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A Modified Specification for use of the IPv6 Flow Label for providing efficient Quality of Service using hybrid approach.

Status of This Memo

Abstract

This memo suggests a modified specification for defining the 20-bit Flow Label field using a hybrid approach that includes options to provide IntServ as well as DiffServ-based support for Quality of Service. It also compares various suggested approaches for defining the 20-bit Flow Label field in IPv6 Base Header based on RFC 2460 (December 1998) and draft-conta-ipv-flow-label-02.txt by Conta & Carpenter (July 2001). The resultant mechanism is fully implementable and unambiguous, as even the lower-level details have been worked out as may be required for real implementations.

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1. Introduction

At the time when the IPv6 specifications were written, the IPv6 Flow Label was still experimental, and subject to change, as the requirements for flow support in the Internet were evolving.

The last several years of work in IETF on Internet Protocols Quality of Service (IntServ, and DiffServ) has provided a more solid and ample architectural perspective, and framework for the standardization of the IPv6 Flow Label. IntServ and DiffServ present two alternative solutions of resolving QoS problems in the Internet.

This paper talks about the design of Quality of Service (QoS) in IPv6. Though IPv6 main header has a 20-bit Flow Label field for QoS implementation purposes, it has not yet been exploited. Few Internet drafts give various definitions of the 20-bit Flow Label in IPv6, each with its own advantages and disadvantages. This paper provides an analysis of these definitions and subsequently suggests a specification, which in view of the author can provide an efficient Quality of Service using a hybrid approach.

2. IPv6 Flows and Flow Label

A flow is a sequence of packets sent from a particular source, and a particular application running on the source host, using a particular host-to-host protocol for the transmission of data over the Internet, to a particular (unicast or multicast) destination, and particular application running on the destination host, or hosts, within a certain set of traffic, and QoS requirements.

The IPv6 Flow Label is defined as a 20-bit field in the IPv6 header which may be used by a source to label sequences of packets for which it requests special handling by the IPv6 routers, such as non-default quality of service or “real-time” service. According to RFC 2460, the nature of that special handling might be conveyed to the routers by a control protocol, such as RSVP, or by information within the flow’s packets themselves, e.g., in a hop-by-hop option.

The characteristics of IPv6 flows and flow labels given in [RFC 2460], are rearranged as follows:

(a) A flow is uniquely identified by the combination of a source address and a non-zero Flow Label.

(b) Packets that do not belong to a flow carry a Flow Label of zero

(c) A Flow Label is assigned to a flow by the flow's source node.

(d) New Flow Labels must be chosen (suede) randomly and uniformly from the range 1 to FFFFF hex. The purpose of the random allocation is to make any set of bits within the Flow Label field suitable for use as a hash key by routers, for looking up the state associated with the flow.

(e) All packets belonging to the same flow must be sent with the same source address, destination address, and Flow Label.

(f) If packets of flow include a Hop-by-Hop options header, then they all must be originated with the same Hop-by-Hop options header contents.

(g) If packets of a flow include a routing header, then they all must be originated with the same contents in all extension headers up to and including the routing header.

(h) The maximum's lifetime of any flow-handling state established along a flow's path must be specified as part of the description of the state-establishment mechanism, e.g., the resource reservation protocol or the flow-setup hop-by-hop option.

(i) The source must not reuse a Flow Label for a new flow within the maximum lifetime of any flow-handling state that might have been established for the prior use of that Flow Label.

3. Integrated Services Flow

The Integrated Services architecture defines a flow as an abstraction, which is a distinguishable stream of related datagrams that results from a single user activity and requires the same QoS.

The IntServ architecture supports services on per flow basis. The IntServ model uses Resource Reservation Protocol (RSVP) as the standard signaling protocol to provide QoS to application flows in the network. It offers three classes of service:

1. Best Effort Service (FCFS, meant for ordinary data: default).

2. Guaranteed Service (meant for Hard Real time requirements)
   - Known upper bound on delay.
   - Reliable (lossless) delivery for IP packets that conform to specification.
   - Guaranteed Bandwidth support.

