

Quality of Service and MPLS Methodologies

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Quality of Service (QoS)

This purpose of this paper is to provide an introduction and overview of the Quality of Service (QoS) protocols now available or under development for Internet Protocol (IP) based networks.

Introduction

Routers that forward Internet traffic on a first-in-first-out basis (called *best-effort* (BE)), work well as long as there is enough buffer capacity on the interface.

As the amount of traffic on the Internet grows the network performance gradually decreases, causing network degradation, network delay or jitter, and packet loss. Applications such as Web access, email, and file transfer can typically withstand network delays, but delay-sensitive applications such as voice, video, and other real-time applications cannot.

In a best-effort data delivery network, increasing bandwidth is a necessary first step to help with these delay-sensitive and real-time applications. Faster links require faster memory/buffers or more forwarding resource on the routers to eliminate delays, but it is still not enough to avoid jitter during traffic bursts.

To provide adequate service in a network, some level of intelligence must be built into the network. *Quality-of-Service* (QoS) protocols are designed to provide some level of predictability and control to an IP best-effort service.

Methods of Implementing QoS

- Asynchronous Transfer Mode (ATM)
- Integrated Services (IntServ)
- Differentiated Services (DiffServ)
- Multi-protocol Label Switching (MPLS)

QoS and Asynchronous Transfer Mode

Asynchronous Transfer Mode (ATM) is a protocol that transmits data as fixed 53 byte packets or cells. In order for a workstation with variable length packets to communicate with a fixed length cells network, the *International Telecommunication Union -Telecommunication* (ITU-T) defined a collection of *ATM Adaptation Layers* (AAL).

The AAL lies between the ATM layer and the higher layers that use the ATM service. Its main purpose is to resolve any disparity between a service required by the user and services available at the ATM layer. The AAL maps user information into ATM cells and accounts for transmission errors. It also might transport timing information so the destination can regenerate time dependent signals. The information transported by the ATM adaptation layer is divided into five classes according to the following properties:

- **AAL1** is used for connection-oriented services that requires *constant bit rate* (CBR) such as voice that has time dependency. It sends timing information with the data so that the time dependency may be recovered.

- **AAL2** is used for connection-oriented services that require *variable bit rate* (VBR) and do not require CBR, such as video.
- **AAL3/4** AAL3 and AAL4 have been merged into a single AAL which name is AAL3/4 to support both connection-oriented (VBR) and connectionless oriented services.
- **AAL5** is designed for connection-oriented services (mostly data) where no specific timing relationship required.

QoS and Integrated Services

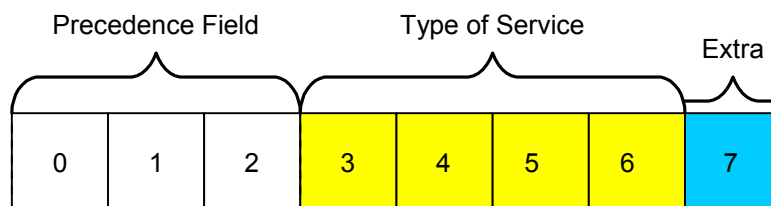
The goal of *Integrated Services* (IntServ) is to provide an end-to-end QoS solution. It is an overall QoS architecture developed by IETF and supports two broad classes of applications:

- **Guaranteed Services (GS)**: For real-time applications with strict bandwidth and latency requirements (latency sensitive traffic).
- **Controlled Load (CL)**: For traditional applications with performance of a lightly loaded best-effort IP network (best-effort).

IntServ uses RSVP signaling protocol to communicated QoS requirements to the network. The network then acknowledges the QoS request with a success or failure reply. RSVP carries classification information, such as the source and destination IP addresses and UDP port numbers, so that traffic with specific QoS requirements can be recognized within the network.

Type of Service Field

The *Type-of-Service* field (ToS), in the IP header, consists of 8 bits: 3 bits of precedence; 4 bits of ToS; and one unused bit. The precedence bits are set at the edge of the network into 8 different classes. The network nodes along the packet's path forward packet preferentially based on its precedence bits.



