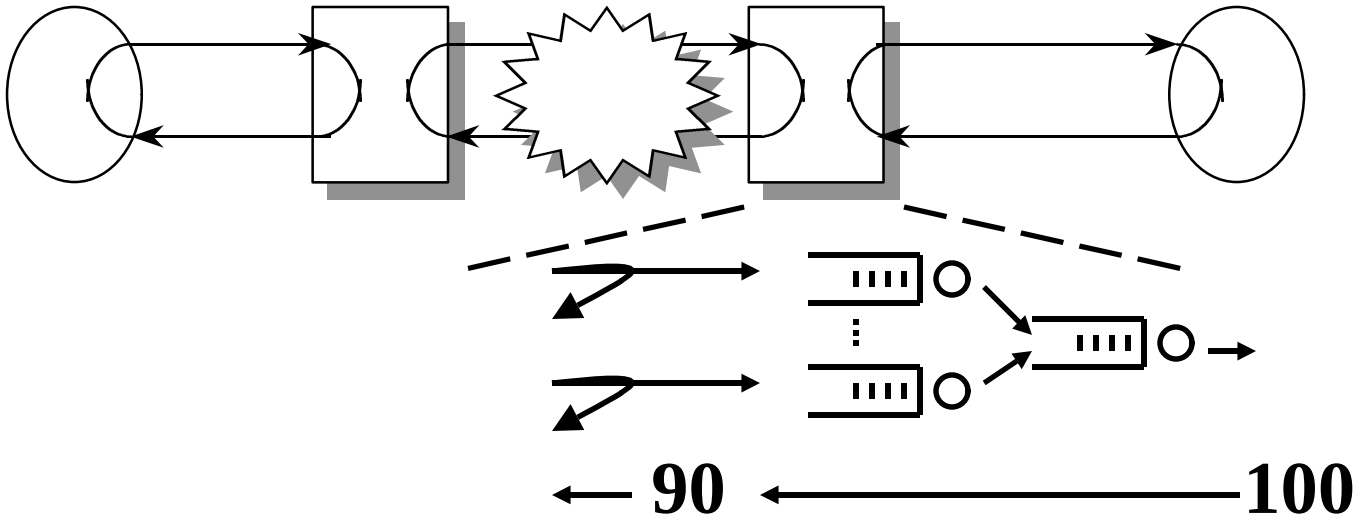


- Segments the end-to-end ABR control loop.
- Coupling between loops is implementation specific.
- ABR switches separated by non-ATM network could also implement VS/VD.

VS/VD Issues

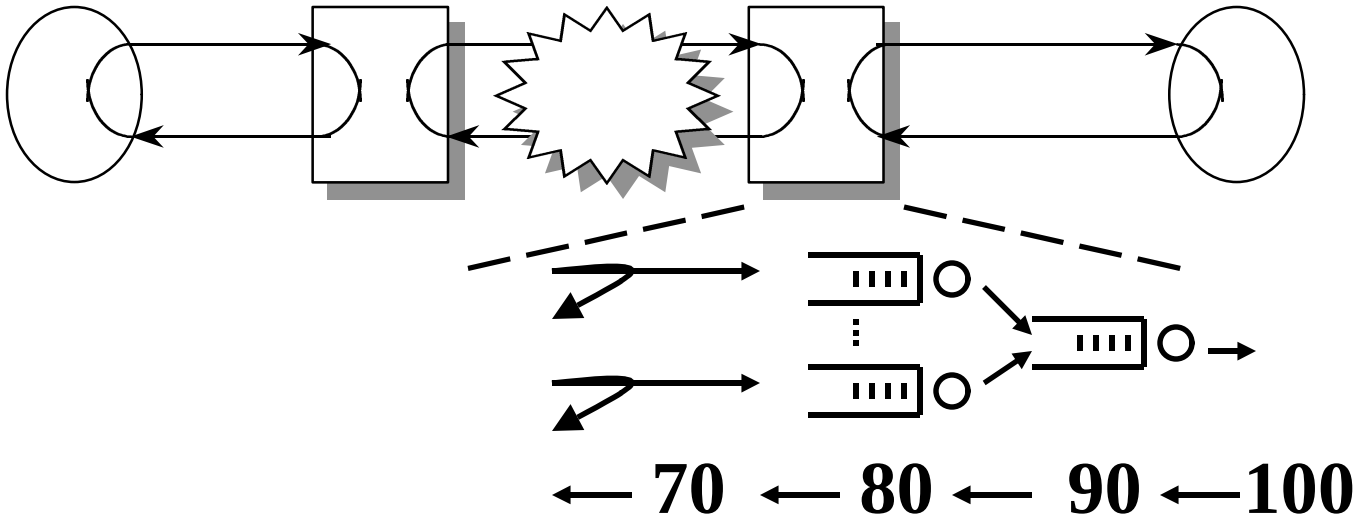
- Although TM4.0 allows VS/VD, it does not describe how the feedback must be passed from VS to previous VD.
- It is not clear if and when VS/VD help.
- Our Accomplishments:
  - Analyzed issues in designing rate allocation schemes for VS/VD switches.
  - Developed a per-VC rate allocation scheme for VS/VD.
  - Showed how VS/VD can help in buffer management across the network.

