TCP/IP over ATM using ABR, UBR, and GFR Services

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Overview

- Why ATM?
- ABR: Binary and Explicit Feedback
- ABR Vs UBR
- TCP/IP over UBR
- TCP/IP over GFR
Why ATM?

ATM vs IP: Key Distinctions

1. Traffic Management: Explicit Rate vs Loss based
2. Signaling: Coming to IP in the form of RSVP
3. QoS: PNNI routing, Service categories. Integrated/Differentiated services
4. Switching: Coming to IP as MPLS
5. Cells: Fixed size or small size is not important
Traffic Mgmt Functions

- Connection Admission Control (CAC):
  Can quality of service be supported?
- Usage Parameter Control (UPC):
  Monitor and control traffic at the network entrance.
- Network Resource Management:
  Scheduling, Queueing, resource reservation
- Priority Control: Cell Loss Priority (CLP)
- Selective Cell Discarding: Frame Discard
- Feedback Controls: Network tells the source to increase or decrease its load.
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.
ABR: Binary vs Explicit Rate

- DECbit scheme in 1986: Bit $\Rightarrow$ Go up/Down
  - Used in Frame Relay (FECN) and ATM (EFCI)
- In July 1994, we proposed Explicit Rate Approach. 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

- NOTE: Explicit congestion notification (ECN) in IP is binary and applies only to TCP.
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
- If ATM not end-to-end: intelligent Q mgmt in routers
- Works for all protocols

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

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Improving Performance of TCP over UBR

TCP End
System 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

ATM Switch
Drop Policies

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<table>
<thead>
<tr>
<th></th>
<th>No FRR</th>
<th>FRR</th>
<th>New Reno</th>
<th>SACK + New Reno</th>
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</thead>
<tbody>
<tr>
<td><strong>No EPD</strong></td>
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<tr>
<td>Plain EPD</td>
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<tr>
<td>Selective Drop</td>
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<td>Fair Buffer Allocation</td>
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<td><strong>EPD</strong></td>
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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
    \[\Rightarrow\] 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>
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</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 (GR) service guarantees a small fraction of bandwidth for the UBR class.
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.
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?
Differential Fair Buffer Allocation

Throughput

Load

Delay

Buffer occupancy (X)

H (cliff)  L (knee)

Desired operating region

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DFBA (contd.)

ith VC’s Queue (Normalized) $X_i(W/W_i)$

Accept All frames.

Drop all low priority. Drop high priority with probability $P()$

Drop all low priority. Do not drop high priority

Drop all

Low Threshold $L$  High Threshold $H$

TCP Rate $D \propto \frac{MSS}{RTT \times \sqrt{P(drop)}}$

$X < L$  $X > H$

$1$  $2$  $3$  $4$
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
Traffic management distinguishes ATM from its competition.

Binary feedback too slow. 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.
Summary (Cont)

- 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.