



IPv6 (IP version 6) Essentials

Ch6: Quality of Service in IPv6



Louis Chuang
Fu Jen Catholic University
EE ENCL



Introductoion (1)

- Changing the Internet to handle **real-time traffic**:
 - QoS is still a topic of research and controversy, and corresponding services and protocols employ very complex.
 - It requires to change the very root of the Internet:
 - ❖ The IP packet design.
 - ❖ The routing.
 - ❖ The forwarding functions.
 - Routes in IP are determined by:
 - ❖ The IP destination address.
 - ❖ The state of routing tables in each router on the path to the destination.
 - All IP packets of **the same streaming** follow **the same route** until the route changes due to congestion, topology updates, etc.
 - ❖ TCP, SCTP are connection-oriented.
 - ❖ But UDP is connectionless.



Introductoion (2)

- IPv4 network **classifies traffic** according to **the type of service (TOS) field (8-byte)** in the IP header, but it **did not succeed** → the TOS field was never used uniformly.
- For true **real-time support**, users or programs must be able to specify **acceptable upper and/or lower service limits**.
 - ❖ It requires information about **which routes** in the network **are suited for real-time traffic and at what time**.
- The **edge routers** keep **the complexity** at the edge network; but the routing and forwarding of **the core routers** in core networks **should be as simple (and fast) as possible**.



QoS Paradigms (1)

- The issue: to identify **the right location for providing QoS**.
 - End system-based (client-based) QoS:
 - ❖ **The end systems** must be able to **compensate**:
 - Packet loss.
 - Packet Delay.
 - Delay jitter, etc.
 - For streaming.
 - ❖ In end system, there are **some mechanisms** that use **extrapolation of missing data**, **intelligent playback buffers** to **compensate for variances in interarrival times** of packets.
 - Service-based QoS:
 - ❖ In IPv6, **different service classes** could be formed **different groups** with **different multicast addresses**.
 - ❖ Ex) **Four different classes** of the same audio traffic-each encoded with **different quality**:
 - Such as 5.5, 11, 22, and 44 KHz.



QoS Paradigms (2)

- They form **four multicast group** (have **different queuing** and **processing** by the routers and end systems).
- The existing **IPv6 ICMP** multicast feedback control message mechanism:
 - Can be used **to shape the traffic characteristics** at the sender and intermediate routers (e.g., the highest quality to be generated by the sender, which links need to carry this multicast group because of a multicast member downstream, how to enter/leave an multicast group, etc.).
- ❖ The sender have to provide **the same data** (but of **different quality**) multiple times.



QoS Paradigms (3)

■ Class/Priority-based QoS:

- ❖ To handle **multimedia traffic requirements**, routers need to know **how to deal with packets with different service requirements** (real-time, non-real-time, etc.).
- ❖ **IP packets** have to **contain corresponding information**:
 - **IPv6 Routing Extension header** can be used:
 - Such as **the Hop-By-Hop Extension header** can transmit required information to all routers on the path.
- ❖ Network basically transmits packets **in best-effort mode**.
- ❖ Network may implement **a feedback loop to the sender** so that the sender can **adapt its multimedia coding**.
 - **Senders code** and **label packets with proper priority**.
 - Ex) Transmit high-quality (44 KHz) audio, **hierarchical coding may be used**.
 - Data is encoded as a **base audio packet** containing the data for **5.5 KHz quality**.



QoS Paradigms (4)

- A second packet containing the difference between 5.5 and 11 KHz.
- A third packet containing the difference between 11 and 22 KHz.
- A fourth packet containing the difference between 22 and 44 KHz.
- Like MPEG coding: I frame, B frame, & P frame.
- ❖ Routers may drop packets according to priority.
 - They allow to drop packets in case of congestion: the order is fourth, third, second, and finally first.
 - The audio quality may differ, the audio packet is completely lost only if all four kinds of packets are all dropped.
 - The negative effect of class/priority-based QoS is the additional overhead for the sender:
 - IP header management and hierarchical coding.