3. Controlled Load service (meant for Soft Real time requirements)

As specified in [RFC 1633], the IntServ architecture defines a classifier:

> For the purpose of traffic control (and accounting), each incoming packet must be mapped into some class; all packets in the same class get the same treatment from the packet scheduler. This mapping is performed by the classifier. Choice of a class may be based upon the contents of the existing packet header(s) and/or some additional classification number added to each packet.
>
> A class might correspond to a broad category of flows, e.g., all video flows or all flows attributed to a particular organization. On the other hand, a class might hold only a single flow.

4. Differentiated Services Flow

The Differentiated Services architecture defines a flow or micro-flow as a single instance of an application-to-application flow of packets, which is identified by the source address, source port, destination address, destination port and protocol id (fields in the IP and host-to-host protocol headers).

Unlike IntServ, which offers 'Per-Flow-based' QoS support, the DiffServ offers 'Aggregate-Flow-based' QoS support. It has the potential to complement the IntServ (rather than replacing it).

As specified in [RFC 2475], the DiffServ architecture defines a classifier:

> as a mechanism that selects packets in a traffic stream based on the content of some portions of the packet header. The MF (Multi-Field) classifier selects packets based on the value of a combination of one or more header fields, such as source address, destination address, DS field, protocol ID, source port and destination port numbers, and other information.

In order to support the Flow Label, a Differentiated services IPv6 classifier definition should be added. This classifier would be a multi field classifier that would include at least the Flow Label and the source address as the IPv6 specification suggests.

According to Differentiated Services architecture, the classification fields have values according to the Service Level Agreements (SLA) and Traffic Conditioning Agreements (TCA),

(Service Level Specifications - SLS and Traffic Conditioning Specification - TCS) which are contractual agreements between clients and network service providers. The Flow Label based DiffServ MF classifier would allow the same model, and would rely on the Flow Label that is a field with a value or a range of values on which or service providers would have to agree on. These values will be reflected in SLAs, TCAs, SLSs and TCSs.

The potential advantage of the DiffServ model is a substantial reduction in router state and a simplification in router design and implementation. The potential drawback to the DiffServ model is that all flows in the same service aggregate may receive the same level of service. This may force flows with very different QoS requirements into the same service class.

5. Issues related with IPv6 Flow Label

The IPv6 specification originally left open a number of questions, of which the following are important.

5.1 What should a router do with Flow Labels for which it has no state?

What should the default action of the router be on receiving a datagram with a non-zero Flow Label for which it has no state information?

Unknown Flow Labels may also occur if a router crashes and loses its state.

The IPv6 specification gives the following possible solutions to the above-mentioned problem.

1. The routers can ignore the Flow Label.

2. IPv6 datagram may carry flow setup information in their options.

In any case, it is clear that treating this situation as an error and, say dropping the datagram and sending an ICMP message, is inappropriate. Indeed, it seems likely that in most cases, simply forwarding the datagram as one would a datagram with a zero Flow Label would give better service to the flow than dropping the datagram.

There may be situation in which routing the datagram as if its Flow Label were zero might cause the wrong result, but these situations can be treated as the exceptions rather than the rule. It is also reasonable to handle these situations using options that indicate that if the flow state is absent, the datagram needs special

handling. (The options may be Hop-by-Hop or only handled at some routers, depending on the flow's needs).

Finally, [RFC 1809] and the author's view says that the default rule should be that if a router receives a datagram with an unknown Flow Label, it treats the datagram as if the Flow Label is zero. As part of forwarding, the router will examine any hop-by-hop options and learn if the datagram requires special handling. The options could include simply the information that the datagram is to be dropped if the Flow Label is unknown or could contain the flow state the router should have.

5.2 Flushing old Flow Labels

How does an Internetwork flush old Flow Labels?

The flow mechanism assumes that state associated with a given Flow Label is somehow deposited in routers, so they know how to handle datagrams that carry the Flow Label. A serious problem is how to flush Flow Labels that are no longer being used (stale Flow Labels) from the routers.

Stale Flow Labels can happen a number of ways, even if we assume that the source always sends a message deleting a Flow Label when the source finishes using a Flow.