IPv4 Type of Services

Figure 1

Precedence Field: 3 LSB determines packet relative priority, 0-7, low to high

Precedence Values:

0	Routine
1	Priority
2	Immediate

3	Flash
4	Flash override
5	Critical
6	Internet control
7	Network control

ToS Field: 4-bits indicates packet classifications

0	Normal service
1	Minimum monetary cost
2	Maximum reliability
4	Maximize throughput
8	Minimize delay

Only 5 out of 16 possible values are defined; the remaining 11 possible values are not.

There were multiple problems with the above model:

- The Precedence field allowed only for relative priorities 0-7.
- Very few routers used deployed the ToS subfield within the Internet.

Only recently, the IETF revisited this model and as part of DiffServ architecture, the Type-of-Services field became the DiffServ field.

QoS and Differentiated Services

Differentiated Services (DiffServ) provides a rough and simple way to categorize and prioritize network traffic aggregates. DiffServ architecture (IETF-RFC2475) came as a counterpoint to the relatively complex nature of the IntServ architecture. In IPv4, every router looked at the Address, Protocol, and Port Number fields, and then applied classification rules to each packet on a per-hop basis. The classification rules were applied to a 4-bit field on the packet called ToS; then a forwarding decision was made. DiffServ takes the IP ToS field, renames it the DS byte, and uses it to carry information about IP packet service requirements. It operates at Layer 3 only and does not deal with lower layers. DiffServ relies on traffic conditioners sitting at the edge of the network to indicate each packet's requirements.

DiffServ classifies packets at the edge of the network, by setting the DS-fields of the packets according to their DS value. In the middle of the network, packets are buffered and scheduled in accordance to their DS-fields by *Weighted Random Early Detection* (WRED) and *Weighted Round Robin* (WRR). Important traffic such as network control traffic and traffic from premium customers will be forwarded preferentially.

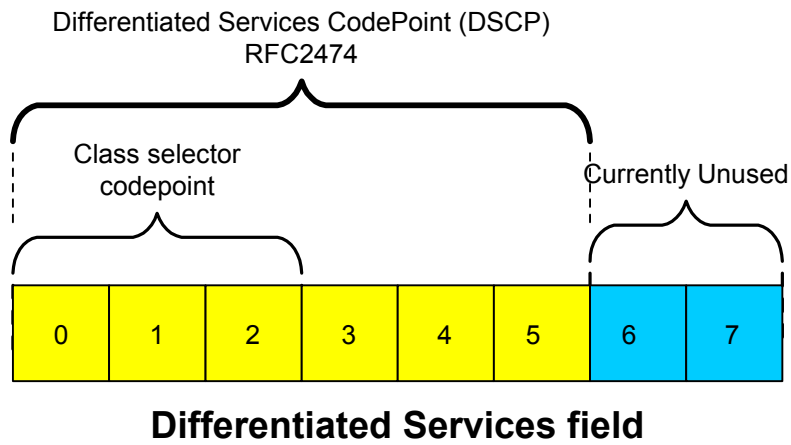


Figure 2

The DSCP (6 bits) is used to queue and schedule packets, this would theoretically allow up to 64 different contexts.

Per-Hop Behaviors and Codepoints

Per-Hop Behaviors (PHBs) are applied by the conditioner to traffic at a network ingress point (network border entry) according to pre-determined policy criteria. The traffic may be marked at this point, routed according to the marking, and then unmarked at the network egress (network border exit).

DiffServ provides a simple and coarse method of classifying services of various applications. There are currently two standard PHBs defined that effectively represent two service levels (traffic classes):

- **Expedited Forwarding (EF):** Has a single codepoint (DiffServ value). EF minimizes delay and jitters and provides the highest level of aggregate quality of service. Any traffic that exceeds the traffic profile (which is defined by local policy) is discarded. Recommended codepoint for EF is 101110.
- **Assured Forwarding (AF):** Has four classes and three drop-precedences within each class (equaling twelve codepoints). Excess AF traffic is not delivered with as high a probability as the traffic "within profile," which means it may be demoted but not necessarily dropped.