QoS Paradigms (5)

■ Resource Reservation-based QoS:

- ❖ It is **the most complex** QoS paradigm.
 - Because **the routers** must have **full knowledge of connections** and **their QoS requirements** to **reserve sufficient resources**.
 - Including queues and buffer space, computing time, specific algorithms, etc.
 - With **proper resource reservation setup negotiations** and signaling, thus **QoS can be guaranteed** end-to-end between sender and receiver(s).
- ❖ Ex) **The Resource Reservation Protocol (RSVP)**.
 - RSVP establishes **packet classification** and **forwarding** status information **in each router** along the path.
- ❖ The main question is:
 - The substantial **complexity**:
 - **The amount of state on each router** scales in proportion to the number of concurrent reservations.



Quality of Service (QoS) in IPv6 Protocols (1)

- In the IP header and extension headers, IPv6 protocols implement a small number of QoS-specific service elements to support different QoS requirements.
- In IPv6 header:
 - Flows and their flow labels.
 - Flows:
 - ❖ A flow is a sequence of packets sent from a particular source to a particular destination(s).
 - ❖ The handling for different flows in the routers can use:
 - Control protocol (such as RSVP), or
 - Information carried in the flow's packets.
 - Carried in IP header (flow labels) or hop-by-hop extension header.
 - ❖ A flow is uniquely identified by:
 - The source/destination IP address/port numbers, and a non-zero flow label.
 - ❖ If the flow label is zero, these packets do not belong to any flow.



Quality of Service (QoS) in IPv6 Protocols (2)

- ❖ All packets **belonging to the same flow**:
 - If these packets contain the hop-by-hop extension header: they all must be originated with **the same hop-by-hop extension header contents**.
 - If these packets contain the routing extension header: they all must be originated with **the same routing extension header contents**.
- Flow labels:
 - ❖ The flow label field in the IPv6 header is 20-bit.
 - ❖ A flow label is assigned by the flow's source node.
 - ❖ The value is randomly assigned from the range of 00001 ~ FFFFF.
 - ❖ Hosts or routers, which do not support the functions of the flow label field, will ignore the field content.



Quality of Service (QoS) in IPv6 Protocols (3)

■ Priority/Class:

- In the original 1996 IPv6 proposal, a 4-bit priority field in the IPv6 header was designed.
 - ❖ In the same source host, It can be used to identify different flow priorities.
 - ❖ It was divided into two ranges:
 - 0 ~ 7: for fixed transmission priorities.
 - To indicate traffic classes, such as interactive traffic, attended transfers, unattended transfers, filler traffic, etc.
 - The source provides congestion control-traffic, to limit their bandwidth.
 - 8 ~ 15: for real-time traffic drop priorities.
 - The lowest priority (8): the sender will drop it first in a congestion situation (e.g., high-quality video traffic).
 - The highest value (15): the sender will drop it last in a congestion situation (e.g., low-quality audio traffic).



Quality of Service (QoS) in IPv6 Protocols (4)

- After discussions within the IETF, the IPv6 header was redesigned to contain:
 - ❖ 8-bit class field.
 - ❖ 20-bit flow label.
- In 1997, the class field (8-bit) contains:
 - ❖ A "D" bit is for marking delay-sensitive traffic.
 - ❖ 3-bit is for priorities (8 different traffic classes).
 - ❖ 4-bit is reserved for congestion-control protocol.
- In 1998, the class field is defined for the DiffServ (differentiated services, DS) (RFC 2474).
 - ❖ DS field can use the IPv4 TOS field (8-bit) or the IPv6 traffic class field (8-bit).
 - DSCP (DS codepoint, 6-bit) in DS field: has 64 codepoints to be divided into 3 pools:



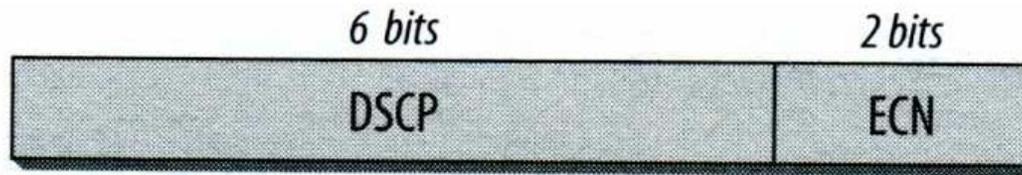
Quality of Service (QoS) in IPv6 Protocols (5)

- Pool 1: 32 recommended codepoints.
- Pool 2: 16 codepoints.
- Pool 3: 16 codepoints.
- DSCP is used to select the proper PHB (per-hop behavior).
 - PHB is a router's processing behavior for packets.
 - A default PHB (an all-zeros DS codepoint) is provided for routers to provide the best-effort forwarding behavior.
- In Pool 1, 8 recommended class selector codepoints (000000 ~ 111000) (RFC 2474).
 - A larger value of class selector codepoint has a higher / better treatment by routers.
 - For routing packets (routing traffic), their codepoints are 110000 and 111000. They have a preferential forwarding comparing to other packets with the default codepoint 000000.



Quality of Service (QoS) in IPv6 Protocols (6)

- Format of the DS field.



DSCP	Differentiated services codepoint	RFC 2474
ECN	Explicit congestion notification	RFC 3168

- The codepoint pools.

Pool	Codepoint space	Assignment policy
1	xxxxx0	Standard use
2	xxxx11	Experimental/local use
3	xxxx01	Experimental/local use; potential standard use in the future



Quality of Service (QoS) in IPv6 Protocols (7)

- In a router, PHBs can be implemented by:
 - Strict priority queuing.
 - Weighted fair queuing.
 - Class-based queuing.
 - Etc..
- ECN (explicit congestion notification, 2-bit):
 - 4 codepoints (00 ~ 11) are used for congestion notification → based on packet loss.
 - Routers can signal overload before packet loss.
 - 00: packet does not use ECN.
 - 01/10: sender & receiver are ECN-enable.
 - 11: router signals congestion.



Quality of Service (QoS) in IPv6 Protocols (8)

- The DS field in a trace file.

No.	Sta	Source Address	Dest Address	Summary
1	M	fe80::210:7bff:fe0b:75a0	ff02::9	RIPng: Response Version=1

DLC: Ethertype=86DD, size=106 bytes

IPv6: ----- IPv6 Header -----

- IPv6: Version = 6
- IPv6: Traffic Octet = 224
- IPv6: Differentiated Services Field : 0xE0 (Preferential Forwarding)
- IPv6: Currently Unused Field : 0x00
- IPv6: Flow Label = 0x00000
- IPv6: Payload Length = 52
- IPv6: Next Header = 17 (UDP)
- IPv6: Hop Limit = 255
- IPv6: Source address = fe80::210:7bff:fe0b:75a0
- IPv6: Destination address = ff02::9

UDP: ----- UDP Header -----

- UDP: Source port = 521 (RIPng)
- UDP: Destination port = 521 (RIPng)
- UDP: Length = 52
- UDP: Checksum = 9E60 (correct)
- UDP: [44 byte(s) of data]

RIPng: Response Version=1



Quality of Service (QoS) in IPv6 Protocols (9)

- IPv6 extension headers:
 - 2 IPv6 extension headers can be used to support QoS:
 - The routing extension header:
 - ❖ It can be used to request a specific route for supporting QoS.
 - ❖ In IPv4, it is called a loose source route.
 - It needs to know that:
 - The network topology, possible throughput / bandwidth, etc.
 - The hop-by-hop extension header:
 - ❖ It can send “router alert signaling message” (RFC 2711) to every router on the path.
 - ❖ The router alert signal (2-byte):
 - It is carried in the option field of the hop-by-hop extension header.
 - ❖ If routers can not recognize the router alert option, it will ignore this option and continue processing the header.



Quality of Service (QoS) in IPv6 Protocols (10)

- Currently defined **router alert signal types** (2-byte, $2^{16} = 65536$).