1. The deletion message may be lost before reaching all routers.

2. Furthermore, the source may crash before it can send out a Flow Label deletion message.

The mechanism suggested by [RFC 1809] is to use a timer. Routers should discard Flow Labels whose state has not been refreshed within some period of time. At the same time, a source that crashes must observe a quiet time, during which it creates no flows, until it knows that all Flow Labels from its previous life must have expired. (Sources can avoid quiet time restrictions by keeping information about active Flow Labels in stable storage that survives crashes). According to [RFC 1809], there are two options for refreshing the Flow Label and its state:

1. The source could periodically send out a special refresh message to explicitly refresh the Flow Label and its state.

2. The router could treat every datagram that carries the Flow Label as an implicit refresh or sources could send explicit refresh options.

The choice is between periodically handling a special update message and doing an extra computation on each datagram (namely noting in the Flow Label's entry that the Flow Label has been refreshed).

Based on the discussion mentioned above according to [RFC 1809], the authors of the document suggest the following approach as a solution to this problem:

1. The MRU (Most Recently Used) algorithm should be used for maintaining the Flow Labels. At any point of time, the most recently used labels only will be kept and the remaining should be flushed.

2. Before flushing a label, the router should send an ICMP message to the source saying that the particular label is going to be flushed. So the source should send a KEEPALIVE Message to the router saying that not to flush the Flow Label in case the source requires the Flow Label to be used again. On the other hand, if the source agrees with the router to delete the Flow Label, it should send a GOAHEAD Message to the router. On receiving the GOAHEAD Message, the router immediately deleted the label for that particular source. These messages are also sent to all the intermediate routers, so that, those routers can as well flush the Flow Labels for that particular source.

3. In case, the router does not receive any consent from the source, it will resend the ICMP message for at most two or three times. If at all the router does not receive any reply from the source, it can flush that particular Label assuming that the Flow Label was not important enough for the source or any other intermediate router. The intermediate routers will also delete that Flow Label as they didn’t receive any message from the source. The policy of sending the ICMP message to the source two or three times ensures the proper behavior of the method of flushing Flow Labels in case of packet loss. This method assumes that the ICMP message would not be lost all the three times as the probability of happening that is very less. Hence, if the router doesn’t receive any reply from the source even after sending the ICMP message three times, it deletes the label.

5.3 Which datagrams should carry non-zero Flow Labels?

According to RFC 1809, following were some points of basic agreement:

1. Small exchanges of data should have a zero Flow Label since it is not worth creating a flow for a few datagrams.

2. Real-time flows must always have a Flow Label.

One option specified in [RFC 1809] is to use Flow Labels for all long-term TCP connections. The option is not feasible in the view of the authors as it will force all the applications on that particular connection to use the Flow Labels, which in turn will force routing vendors to deal with cache explosion issue.

5.4 Mutable/Non-mutable IPv6 Flow Label

Should the Flow Label be mutable or non-mutable, that is it should be read only for routers or not?

This paper suggests the Flow Labels to be non-mutable because of the following reasons:

1. Using mutable Flow Labels would require certain negotiation mechanism between neighboring routers, or a certain setup through router management or configuration, to make sure that the values or the changes made to the Flow Label are known to all the routers on the portion of the path of the packets, in which the Flow Label changes. On the other hand, the non-mutable Flow Labels certainly have the advantage of the simplicity implied by such a characteristic.

2. A mutable Flow Label characteristic goes against the IPv6 specification of the Flow Label explained in section 2 and the IPv6 Flow Label characteristics explained in the coming sections.

5.5 Using random numbers in setting the IPv6 Flow Label

The IPv6 specification specifies the requirement of pseudo-randomness in setting the value of a Flow Label as it can be used as hash key by routers for flow lookup.

However, a random value in the header introduces unpredictability of the field. Since predictability is a necessary condition for a deterministic behavior, network operators may require that packets of a flow have always the same IPv6 content. Random values in the IPv6 Flow Label certainly break this requirement. So supporting the arguments given in [draft-conta-ipv6-flow-label-02.txt], the authors of this document suggest the IPv6 specification of having a random number in the Flow Label field to be relaxed.

5.6 Filtering using Flow Label

If, at all, any filtering has to be done based on the Flow Label field in the IPv6 header, the expectation is that the IPv6 Flow Label filed carries a predictable or well-determined value. This is not the case if the Flow Label has randomly chosen values.

