Internet QoS

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Introduction

• The Internet only provides a ‘best effort’ service model
  – It does not provide any guarantee in terms of delay and/or bandwidth.

• This service model is not suitable for many applications
  – Interactive sessions like live audio/video conferencing, real-time applications require strict delay and bandwidth guarantee
Quality of Service (QoS)

• QoS is all about providing different class of services in IP networks
  – Each class may support different subclasses
• Applications and/or users will specify the service they require from the network and the network will provide that.
• QoS is a superset of ‘best effort’ service model
  – It requires additional features/mechanisms on the end host and routing devices
QoS Architectures

• There are two prominent architectures for QoS:
  – Integrated Services (IntServ)
  – Differentiated Services (DiffServ)

• They differ in their granularity of service
  – IntServ provides per flow guarantees
  – DiffServ provides aggregated service classes

• DiffServ is more popular than IntServ
  – IntServ is not scalable and incremental deployment is not possible
Integrated Services (IntServ)

- Packets with same source, destination IP address, port number and protocol number are identified as flows
- Two level of service class for each flow:
  - **Controlled load service**: as good as an unloaded network
  - **Guaranteed service**: provides firm guarantees
- Makes use of **Resource Reservation Protocol (RSVP)**
  - RSVP reserves resources for a particular flow in all the routers in a particular path between a source and destination
  - All the in-path routers must store per flow resource reservation information
- IntServ has scalability and deployment problem
  - This is an end-to-end model
  - All in-path routers must also classify packets into flows
IntServ: Mechanism

- **Signaling and/or admission control**: A signaling protocol RSVP is required for reservation of resources. Admission control blocks incoming traffic if the desired QoS cannot be met.
Differentiated Services (DiffServ)

- Provides per hop behavior instead of end-to-end
  - No signaling/reservation needed.
  - No need to classify packets into flows
- Support a small number of forwarding classes at each router
  - Service models to be accomplished through provisioning
- Edge routers map packets into forwarding classes based on service level agreement (SLA).
  - Forwarding class is encoded in the packet header.
  - Six bits in the TOS file in the IP packet is used in DiffServ:
    - Examples of forwarding classes:
      - 101 110 - Expedited Forwarding
      - 010 010 - Assured forwarding
    - Problems with DiffServ:
      - end-to-end service guaranteed is hard to
DiffServ Code Point (DSCP)
Mechanisms for QoS

• The mechanisms need to be in place to augment the network with QoS capabilities:

  – **Signaling and/or admission control**: A signaling protocol is required for reservation of resources. Admission control blocks incoming traffic if the desired QoS cannot be met.

  – **Packet classification/marking**: Packet classifiers select packets in a traffic stream based on the content of some portion of the packet header.

  – **traffic conditioning**: Traffic conditioning performs metering, shaping, policing and/or re-marking to ensure that the traffic entering the DS domain conforms to the rules.
Mechanisms Contnd..

- **Marking**: the process of setting the DS codepoint in a packet based on defined rules; pre-marking, re-marking.
- **Metering**: the process of measuring the temporal properties (e.g., rate) of a traffic stream selected by a classifier.
- **Shaping**: the process of delaying packets within a traffic stream to cause it to conform to some defined traffic profile.
Assure Forwarding (AF)

- A general use DiffServ Per-Hop-Behavior (PHB) Group defined by RFC 2597
  - The AF PHB group provides delivery of IP packets in four independently forwarded AF classes
  - Within each AF class IP packets are marked with one of three possible drop precedence values
- In a DS node, the level of forwarding assurance of an IP packet thus depends on
  - how much forwarding resources has been allocated to the AF class that the packet belongs to
  - what is the current load of the AF class, and, in case of congestion within the class
  - what is the drop precedence of the packet.
AF Example

- **Recommended values of AF DS code points (DSCP)**

  
  \[
  \begin{align*}
  AF11 &= '001010', \quad AF12 = '001100', \quad AF13 = '001110', \\
  AF21 &= '010010', \quad AF22 = '010100', \quad AF23 = '010110', \\
  AF31 &= '011010', \quad AF32 = '011100', \quad AF33 = '011110', \\
  AF41 &= '100010', \quad AF42 = '100100', \quad AF43 = '100110'.
  \end{align*}
  \]