Recommended Codepoints for the four general uses of AF classes are given below. These codepoints do not overlap with any other general use PHB groups.

Drop-Precedence	Class 1	Class 2	Class 3	Class 4
Low Drop	AF11= 001010	AF21= 010010	AF31= 011010	AF41= 100010
Medium Drop	AF12= 001100	AF22= 010100	AF32= 011100	AF42= 100100
High Drop	AF13= 001110	AF23= 010110	AF33= 011110	AF43= 100110

- **Default Forwarding (DF):** No special operation and is the same as best-effort forwarding.

Multi-Protocol Labeling Switching and DiffServ

Multi-Protocol Labeling Switching (MPLS) provides bandwidth management for aggregates through network routing control according to the labels in (encapsulating) packet headers.

Historically, the Internet infrastructure was developed and optimized solely for data. But, the addition of *Hypertext Transfer Protocol* (HTTP), voice, multimedia traffic, and real-time electronic-commerce applications to the infrastructure are pushing the bandwidth demands toward higher limits and the ability to guarantee that bandwidth.

The primary focus of early protocol development was to ensure that a distributed network should operate properly, subsequently designers concentrated on functionality that supported segmentation, retransmission, and dynamic routing. Successful delivery of the data was their main and primary concern. Because of the above condition, every packet was checked at each stop along its path through the network, the IP datagram was decomposed, verified, analyzed, and reconstructed before it was finally sent on its way.

MPLS is one of several initiatives to enable delivery on the promise of a converged network. By combining the attributes of Layer-2 switching and Layer-3 routing into a single entity, MPLS provides the following benefits:

- Enhanced scalability through switching technology
- *Class-of-service* (CoS)- and *Quality-of-service* (QoS)-based services (Modified to incorporate DiffServ support)
- *Internet protocol* (IP)-over-*asynchronous transfer mode* (ATM) overlay model and its associated management overhead
- Interoperability from a standards-based solution
- Traffic-engineering capabilities

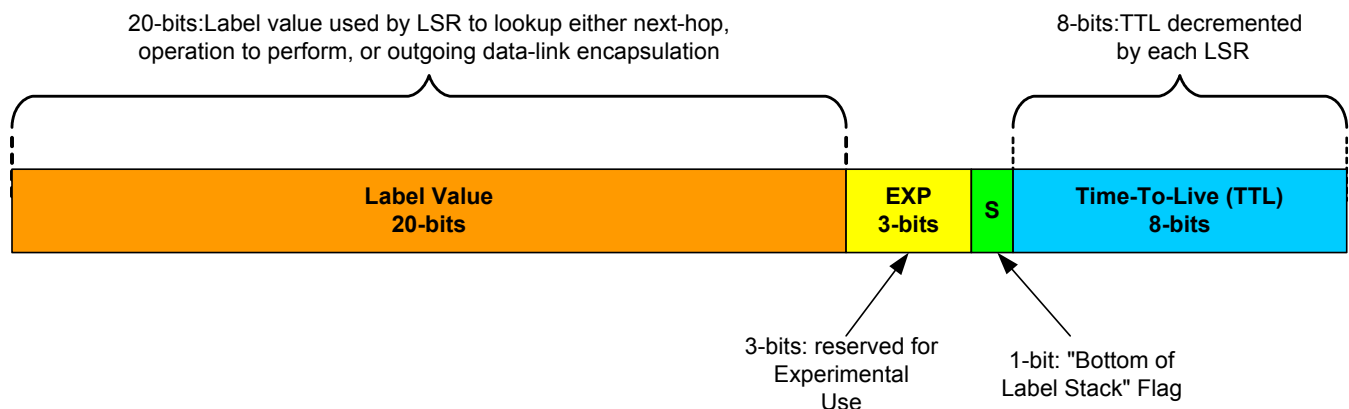


Figure 3: Example of a Generic MPLS Label

MPLS specifies ways that Layer 3 traffic can be mapped to connection-oriented Layer 2 transports like ATM and Frame Relay. It adds a label that contains specific routing information to each IP packet and allows routers to assign explicit paths to various classes of traffic. MPLS offers traffic engineering and other techniques that can boost IP routing efficiency. Additionally, MPLS requires investment in a network of sophisticated label-switching routers