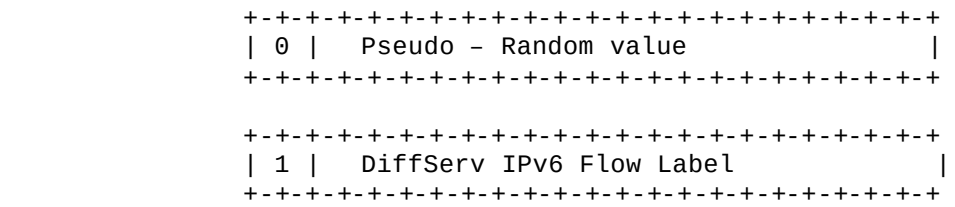
Again, supporting the arguments given in [draft-conta-ipv6-flow-label-02.txt], the authors of this document suggest that the problem of not being able to configure load-filtering rules, which are based or are including the Flow Label, can be resolved by relaxing IPv6 specification of having a random number in the Flow Label field.

6. Various approaches in defining IPv6 Flow Label format

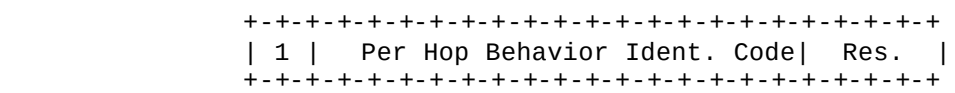
This section discusses the various already suggested approaches for defining the 20-bit Flow Label. It discusses the advantages and disadvantages of these approaches. Finally it tells about accepting or rejecting these approaches and includes the accepted approaches (with modifications wherever required) in the final definition of the Flow Label discussed in the next section.

6.1 First approach [draft-conta-ipv6-flow-label-02.txt]

Following format can be used for the Flow Label:



The DiffServ IPv6 Flow Label is a number that is constructed based on the Differentiated services “Per Hop Behavior Identification Code”.



The “Res” bits are reserved.

The PHB ID is either directly derived from a standard differentiated services code point, or it is an “IANA Assigned Value”.

Advantages:

Preserves compatibility with the random number method of selecting a Flow Label value defined in IPv6 specification.

Captures the differentiated services treatment intended to be applied to the packet.

Unlike the value of the traffic class field, it is not locally mapped and is therefore suitable for use in an end-to-end header field.

Disadvantage:

It captures less information than the port number and protocol number normally used in multi field classifier.

6.2 Second Approach [draft-conta-ipv6-flow-label-02.txt]

DiffServ with multi field classifier can be used in a more efficient and practical manner as an alternative to IntServ and RSVP. The Flow Label classifier is basically a 3-element tuple – source and destination addresses and IPv6 Flow Label.

The classifier can be defined in any of the following two ways:

C = (SA, SAPrefix, DA, DAPrefix, Flow Label).

C` = (SA, SAPrefix, DA, DAPrefix, Flow Label min: Flow Label max).

Incoming packet header (SA, DA, Flow Label) is matched with classification rules table entry C or C`.

Advantage:

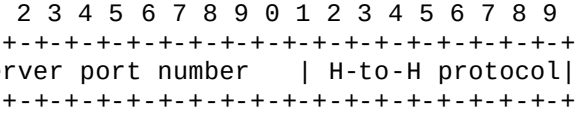
Helps the IPv6 Flow Label to achieve, as it is supposed, in a more efficient processing of packets in QoS engines in IPv6 forwarding devices.

Disadvantage:

When packets are transmitted, the end nodes have to force the correct Flow Label in the IPv6 headers of outgoing packets or the first hop routers have to do thus job. To accomplish these rules, these routers will be configures with MF classifiers. This puts extra computations to be done by the routers.

6.3 Third approach [draft-conta-ipv6-flow-label-02.txt]

Includes the algorithmic mapping of the port numbers and protocol into the Flow Label. It reserves 12 bits for the port number and 8 bits for the protocol.



Advantage:

Classification rule is 5 or 6 element tuple format of a DiffServ MF classifier, containing the source and the destination address, the source and the destination ports, the host-to-host protocol. So no new classification rule format is needed.