Value	Description
0	IP packet contains a Multicast Listener Discovery message.
1	IP packet contains an RSVP message.
2	IP packet contains an Active Networks message—the sender is attempting to load a program into the router for executing customized functions.
3–35	IP packet contains an Aggregated Reservation Nesting Level (RFC 3175, RSVP)
36–65,535	Reserved to IANA for future use.



Quality of Service (QoS) in IPv6 Protocols (11)

■ RSVP:

- The RSVP (Resource Reservation Protocol, RFC 2205) is **not** a part of the core IPv6 standardization, **but it is** implemented in **many applications**.
- It utilizes **the flow label** to reserve resource for each flow.
- The RSVP needs to be run **on end systems (sender & receiver)**, and **routers**.
- **Host** uses RSVP to **send QoS requests** to **all routers** along the path to **establish / maintain their status information**.
- **RSVP** executes **traffic control**, which **contains 4 subsystems**:
 - ❖ **A packet classifier**: to determine the QoS class.
 - ❖ **An admission control entity**: to decide whether the system can provide sufficient resources to the requested QoS.
 - ❖ **A policy control entity**: to decide whether the requester is permitted to obtain a specific QoS.



Quality of Service (QoS) in IPv6 Protocols (12)

- ❖ A **packet scheduler**: to ensure timely forwarding of IP packets to the next hop.
- RSVP uses a **flow descriptor** to describe the **QoS requirement of each flow**:
 - ❖ **R-spec**: a flow specification.
 - The reserved parameters for its QoS.
 - ❖ **T-spec**: a filter specification.
 - The flow traffic characteristics.
- The main **RSVP messages** are:
 - ❖ **Path messages**.
 - Each sender transmits **path messages downstream** to find a **routing path to destination**.
 - ❖ **Reservation requests**.



Quality of Service (QoS) in IPv6 Protocols (13)

- Each receiver sends RSVP reservation requests upstream toward the sender(s) on the reverse path of the flow received.
- These packets create and maintain state information (reservations) in each router.
- Routers on the path may not understand RSVP, but they are still able to forward IP packets with RSVP content to the next router.
- Tear-down messages are used to release reserved resource.



QoS Architectures (1)

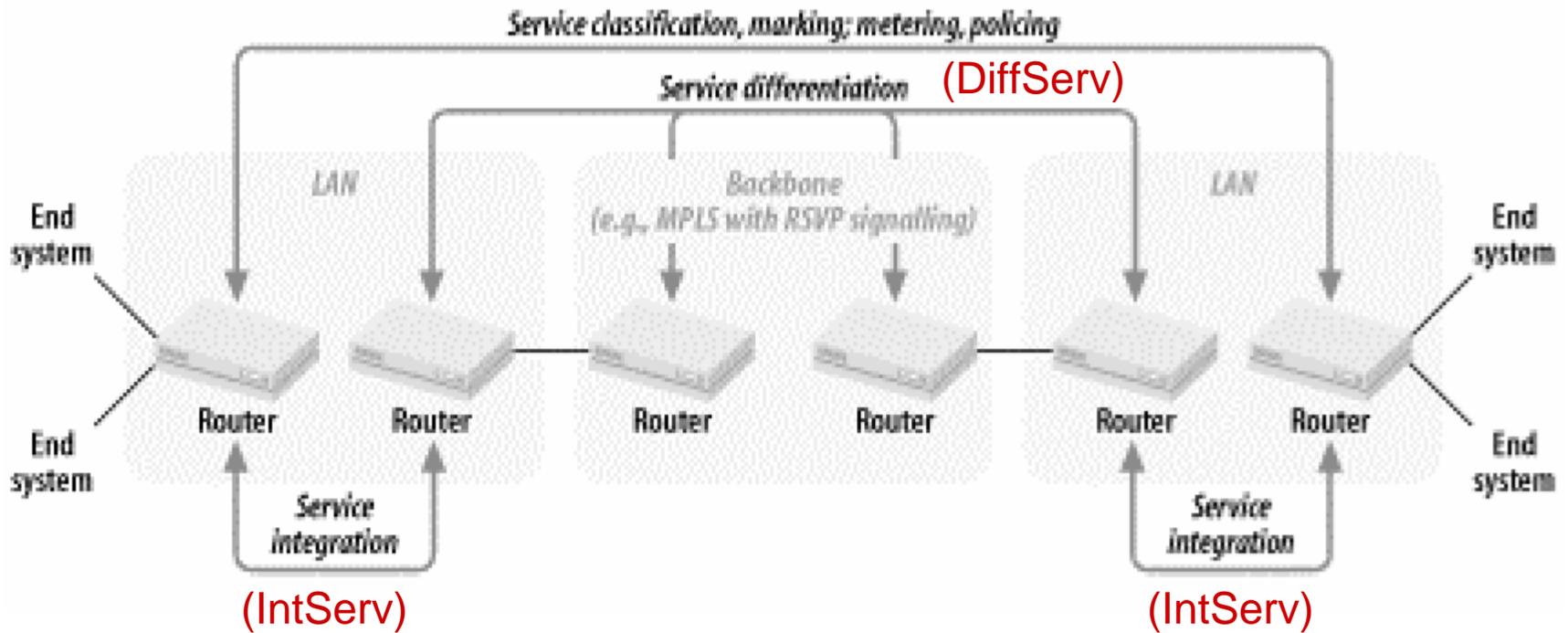
- Three different QoS architectures:
 - Integrated service (IntServ).
 - Differentiated service (Diffserv).
 - IPv6 label switch architecture (6LSA).
- IntServ & DiffServ can be combined to operate.