capable of reading header information and assigning packets to specific paths, such as virtual circuits, on a switched network.

To support DiffServ over MPLS packets with a variety of *Differentiated Services CodePoint* (DSCP) values need to get the proper QoS at each LSR in the network. Because MPLS label standards were defined before DSCP standards, MPLS labels used 3 bits for Experimental bits that came from the old 3-bits Precedence in the IP header. The problem is that DiffServ can have 64 possible DSCPs whereas MPLS/Exp bits can only address up to 8 possible types of Per-Hop Behaviors (PHBs).

There are two methods that are used to convey information to the LSRs in the MPLS Header:

1. **E-LSP**

If a network supports up to 8 PHBs, then the Exp bits are sufficient for that network. A LSR keeps a mapping of Exp values to PHBs, similar to an LER, and this maintains a mapping of DSCPs to PHBs. In this case, the label tells an LSR where to forward a packet, and the Exp bits determine the PHB that should be used to treat the packet. A LSP that is set up under these conditions is referred to as E-LSP. For E-LSP, PHB is determined from the Exp bits and there is not a need for additional signaling.

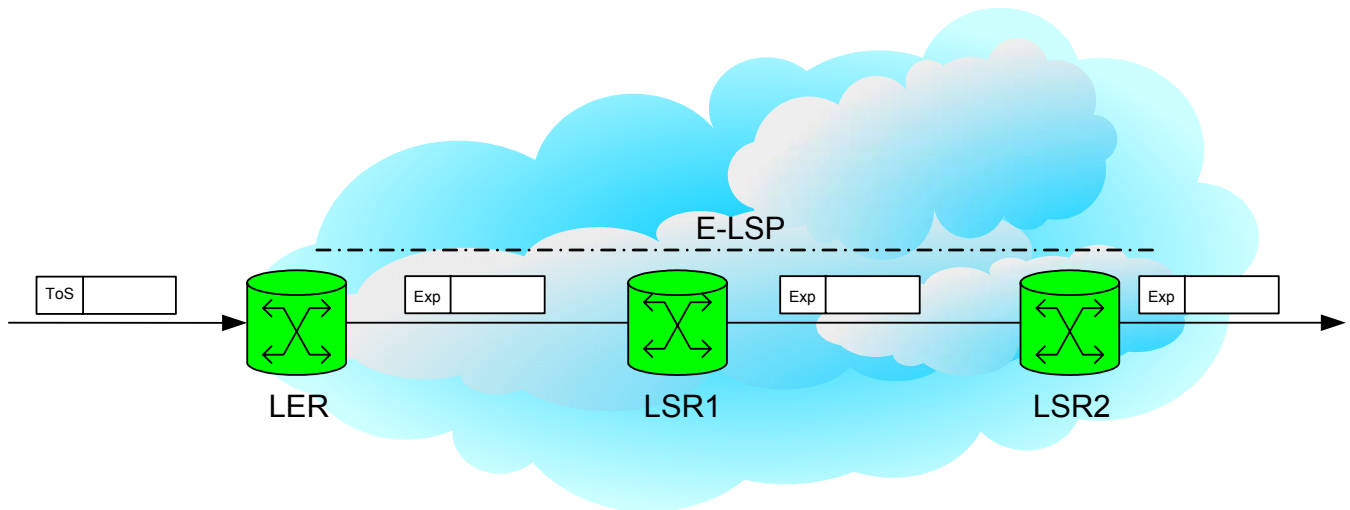


Figure 4: ToS bits or the first 3 bits of the DSCP are copied into the MPLS Exp field at the edge of the network.