Simple VS/VD Model



- Internal Service Rate = f(Downstream Feedback, Switch algorithm using class Q + per-VC Q)
- Upstream Feedback =Internal Service Rate
- Example: Downstream = 100, Service =90, Upstream feedback=90 Mbps

Correct VS/VD Model

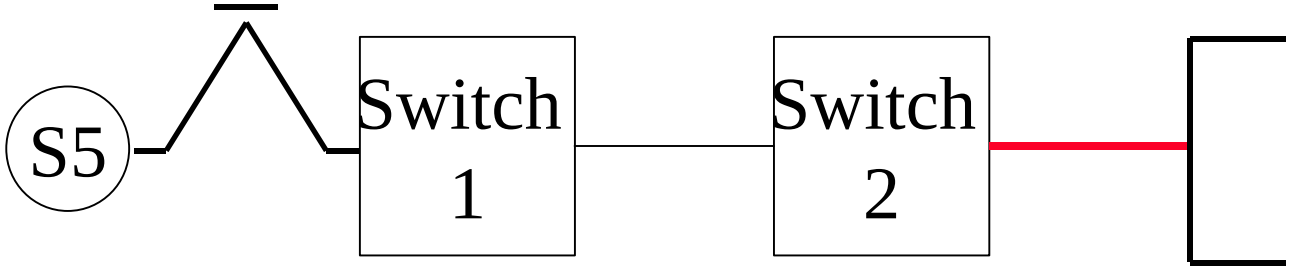


- Internal Service Rate = f(Downstream Feedback, Switch algorithm using class Q)
- ACR_{ij} = f(Internal service rate, end system rules)
- Upstream feedback =f(VC Q)ACR_{ij}
- Example: Downstream = 100, Service =90, ACR=80, Upstream feedback=70 Mbps

Simulation Results

- Without VS/VD:
  - Single control loop for the entire connection.
  - All queues are in the bottleneck switch.
  - Buffer requirements for terrestrial switch are proportional to satellite propagation delay.
- With VS/VD:
  - Control loop broken at each switch.
  - Queues remain at the switch between the satellite and the terrestrial loop (satellite switch).
  - Terrestrial switch only requires small buffers.

Results (Cont)



- With correct implementation of VS/VD:
  Maximum queue at each switch
  $\leq$ A small multiple of bandwidth delay product of the previous loop
  $\Rightarrow$ Can help isolate long-delay hops from short-delay hops.
- Workgroup switches on satellite paths will not need buffering proportional to round-trip even if they are the bottleneck.

Impact II

- Our extension of the ERICA switch algorithm including VS/VD was accepted for inclusion as a sample algorithm in the TM5.0 baseline text.

3. Real-Time ABR: Generalized Fairness

- Real-time applications need non-zero Minimum Cell Rate (MCR)
- In TM4, Distribution of excess bandwidth (fairness) is implementation specific.
- TM4.0 has five examples of fair distribution
- We have shown that two of the examples are not meaningful and have proposed a sixth example that is a superset of the remaining three definitions
- We developed a switch algorithm that implements the proposed definition

TM4.0 Definitions

1. B(i) = B/n
2. B(i) = MCR(i) + (B-M)/n
3. B(i) = Max{MCR(i), Max-Min Share}
4. B(i) = B*(MCR(i)/M)
5. B(i) = w(i)*B/Sum(w(j))

- Definition 5 does not always guarantee MCR
- Definition 3 may result in total of fair share being more than the capacity
- Notation: n = # of active VCs bottlenecked here
  B = Bandwidth available for the bottlenecked VCs
  $M = \Sigma MCR(I)$

General Definition

- Fair Share

$$B(i) = MCR(i) + \frac{w(i)\,(B - M)}{\Sigma_{j=1,n}\, w(j)}$$

- This definition is a superset of 1, 2, 4 in TM4.0
- Always ensures MCR

Mapping to TM 4.0

- w(i) = w, MCR(i)=0: B(i) = B/n
  This is Definition 1 (Max-min Fair).
- w(i) = w: B(i) = MCR(i) + (B - M)/n
  This is Definition 2 (MCR plus equal share)
- w(i) = MCR(i):
  B(i) = MCR(i) + (B-M) MCR(i) / M
  = B* (MCR(i)/M)
  This is Definition 4 (Proportional to MCR)