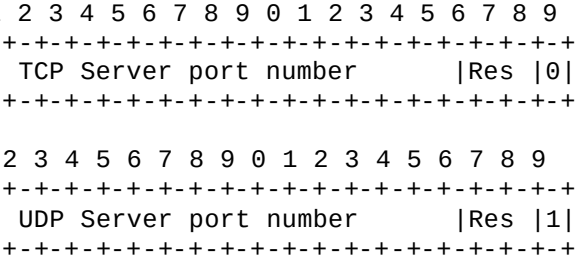
Disadvantages:

It cannot differentiate among multiple instances of the same application running on the same two communication end nodes.

The reduced number of bits (12 out of 16) limits the value of ports. In 12 bits only the "IANA well-known ports", that is from 1 to 1023 and a subset of "IANA registered ports", that is from 1024 to 4095. Registered ports have values between 1024 and 65535.

6.4 Fourth approach [draft-conta-ipv6-flow-label-02.txt]

The field occupied by host-to-host protocol could be reduced to 1, as TCP and UDP are the only well known protocols.



The "Res" bits are reserved.

The "TCP Server Port Number" or "UDP Server Port Number" is the 16-bit port number assigned to the server side of the client/server application.

Advantages:

Again the classification field is a 5 or 6 element tuple. So new classification rule is needed.

This approach keeps 16 bits for the port number so that all the "IANA well-known ports" and "IANA registered ports" can be accommodated in these 16 bits.

Disadvantages:

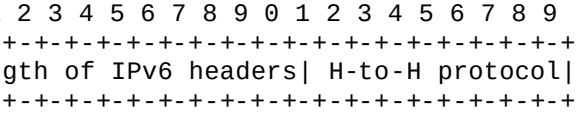
This approach, too, cannot differentiate among multiple instances of the same application running on the same two communication end nodes.

Reserving only 1 bit for the protocol field in the Flow Label restricts the use of any protocol other than TCP and UDP.

6.5 Fifth approach [draft-conta-ipv6-flow-label-02.txt]

Header length format:

Another possible solution is to store the length of IPv6 headers length that is the length of the IPv6 main headers and IPv6 extension headers preceding the host-to-host or transport header. The length of IPv6 headers in the Flow Label value would provide the information, which a DiffServ QoS engine classifier could use to locate and fetch the source and destination ports and apply those along with the source and destination address and host-to-host protocol from the Flow Label, to match the source and destination address, the source and destination ports and the protocol identifier elements of a DiffServ MF classifier.



Advantage:

“Length of IPv6 headers” allows skipping the IPv6 headers to access directly the host-by-host header for other purposes. This format is useful for classifying packets that are not TCP or UDP, and have no source and destination ports.

Disadvantages:

IPv6 header does not include "Total Headers Length" field. So introducing this new field in the Flow Label puts extra computation to be done that may result in the processing delays.

Including "Length of IPv6 headers" in the Flow Label does not carry any significance in case ESP is used for IP Security.

This approach is discarded in this paper because of the reasons given above. Again, it does not carry any direct advantage in keeping the “Length of IPv6 headers” in the Flow Label.

7. A modified specification for the IPv6 Flow Label and related implementation mechanism: A hybrid approach suggested by this work

7.1 Overview

This section specifies a modified Flow Label for IPv6 for providing efficient Quality of Service that utilizes the results of some of the works referred above, extends some of the suggested mechanisms and finally presents an integrated hybrid approach.

7.2 Definition of first three bits of the Flow Label

As a hybrid approach is suggested in this document that includes various approaches already mentioned earlier in the previous section, the management of the 20-bits in the IPv6 Flow Label becomes very critical. The 20-bits of the Flow Label should be defined in an appropriate manner so that the various approaches can be included to produce a more efficient hybrid solution. Hence, for this purpose, the first 3 bits of the IPv6 Flow Label are used to define the approach used and the next 17 bits are used to define the format used in a particular approach.

Following is the bit pattern for the first 3 bits of Flow Label that define the type of the approach used:

0 0 0	Default
0 0 1	A random number is used to define the Flow Label.
0 1 0	The value given in the Hop-by-Hop extension header is used instead the Flow Label.
0 1 1	Multi Field Classifier is used.
1 0 0	A format that includes the port number and the protocol in the Flow Label is used.
1 0 1	A new definition explained later in this section is used.

1 1 0 Reserved for future use.

1 1 1 Reserved for future use.

