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 UBR
- ATM Research at OSU
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
Binary vs Explicit Rate

- **Binary:** Explicit forward congestion indication (EFCI) bit in the cell header set by congested switches. Based on DECbit scheme.

- **Explicit Rate:** Sources send one **RM cell** every n cells. The switches adjust the explicit rate field **down**.
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
**ABR vs UBR**

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

**UBR**
- Queue in the network
- No backpressure
- Same end-to-end or backbone
- Generally unfair
- Works with TCP

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Improving Performance of TCP over UBR

TCP End Policies

System Policies

ATM Switch Drop Policies

TCP over UBR

Vanilla TCP: Slow Start and Congestion Avoidance

TCP Reno: Fast Retransmit and Recovery

Selective Acknowledgments

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>No EPD</th>
<th>EPD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No FRR</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>FRR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>New Reno</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>SACK + New Reno</strong></td>
<td></td>
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<tr>
<td><strong>Plain EPD</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Selective Drop</strong></td>
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<tr>
<td><strong>Fair Buffer Allocation</strong></td>
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</tbody>
</table>

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Policies: Results

- 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
  \[ \Rightarrow \text{SACK can hurt under extreme congestion.} \]
Guaranteed Frame Rate (GFR)

- UBR with minimum cell rate (MCR)
  \[ \Rightarrow \text{UBR}+ \]
- 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.
GFR: Results

- Per-VC queuing and scheduling is sufficient for per-VC MCR.
- FBA and proper scheduling is sufficient for fair allocation of excess bandwidth.

Questions:
- How and when can we provide MCR guarantee with FIFO?
- What if each VC contains multiple TCP flows?
Distributed Fair Buffer Allocation

Buffer occupancy (X)

Desired operating region

Load

Throughput

Delay

H (cliff)

L (knee)
VS/VD

- Without Virtual Source/Virtual Destination:

- With VS/VD:

- With VSVD, the buffering is proportional to the delay-bandwidth of the previous loop

⇒ Good for satellite networks
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.

<table>
<thead>
<tr>
<th></th>
<th>CBR</th>
<th>rt-VBR</th>
<th>nrt-VBR</th>
<th>ABR</th>
<th>UBR</th>
</tr>
</thead>
</table>

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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
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.
Reserving a small fraction of bandwidth for the entire UBR class improves its performance considerably.

It may be possible to do GFR with FIFO
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.