Our Research on Real-
Tasks:

1. Multipoint Communication
2. Virtual Source/Virtual Destination
3. Real-Time ABR
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
Point-to-Multipoint ABR

RM Cell_A

RM Cell_B

RM Cell_c

RM Cell_{\text{min}(B,C)}
Point-to-Multipoint Connections: Issues

- Minimum of ER from branches is sent upstream. Should we wait for all branches?
- If you send BRM on every FRM, you may give feedback without receiving any feedback. Need to ensure that at least one feedback has been received before sending a BRM. Otherwise, you may give PCR.
- Not all downstream feedbacks in an upstream feedback. Consolidation noise.
Basic Pt-Mpt: Results

- ABR with ERICA (extended for multipoint) works ok
- Efficiency, fairness, responsiveness is maintained
- Consolidation noise due to asynchronous arrival of feedback from different leaves appears as oscillations
- Additional delay due to FRM wait and BRM consolidation
  - slower transient response than point-to-point
- Minimum of all paths is allocated
  - Some links are underutilized
- Queue control (ERICA+) is required for stability
Impact I

- A summary of our ATM Forum contribution 97-0615 has been included in the base line for the next phase (TM4.1) of ATM Forum Traffic Management Specification
- Several leading industry members expressed interest in results
Multipoint-to-Point VCs

- A multipoint-to-point VC can have more than one concurrent sender
- Traffic at root = \( \Sigma \) Traffic originating from leaves
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 $\Rightarrow$ 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 and Results

- 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

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Impact II

- A new item has been added to the living list of TM specs describing the issues in Mpt-to-pt ABR.
- A sample merge point algorithm, which applies to mpt-to-mpt also, has been added.
- Our Fairness definitions have been added to TM4.1 spec.
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.
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 correct implementation of VS/VD: Maximum queue at each switch \( \leq k^* \) bandwidth delay product of the previous loop \( \Rightarrow \) 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.
Our extension of the ERICA switch algorithm including VS/VD was accepted for inclusion as a sample algorithm in the TM4.1 baseline text.
Video over ABR: How?

- Compression parameters can be dynamically adjusted to match the available bandwidth ⇒ real-time ABR or rt-ABR

- With proper switch algorithm, ABR queues in the switches are very small ⇒ 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
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
Generalized Fairness

- Real-time applications need non-zero Minimum Cell Rate (MCR)
- In TM4.0, 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
Impact IV

The proposed definition was added to TM4.1 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 TM4.0 policies.

4. Extensions of ERICA to cover the above three cases have been developed


Our Contributions and Papers

- This project resulted in 6 papers and 15 ATM Forum contributions.
- ATM Forum TM4.1 specs (hence, the industry) was impacted as a result of this project.
- All our contributions and papers are available on-line at http://www.cis.ohio-state.edu/~jain/
Thank You!

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