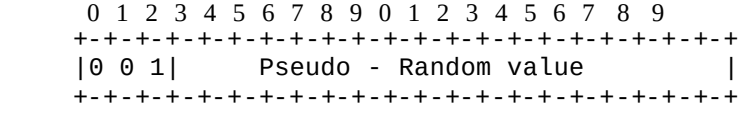
This definition of Flow Label includes IntServ and DiffServ and includes above-mentioned options for defining Flow Label. A further explanation of these options is provided in the remaining of the document. The default value specifies that the datagram does not need any special Quality of Service.

7.3 Defining the remaining 17 bits of the IPv6 Flow Label

The remaining 17 bits of the IPv6 Flow Label are defined based on the approach defined in the first three bits of the Flow Label as mentioned in the previous section.

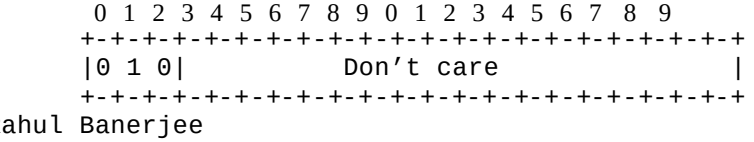
7.3.1 Random Number

As specified in IPv6 specification, a random number can be used to define the Flow Label. Here a 17-bit random number can be used. The random numbers can be generated in the range from 1 to 1FFFF. The advantages and disadvantages of using a random number are already discussed in the previous section. Keeping the IPv6 specifications in mind, the authors of this document believe that the random number can be used as one of the approaches. As other approaches are defined in the Flow Label, this random number approach might not be used whenever not feasible or efficient to do so.



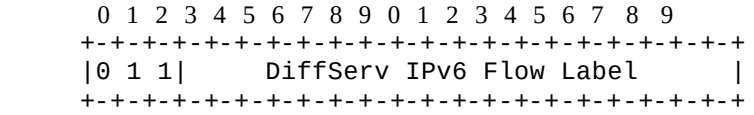
7.3.2 Using Hop-by-Hop extension header

As defined in [draft-banerjee-ipv6-quality-service-00.txt], Hop-by-Hop extension header can be used for defining the Flow Label in case IntServ is used. In this case the value given in the Flow Label is not used to provide Quality of Service. The Hop-by-Hop extension has been suggested and defined in the reference [draft-banerjee-ipv6-quality-service-00.txt]. In that document, the Hop-by-Hop extension header has been defined to be used with IntServ. The same can be used to define for DiffServ also. That discussion is outside the scope of this document.

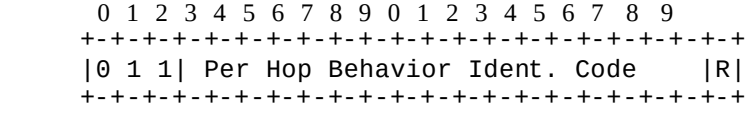


7.3.3 Using Multi Field Classifier

As mentioned in the previous section, DiffServ with MF classifier can be used. In that case the format of the Flow Label will be as shown below:



As suggested in [draft-conta-ipv6-flow-label-02.txt], this Flow Label can be PHB ID (Per Hop Behavior Identification Code). In this case 1 16-bit PHB ID will be used and the remaining 1 bit is reserved for future use.



‘R’ is reserved.

Packets coming into the provider network can be policed based on the Flow Label. The provider, based on the SLAs, SLSs, TCAs, TCSs agreed with the client configures MF classifiers. This document specifies the classifier to be a little different from the one suggested in the [draft-conta-ipv6-flow-label-02.txt]. The classifier looks like:

C = (SA/SAPrefix, DA/DAPrefix, Flow-label).

Or

C` = (SA/SAPrefix, DA/DAPrefix, Flow-Label-Min: Range).

The range here specifies the difference between the maximum and the minimum Flow Label. The significance of using the range instead of Maximum Flow Label is the reduced number of bits. Definitely the difference between the two values can be specified in a lesser number of bits as compared to the value itself.

