Traffic Management of Internet Protocols over ATM

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Why ATM?
ATM Service Categories: ABR and UBR
Binary and Explicit Feedback
ABR Vs UBR
TCP/IP over ABR
TCP/IP over UBR
Why ATM?

- ATM vs IP: Key Distinctions
  - Traffic Management:
    - Explicit Rate vs Loss based
  - Signaling: Coming to IP in the form of RSVP
  - PNNI: QoS based routing
  - Switching: Coming soon to IP
  - Cells: Fixed size or small size is not important
Service Categories

- **ABR** (Available bit rate): Source follows network feedback. Max throughput with minimum loss.
- **UBR** (Unspecified bit rate): User sends whenever it wants. No feedback. No guarantee. Cells may be dropped during congestion.
- **CBR** (Constant bit rate): User declares required rate. Throughput, delay and delay variation guaranteed.
- **VBR** (Variable bit rate): Declare avg and max rate.
  - **rt-VBR** (Real-time): Conferencing. Max delay guaranteed.
  - **nrt-VBR** (non-real time): Stored video.
- DECbit scheme in many standards since 1986.
- Forward explicit congestion notification (FECN) in Frame relay
- Explicit forward congestion indicator (EFCI) set to 0 at source. Congested switches set EFCI to 1
- Every nth cell, destination sends an resource management (RM) cell to the source
The Explicit Rate ABR

- Proposed in July 1994
- 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
Why Explicit Rate Indication?

- Longer-distance networks
  ⇒ Can’t afford too many round-trips
  ⇒ More information is better

- Rate-based control
  ⇒ Queue length = ΔRate × ΔTime
  ⇒ Time is more critical than with windows
Internet Protocols over ATM

- ATM Forum has designed ABR service for data
- UBR service provides no feedback or guarantees
- Internet Engineering Task Force (IETF) prefers UBR for TCP
Observations About ABR

- ABR performance depends upon the switch algorithm. Assuming *ERICA*. (Ref: http://www.cis.ohio-state.edu/~jain/)

- No cell loss for *TCP* if switch has buffers $\approx 4 \times RTT$.

- No loss for any number of TCP sources w $4 \times RTT$ buffers.

- No loss even with *VBR* background. W/o VBR, $3\times RTT$ buffers will do.

- Under many circumstances, $1\times RTT$ buffers may do.

- Required buffers depend upon RTT, feedback delay, switch parameters, and characteristics of VBR.
Observations about UBR

- No loss for TCP if Buffers = \( \sum \) TCP receiver window
- Required buffering depends upon number of sources.
- Receiver window \( \geq \) RTT for full throughput
- Unfairness in many cases.
- Fairness can be improved by proper buffer allocation, selective drop policies, and scheduling.
- No starvation \( \Rightarrow \) Lower throughput shows up as increased file transfer times = Lower capacity

Conclusion: UBR may be OK for: LAN, w/o VBR, Small number of sources, AND cheap implementation
**ABR vs UBR**

**ABR**
- Queue in the source
- Pushes congestion to edges
- Good if end-to-end ATM
- Fair
- Good for the provider

**UBR**
- Queue in the network
- No backpressure
- Same end-to-end or backbone
- Generally unfair
- Simple for user

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The Ohio State University

Raj Jain
Improving Performance of TCP over UBR

TCP End System Policies

Vanilla TCP: Slow Start and Congestion Avoidance

TCP Reno: Fast Retransmit and Recovery

Selective Acknowledgments

ATM Switch Drop Policies

Minimum Rate Guarantees: per-VC queuing

Per-VC Accounting: Selective Drop/FBA

Early Packet Discard

Tail Drop
## Policies

<table>
<thead>
<tr>
<th>Switch Policies</th>
<th>End-System Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No FRR</td>
</tr>
<tr>
<td>No EPD</td>
<td></td>
</tr>
<tr>
<td>Plain EPD</td>
<td></td>
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<tr>
<td>Selective Drop</td>
<td></td>
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<tr>
<td>Fair Buffer Allocation</td>
<td></td>
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</tbody>
</table>
In LANs, switch improvements (PPD, EPD, SD, FBA) have more impact than end-system improvements (Slow start, FRR, New Reno, SACK). Different variations of increase/decrease have little impact due to small window sizes.

