Quality of Service In Data Networks

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Overview

- ATM QoS and Issues
- Integrated services/RSVP and Issues
- Differentiated Services and Issues
- QoS using MPLS
- End-to-end QoS
QoS Components

① Signaling
and Admission control

② Shaping

③ Policing

⑤ Scheduling

④ Routing

⑥ Buffer Mgmt

⑦ Traffic Monitoring
and feedback
ATM QoS: Issues

- Can’t easily specify QoS: What is the CDV required for a movie?
- Signaling too complex ⇒ Need Lightweight Signaling
- Need priority or weight among VCs to map DiffServ and 802.1D
- Need Group Address
- Need Heterogeneous Point-to-Multipoint: Variegated VCs
- Can’t easily aggregate QoS: \( VP = \Sigma VCs \)
- Need QoS Renegotiation
Integrated Services

1. **Best Effort Service:** Like UBR.
2. **Controlled-Load Service:** Performance as good as in an unloaded datagram network. No quantitative assurances. Like nrt-VBR or UBR w MCR
3. **Guaranteed Service:** rt-VBR
   - Firm bound on data throughput and delay.
   - Like CBR or rt-VBR
- Need a signaling protocol: RSVP
- Design philosophy similar to ATM
  - Per-flow
  - End-to-end
  - Signaling
Problems with IntServ+RSVP

- Complexity in routers: classification, scheduling
- Not scalable with # of flows
  ⇒ Not suitable for backbone.
- Need a concept of “Virtual Paths” or aggregated flow groups for the backbone.
- Need policy controls: Who can make reservations?
  ⇒ RSVP admission policy (rap) working group.
- Receiver Based:
  Need sender control/notifications in some cases.
- Soft State: Need route/path pinning (stability).
- No negotiation and backtracking
- Note: RSVP is being revived for MPLS and DiffServ
**Trend: Differentiation Not Integration**

- DiffServ to standardize IPv4 ToS byte’s first six bits
- Packets gets marked at network ingress
  - Marking $\Rightarrow$ treatment (behavior) in rest of the net
  - Six bits $\Rightarrow$ 64 different per-hop behaviors (PHB)

<table>
<thead>
<tr>
<th>Ver</th>
<th>Hdr Len</th>
<th>Type of Service (ToS)</th>
<th>Tot Len</th>
</tr>
</thead>
<tbody>
<tr>
<td>4b</td>
<td>4b</td>
<td>8b</td>
<td>16b</td>
</tr>
</tbody>
</table>
DiffServ (Cont)

- Per-hop behavior = % of link bandwidth, Priority
- Services: End-to-end. Voice, Video, ...
  - Transport: Delivery, Express Delivery, ...
    Best effort, controlled load, guaranteed service
- DS group will not develop services
  They will standardize “Per-Hop Behaviors”
- Marking based on static “Service Level Agreements” (SLAs). Avoid signaling.
Expedited Forwarding

- Also known as “Premium Service”
- Virtual leased line
- Similar to CBR
- Guaranteed minimum service rate
- Policed: Arrival rate < Minimum Service Rate
- Not affected by other data PHBs
  ⇒ Highest data priority (if priority queueing)
- Code point: 101 110
Assured Forwarding

- PHB Group
- Four Classes: No particular ordering
- Three drop preference per class
DS nodes SHOULD implement all 4 classes and MUST accept all 3 drop preferences. Can implement 2 drop preferences.

Similar to nrt-VBR/ABR/GFR

Code Points:

<table>
<thead>
<tr>
<th>Drop Prec.</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>010 000</td>
<td>011 000</td>
<td>100 000</td>
<td>101 000</td>
</tr>
<tr>
<td>Medium</td>
<td>010 010</td>
<td>011 010</td>
<td>100 010</td>
<td>101 010</td>
</tr>
<tr>
<td>High</td>
<td>010 100</td>
<td>011 100</td>
<td>100 100</td>
<td>101 100</td>
</tr>
</tbody>
</table>

Avoids 11x000 (used for network control)
Problems with DiffServ

- End-to-end $\neq \Sigma$ per-Hop
  Designing end-to-end services with weighted guarantees at individual hops is difficult. Only Expedited Forwarding will work.

- Designed for static Service Level Agreements (SLAs)
  Both the network topology and traffic are highly dynamic.

- How to ensure resource availability inside the network?

- DiffServ is unidirectional $\Rightarrow$ No receiver control
DiffServ Problems (Cont)

- QoS is for the aggregate not micro-flows. Not intended/useful for end users. Only ISPs.
  - Large number of short flows are better handled by aggregates.
  - Long flows (voice and video sessions) need per-flow guarantees.
  - High-bandwidth flows (1 Mbps video) need per-flow guarantees.

⇒ DiffServ alone is not sufficient for backbone. Signaling via RSVP will be required.
MPLS Mechanisms for QoS

- Explicit Routing: Multiple label switched paths (LSPs) can be used in parallel to the same egress.
- Signaling, Admission Control, Routing: Each LSP can have priority, preemption, policing, overbooking
- Constrained based routing of LSPs
  Allows both Traffic constraints and Resource Constraints (Resource Attributes)
- Hierarchical division of the problem (Label Stacks)
- Danger: Too much too soon…again
Bandwidth Broker

- Repository of policy database. Includes authentication
- Users request bandwidth from BB
- BB sends authorizations to leaf/border routers
  Tells what to mark.
- Ideally, need to account for bandwidth usage along the path
- BB allocates only boundary or bottleneck
IEEE 802.1D Model

- Massive bandwidth. Simple priorities will do.
- **Up to eight priorities**: Strict.
  1. Background
  2. Spare
  0. Best Effort
  3. Excellent Effort
  4. Control load
  5. Video (Less than 100 ms latency and jitter)
  6. Voice (Less than 10 ms latency and jitter)
  7. Network Control
End-to-end View

- ATM/PPP backbone, Switched LANs/PPP in Stub
- IntServ/RSVP, 802.1D, MPLS in Stub networks
- DiffServ, ATM, MPLS in the core
Additional Mechanisms

- Policy based Routing
- Weighted Fair Queueing
- Weighted Random Early Detection
- Link Fragmentation and Interleaving
- These internal mechanisms do not require standardization

P(Discard) vs Avg Q
Summary

- ATM: CBR, VBR, ABR, UBR, GFR
- Integrated Services: GS = rtVBR, CLS = nrt-VBR
- Signaling protocol: RSVP
- Differentiated Services will use the DS byte
- MPLS allows traffic engineering and is most promising
- 802.1D allows priority
References

- For a detailed list of references see: refs/ipqs_ref.htm
- Additional papers and presentations on QoS are at: http://www.cis.ohio-state.edu/~jain/