Flow-Label-Classifier:

IPv6SourceAddressValue/Prefix: 10:11:12:13:14:15:16:17:18::1/128
IPv6DestAddressValue/Prefix: 1:2:3:4:5:6:7:8::2/128
IPv6 Flow Label: 50

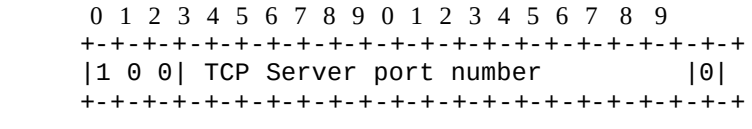
Or

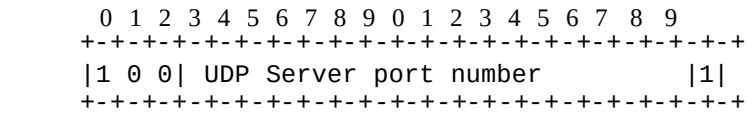
IPv6SourceAddressValue/Prefix: 10:11:12:13:14:15:16:17:18::1/128
IPv6DestAddressValue/Prefix: 1:2:3:4:5:6:7:8::2/128
IPv6 Flow Label:Range: 10:20

Incoming Packet header (SA, DA, Flow Label) is matched against classification rules table entry (C or C`).

7.3.4 Using the Port Number and the Protocol

An approach already discussed in this document in the previous section defines Flow Label by including the server port number and the host-to-host protocol. The “Server Port Number” is the port number assigned to the server side of the client/server applications. As specified in [draft-conta-ipv6-flow-label-02.txt], this approach reserves 16 bits for the port number and 1 bit for the protocol with the remaining bits reserved for the future use.





But this approach puts the restriction on the protocol to be used by any application.

As most of the application seeking Real-time service use TCP or UDP as the transport layer protocol, this approach would work fine in most of the cases. In case the application requires to use any other host-to-host protocol, the other methods for specifying the Flow Label, discussed in this section can be used. Anyhow, this method for specifying the port number and the protocol can be exploited further in the future to remove any limitations.

7.3.5 A new structure and mechanism for the use of the Flow Label

This section describes an innovative approach to define the 20-bit Flow Label field in IPv6 header. By the optimal use of the bits in the Flow Label, this approach includes the various Quality of Service parameters in the IPv6 Flow Label that may be requested by any application. The various Quality of Service parameters are:

1. Bandwidth
2. Delay or Latency
3. Jitter

4. Packet Loss
5. Buffer Requirements

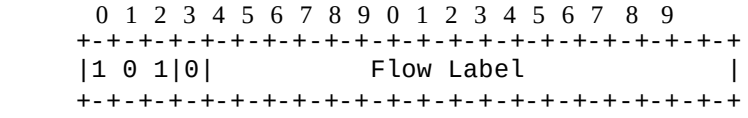
As packet loss and the jitter are always desired to be minimum by any application, these two parameters need not be defined in the Flow Label.

Quality of Service parameters that are to be included in the Flow Label are:

1. Bandwidth (to be expressed in kbps).
2. Delay (to be expressed in nanoseconds).
3. Buffer requirements (to be expressed in bytes).

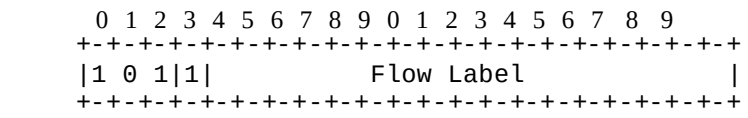
As there are only 17 bits left, the optimal use of the bits is very important so as to obtain the maximum information out of those 17 bits. The first bit out of these 17 bits is used to differentiate between the hard real time and soft real time applications. This bit is set to 0 for soft real time applications and it is set to 1 for hard real time applications.

Soft Real time applications:



This service is meant for RTT (Real Time Tolerant) or soft real time applications, which have an average bandwidth requirement and an intermediate end-to-end delay for an arbitrary packet. Even if the minimum or maximum values specified in the Flow Label are not exactly met, the application can afford to manage with the QoS provided. These RTI applications demand weak bounds on the maximum delay over the network.

Hard Real time applications:



This service is meant for RTI (Real Time Intolerant) or hard Real Time applications, which demand minimal latency and jitter. For example, consider a two-person videoconference. Delay is unacceptable and ends should be brought as close as possible. The whole application should simulate two persons talking face to face.

For this videoconference case, the required resource reservations are

a. Constant bandwidth for the application traffic
b. Deterministic Minimum delay that can be tolerated.