- Traffic policing:
 - It is used **to control traffic (flows) to enter a network.**
 - There are several different methods:
 - ❖ The fair queuing algorithms.
 - ❖ The priority classes.
 - ❖ The adaptive mechanisms.
 - ❖ Etc..



QoS Architectures (2)

- Possible common service architecture (combine IntServ & DiffServ).





QoS Architectures (3)

- Integrated services (IntServ) architecture:
 - The RSVP (RFC 2210) is used to support IntServ architecture.
 - Bandwidth and all corresponding resources are reserved per flow.
 - It is like the telephony service (circuit switch).
 - ❖ A circuit was reserved exclusively for the communication partners and could not be used by any other party while the connection was active.



QoS Architectures (4)

- Differentiated services (Diffserv) architecture (RFC 2475):
 - It is based on **the classification for each flow**.
 - How to **determine the required QoS classes**:
 - ❖ Based on **classifiers & traffic conditioners**.
 - Using **the codepoints (DSCP)** of the DS field in each IP packet.
 - ❖ To indicate the packet's QoS requirements.
 - ❖ Via **the PHB** to get QoS-specific treatment in each router.
 - DiffServ can work with IntServ (cooperation).
 - ❖ **RSVP** would be used **only inside the LAN environments**, and between **routers at the edges**.



QoS Architectures (5)

- IPv6 label switch architecture (6LSA):
 - One new proposal **using the flow label field** → the 6LSA.
 - The 6LSA architecture **is similar to MPLS (Multi-Protocol Label Switching)**.
 - **Labels** are used to **provide QoS services** across a 6LSA domain (the routers need to enable 6LSA function).
 - It will need to go through peer review in the IETF before it is finalized.



Mapping IP QoS to Underlying Transmission Networks

- IP QoS is the function in layer 3 (network layer).
 - How to map to the function of layer 2?
- IP QoS elements have been designed as standalone mechanisms.
- Any mapping onto lower-layer QoS elements, such as:
 - ATM traffic classes:
 - ❖ It has fixed traffic classes.
 - ❖ It may seem straightforward (is easier to map).
 - MPLS (Multi-Protocol Label Switching):
 - ❖ Its traffic classification is dynamic.
 - ❖ The dynamic mapping of IP QoS to MPLS attributes is a much more difficult task.
- Both MPLS and IP QoS are in research & implementation.
- In the future, to support VoIP (voice over IP), multimedia applications.