2. **L-LSP**

If a network has more than 8 PHBs, then 3 Exp bits will not be able to convey all the PHBs to LSPs. One way is to use the label itself to convey PHBs, therefore, an LSR uses the label to determine the PHB. For L-LSP PHB is determined from label and AF drop precedence is determined from Exp bits.

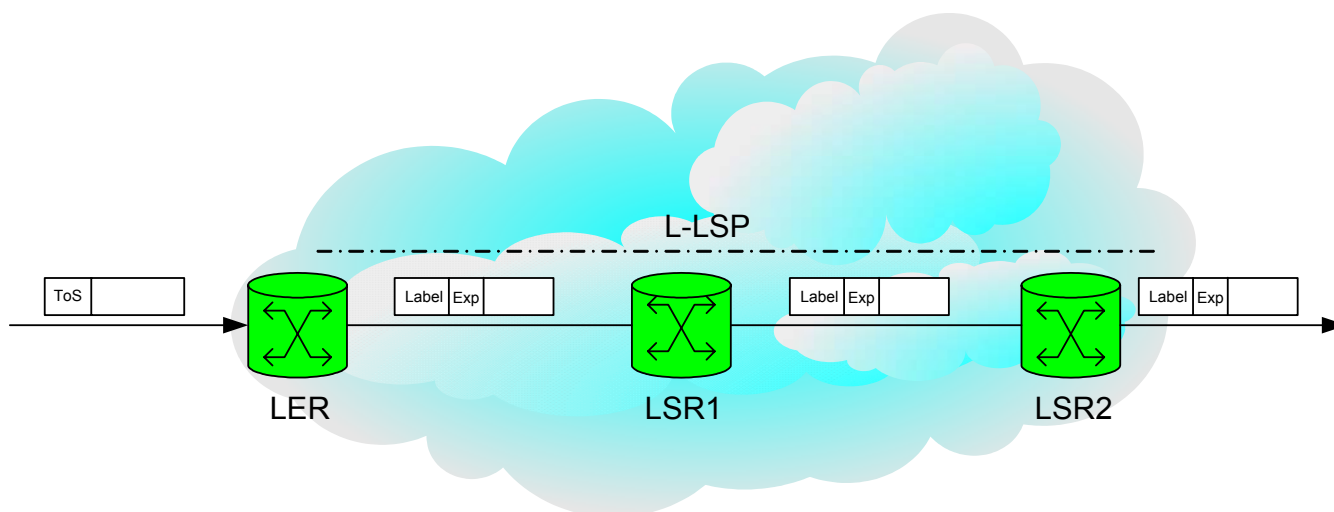


Figure 5: PHB inferred from label value, AF drop preference inferred from Exp bits.

IP Infusion Solutions

IP Infusion's ZebOS® *Advanced Routing Suites* (ARS) provides a series of control plane software solutions for IPv4, IPv6, Multicast, MPLS-VPN, and Layer 2 protocols. Particularly for MPLS and *Traffic Engineering* (TE), IP Infusion provides TE extensions to OSPFv2 and IS-ISv4 as well as RSVP-TE, LDP, and CR-LDP signaling protocols plus MPLS forwarder software. In the area of DiffServ, IP Infusion has developed DiffServ extensions to RSVP-TE for supporting of E-LSP and L-LSP (RFC3270). Further more, IP Infusion has developed DiffServ extensions for support of MPLS Traffic Engineering "*draft-ietf-tewg-diff-te-proto*" in a DiffServ-aware MPLS-TE.

IP Infusion protocol suites are tested & integrated seamlessly on most popular operating systems, such as VxWorks and Linux. They accelerate time to market for OEM and ODM vendors, provide a competitive advantage, and help reduce the costs normally associated with the development of such technologies.

References

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RFC 2597

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RFC 2474

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