In large bandwidth-delay networks, end-system improvements have more impact than switch-based improvements.

FRR hurts in large bandwidth-delay networks.
Policies (Continued)

- Fairness depends upon the switch drop policies and not on end-system policies
- In large bandwidth-delay networks:
  - SACK helps significantly
  - Switch-based improvements have relatively less impact than end-system improvements
  - Fairness is not affected by SACK
- In LANs:
  - Previously retransmitted holes may have to be retransmitted on a timeout
  - SACK can hurt under extreme congestion.
Guaranteed Frame Rate (GFR)

- UBR with minimum cell rate (MCR) ⇒ UBR+
- Frame based service
  - Complete frames are accepted or discarded in the switch
  - Traffic shaping is frame based. All cells of the frame have CLP = 0 or CLP = 1
  - All frames below MCR are given CLP = 0 service. All frames above MCR are given best effort (CLP = 1) service.
Guaranteed Rate Service

- Guaranteed Rate (GR): Reserve a small fraction of bandwidth for UBR class.

<table>
<thead>
<tr>
<th>GR</th>
<th>GFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>per-class reservation</td>
<td>per-VC reservation</td>
</tr>
<tr>
<td>per-class scheduling</td>
<td>per-VC accounting/scheduling</td>
</tr>
<tr>
<td>No new signaling</td>
<td>Need new signaling</td>
</tr>
<tr>
<td>Can be done now</td>
<td>In TM4+</td>
</tr>
</tbody>
</table>
Guaranteed Rate: Results

- Guaranteed rate is helpful in WANs.
- For WANs, the effect of reserving 10% bandwidth for UBR is more than that obtained by EPD, SD, or FBA
- For LANs, guaranteed rate is not so helpful. Drop policies are more important.
Summary

- Traffic management distinguishes ATM from its competition.
- Binary feedback too slow for rate control. ER switches better for high bandwidth-delay paths.
- ABR pushes congestion to edges. UBR+ may be OK for LANs but not for large bandwidth-delay paths.
Our Contributions and Papers

- All our contributions and papers are available on-line at http://www.cis.ohio-state.edu/~jain/
- See Recent Hot Papers for tutorials.
Thank You!
ATM Research at OSU

- Traffic Management:
  - ERICA+ Switch Algorithm
  - Internet Protocols over ATM
  - Multi-class Scheduling
- Voice/Video over ATM
- Performance Testing
- ATM Test bed: OCARnet
Multi-class Scheduling

- Ensures no-starvation for all classes even under overload.
- Each class has an allocation = Guaranteed under overload.
- Some classes need minimum delay ⇒ have priority.
- Some classes are greedy.
  Left-over capacity is fairly allocated.
Voice/Video over ATM

- Speech suppression
  ⇒ Unused bandwidth can be used by data
  Cannot be used by voice.

- Hierarchical compression of Video
  Different users can see different bandwidth video

- Multipoint ABR

- Real-time ABR
Real-Time ABR

- Compressed video is VBR. VBR is subject to connection denial.
- Compression parameters can be adjusted dynamically.
- In situations, where reduced service is preferable over connection denial, such as in tactical environments, Video over ABR is preferable over no Video.
- ABR divides the available bandwidth fairly among contending connections.
- By proper control, ABR can be designed to reduce delay ⇒ Real-time ABR.
OSU National ATM Benchmarking Lab

- Started a new effort at ATM Forum in October 1995
- Defining a new standard for frame-based performance metrics and measurement methodologies
- We have a measurement lab with the latest ATM testing equipment. Funded by NSF and State of Ohio.
- The benchmark scripts can be run by any manufacturer/user in our lab or theirs.
- Modeled after Harvard benchmarking lab for routers
OCARnet

- Ohio Computing and Communications ATM Research Network
- Nine-Institution consortium lead by OSU
  - Ohio State University
  - Ohio Super Computer Center
  - OARnet
  - Cleveland State University
  - Kent State University
  - University of Dayton
  - University of Cincinnati
  - Wright State University
  - University of Toledo