Pricing Function

- T = Small time interval, W = Number of bits
  R = Average rate W/T
- Cost C = f (W,R). If C is restricted to continuous differentiable functions: $C = \Sigma_{ij}\ a_{ij}\ W^i R^j$
- For <u>all</u> values of W and R:
  - $C \geq 0 \quad \partial C/\partial W \geq 0 \quad \partial C/\partial R \geq 0$
  - $\partial(C/W)/\partial W \leq 0$ [Economy of Scale]
  - $\partial(C/R)/\partial R \leq 0$ [Economy of Scale]
- The <u>only</u> function that satisfies all 5 conditions is:

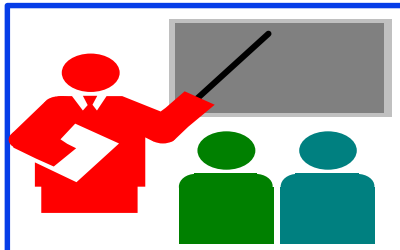
$$C = a_{00} + a_{10}W + a_{01}R + a_{11}\ WR$$

A Simple Pricing Fn

- f() is non-decreasing w.r.t to W
  f() is non-increasing w.r.t to T $\Rightarrow$ non-decreasing w R
- A simple function satisfying these requirements is:
  $C = c + w W + r R$
  Here, c = Fixed cost per connection
  w = Cost per bit (How much)
  r = Cost per Mbps (How fast)
- This cost function implies that the excess bandwidth should be allocated using the proposed generalized fairness function

Impact III

The proposed definition was added to TM5.0 baseline text being developed now.



Summary

1. Multipoint Communication: Source-based fairness can be achieved even though sources can not be distinguished in an mpt-pt VC
2. Virtual Source/Virtual Destination: The buffering required at each VS/VD switch is proportional to the bandwidth-delay product of the next loop
3. Real-Time ABR: Generalized Fairness based on charging policies is a superset of current TM4 policies.
4. Extensions of ERICA to cover the above three cases have been developed

Our Recent ATM Forum Contributions

- All our contributions and papers are available on-line at http://www.cis.ohio-state.edu/~jain/
  See Recent Hot Papers for tutorials.
- S. Fahmy et al, "Proposed appendix on sample ABR point-to-multipoint algorithms," ATM Forum/98-0293, April 1998, http://www.cis.ohio-state.edu/~jain/atmf/a98-0293.htm

Contributions (Cont)

- S. Fahmy et al, "Proposed modifications to the baseline text and living list on multipoint ABR behavior," ATM Forum/98-0150, February 1998, http://www.cis.ohio-state.edu/~jain/atmf/a98-0150.htm
- B. Vandalore et al, "Generalized Fairness support in Switch Algorithms" ATM Forum/98-0151, February 1998, http://www.cis.ohio-state.edu/~jain/atmf/a98-0151.htm

Contributions (Cont)

- S. Fahmy et al, "Determining the number of active ABR sources in switch algorithms," ATM Forum/98-0154, February 1998, http://www.cis.ohio-state.edu/~jain/atmf/a98-0154.htm
- R. Goyal et al, "Per-VC Rate Allocation Techniques for ABR Feedback in VS/VD Networks" ATM Forum/97-1086r1, February 1998, http://www.cis.ohio-state.edu/~jain/atmf/a97-1086r1.htm

Contributions (Cont)

- B. Vandalore et al, "Design and Analysis of Queue Control Function for Switch Schemes," ATM Forum/97-1087, February 1998, http://www.cis.ohio-state.edu/~jain/atmf/a97-1087r1.htm
- S. Fahmy et al, "A switch algorithm for ABR multipoint-to-point connections," ATM Forum/97-1085, December 1997, http://www.cis.ohio-state.edu/~jain/atmf/a97-1085.htm

Our Recent Papers

- R. Goyal et al, "Per-VC Rate Allocation Techniques for ATM-ABR Virtual Source Virtual Destination Networks," Submitted to Globecom'98, February 1998, http://www.cis.ohio-state.edu/~jain/papers/globecom98.htm
- R. Goyal et al, "Design Issues for providing Minimum Rate Guarantees to the ATM Unspecified Bit Rate Service", Proceedings of ATM'98, May 1998, http://www.cis.ohio-state.edu/~jain/papers/atm98.htm

Papers (Cont)

- S. Fahmy et al, "On Determining the Fair Bandwidth Share for ABR Connections in ATM Networks," Proceedings of the IEEE International Conference on Communications (ICC) 1998, June 1998, http://www.cis.ohio-state.edu/~jain/papers/neff.htm

Thank You!

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