These types of applications can decrease delay by increasing demands for bandwidth.

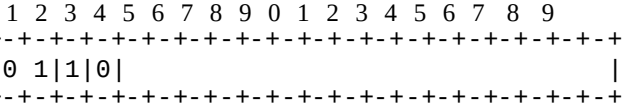
The minimum or maximum values specified in the Flow Label have to be exactly met for these kind of applications.

After keeping one bit for Hard/Soft real time applications, we are left with 16 bits for defining the Flow Label. The remaining part of this section discusses how to represent the values of bandwidth, delay and buffer requirements.

1. Bandwidth

This definition specifies 6 bits out of the 16 bits to be used for specifying the bandwidth value. The application can demand for a minimum or a maximum value of bandwidth. So one bit out of these 6 bits is used for specifying whether the application is asking for a minimum value of bandwidth or a maximum.

0 – minimum expected value is specified.
1 – maximum expected value is specified.



In the above bit sequence, the application uses this new definition for defining the Flow Label, as described by the first 3 bits. The application is a hard real time, as evident by the 4th bit. It asks for a minimum bandwidth of value that will be described in the next few bits.

The 5 bits for the bandwidth can be exploited in two ways as shown below:

Approach 1:

This approach uses a simple formula to calculate the bandwidth from the five bits. The following values of bandwidths can be obtained for various bit-sequences.

00000 – 32 kbps
00001 – 64 kbps
.
.
.
00111 – 4 mbps
.
.
.
01111 – 1 gbps
.
.
.
11111 – 64 tbps

The formula used here to calculate the bandwidth in decimal from the bit pattern is:

Bandwidth (in decimal) = 2^B * 32.

Where B is the decimal equivalent of the bandwidth specified in 5 bits.

Approach 2:

This approach uses a lookup table that maps the value mentioned in the bandwidth field of the Flow Label to the value already defined in the lookup table. These values have to be universally accepted and uniformly defined in all the routers and end-nodes.

In the opinion of the authors, using first approach will result in saving the time for lookup in providing the quality of service. In event of the requirement of certain intermediate values, the second approach could be used. However whichever alternative is used, it shall be recommended in the final version of this specification to use only one of these approaches, preferably the former.

2. Buffer Requirements

This definition specifies 6 bits out of the 16 bits to be used for specifying the buffer value.

00000 – 512 bytes

00001 – 1 kbytes
.
.
.

00111 – 64 kbytes
.
.
.
01111 – 16 mbytes
.
.
.
11111 – 1 tbytes

The formula used here to calculate the buffer in decimal from the bit pattern is:

Buffer (in decimal) = 2^B * 512.

Where B is the decimal equivalent of the buffer specified in 5 bits.

3. Delay

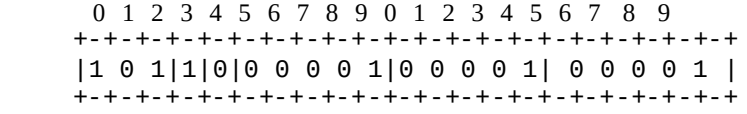
This definition specifies 5 bits out of the 16 bits to be used for specifying the delay value. The application can tolerate a specified value of delay. So the five bits left for the delay value can be used in the following manner:

00000 – 4 nanoseconds
00001 – 8 nanoseconds
.
.
.
01000 – 1 microseconds
.
.
.
11111 – 8 seconds

The formula used here to calculate the buffer in decimal from the bit pattern is:

Delay (in decimal) = 2^B * 4 nanoseconds.

Where B is the decimal equivalent of the delay specified in 5 bits.



In the above bit pattern, the application uses our new definition of the Flow Label. It is a hard real time application. It asks for

a minimum bandwidth of 64 Kbps at any time, a buffer requirement of 1 kilobyte and can tolerate a minimum delay of 8 nanoseconds.

8. Conclusion

This report has dealt extensively with all the suggested formats for defining the 20-bit IPv6 Flow Label and finally has suggested a hybrid approach for efficiently defining the 20-bit IPv6 Flow Label. The emphasis of this work is to result into a practically acceptable specification that could be effectively used for a reasonably long period of time for implementing IPv6 Quality of Service that so far has been elusive in absence of a clear, verifiable and complete specification.

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