<table>
<thead>
<tr>
<th></th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Drop Prec</strong></td>
<td>001010</td>
<td>010010</td>
<td>011010</td>
<td>100010</td>
</tr>
<tr>
<td><strong>Medium Drop Prec</strong></td>
<td>001100</td>
<td>010100</td>
<td>011100</td>
<td>100100</td>
</tr>
<tr>
<td><strong>High Drop Prec</strong></td>
<td>001110</td>
<td>010110</td>
<td>011110</td>
<td>100110</td>
</tr>
</tbody>
</table>
Example AF configuration

<table>
<thead>
<tr>
<th>Class</th>
<th>Resources</th>
<th>Subclass 1</th>
<th>Subclass 2</th>
<th>Subclass 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In</td>
<td>Out</td>
<td>In</td>
</tr>
<tr>
<td>1</td>
<td>40%</td>
<td>2%</td>
<td>50%</td>
<td>3%</td>
</tr>
<tr>
<td>2</td>
<td>25%</td>
<td>2%</td>
<td>60%</td>
<td>4%</td>
</tr>
<tr>
<td>3</td>
<td>20%</td>
<td>3%</td>
<td>70%</td>
<td>5%</td>
</tr>
<tr>
<td>4</td>
<td>15%</td>
<td>3%</td>
<td>100%</td>
<td>6%</td>
</tr>
</tbody>
</table>

- The drop precedence level of a packet could be assigned, for example, by using a *token bucket /leaky bucket* traffic policer, which has as its parameters a rate and a size, which is the sum of two burst values: a *committed information rate (CIR)* and *Peak Information Rate (PIR)*

- **Token Bucket Animation**
Token Bucket Usage

**Token Refill**
Buckets are filled separately. The process adds $\text{CIR} \times \text{Ti}$ bytes to the first bucket and $\text{PIR} \times \text{Ti}$ bytes to the second bucket every $\text{Ti}$ milliseconds.

**Metering(X)**
- If ($\text{EBS} < S$) then
  - Packet Violates;
- Else if ($\text{CBS} < S$) then
  - Packet Exceeds;
  - $\text{Size} = \text{Size} - S$;
- Else
  - Packet Conforms;
  - CBS = CBS - S;
  - EBS = EBS - S;
- End if.

**Packet flow**
Bursts enter metering space at rate $\text{AR}$ each. However, pauses between frames allow buckets to refill.
Expedited Forwarding (EF) PHB

• The EF PHB (RFC 2475) can be used to build a low loss, low latency, low jitter, assured bandwidth, end-to-end service through DS domains.
  – Codepoint 101110 is recommended for the EF PHB.
• Creating such a service has two parts:
  – Configuring nodes so that the aggregate has a well-defined minimum departure rate. ("Well-defined" means independent of the dynamic state of the node. In particular, independent of the intensity of other traffic at the node.)
  – Conditioning the aggregate (via policing and shaping) so that its arrival rate at any node is always less than that node's configured minimum departure rate.
Several types of queue scheduling mechanisms may be employed to deliver the forwarding behavior:

- Class Based Queue (CBQ)
- Token Bucket Flow (TBF)
- Clark-Shenker-Zhang (CSZ)
- First In First Out (FIFO)
- Priority Traffic Equalizer (TEQL)
- Stochastic Fair Queuing (SFQ)
- Asynchronous Transfer Mode (ATM)
- Random Early Detection (RED)
- Generalized RED (GRED)
FIFO Queuing
Random Early Drop (RED) Queuing
Other approaches to QoS

- Multi Protocol Label Switching (MPLS)
- Traffic Engineering
- Constraint Based Routing
- Software Defined Networking
Critics of QoS

• QoS is a highly debated issue
• It's unlikely that Internet wide QoS will ever be deployed
• On the other hand, QoS has been hugely successful in private/enterprise networks
• Net-neutrality vs QoS is an ongoing issue.
Questions?

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