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SBM (Subnet Bandwidth Manager): A Protocol for RSVP-based Admission Control over IEEE 802-style networks

Status of this Memo

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Abstract

This document describes a signaling method and protocol for RSVP-based admission control over IEEE 802-style LANs. The protocol is designed to work both with the current generation of IEEE 802 LANs as well as with the recent work completed by the IEEE 802.1 committee.

1. Introduction

New extensions to the Internet architecture and service models have been defined for an integrated services Internet [RFC-1633, RFC-2205, RFC-2210] so that applications can request specific qualities or levels of service from an internetwork in addition to the current IP best-effort service. These extensions include RSVP, a resource reservation setup protocol, and definition of new service classes to be supported by Integrated Services routers. RSVP and service class definitions are largely independent of the underlying networking technologies and it is necessary to define the mapping of RSVP and Integrated Services specifications onto specific subnetwork technologies. For example, a definition of service mappings and

reservation setup protocols is needed for specific link-layer technologies such as shared and switched IEEE-802-style LAN technologies.

This document defines SBM, a signaling protocol for RSVP-based admission control over IEEE 802-style networks. SBM provides a method for mapping an internet-level setup protocol such as RSVP onto IEEE 802 style networks. In particular, it describes the operation of RSVP-enabled hosts/routers and link layer devices (switches, bridges) to support reservation of LAN resources for RSVP-enabled data flows. A framework for providing Integrated Services over shared and switched IEEE-802-style LAN technologies and a definition of service mappings have been described in separate documents [RFC-FRAME, RFC-MAP].

2. Goals and Assumptions

The SBM (Subnet Bandwidth Manager) protocol and its use for admission control and bandwidth management in IEEE 802 level-2 networks is based on the following architectural goals and assumptions:

I. Even though the current trend is towards increased use of switched LAN topologies consisting of newer switches that support the priority queuing mechanisms specified by IEEE 802.1p, we assume that the LAN technologies will continue to be a mix of legacy shared/ switched LAN segments and newer switched segments based on IEEE 802.1p specification. Therefore, we specify a signaling protocol for managing bandwidth over both legacy and newer LAN topologies and that takes advantage of the additional functionality (such as an explicit support for different traffic classes or integrated service classes) as it becomes available in the new generation of switches, hubs, or bridges. As a result, the SBM protocol would allow for a range of LAN bandwidth management solutions that vary from one that exercises purely administrative control (over the amount of bandwidth consumed by RSVP-enabled traffic flows) to one that requires cooperation (and enforcement) from all the end-systems or switches in a IEEE 802 LAN.

II. This document specifies only a signaling method and protocol for LAN-based admission control over RSVP flows. We do not define here any traffic control mechanisms for the link layer; the protocol is designed to use any such mechanisms defined by IEEE 802. In addition, we assume that the Layer 3 end-systems (e.g., a host or a router) will exercise traffic control by policing Integrated Services traffic flows to ensure that each flow stays within its traffic specifications stipulated in an earlier reservation request submitted for admission control. This then

allows a system using SBM admission control combined with per flow shaping at end systems and IEEE-defined traffic control at link layer to realize some approximation of Controlled Load (and even Guaranteed) services over IEEE 802-style LANs.

III. In the absence of any link-layer traffic control or priority queuing mechanisms in the underlying LAN (such as a shared LAN segment), the SBM-based admission control mechanism only limits the total amount of traffic load imposed by RSVP-enabled flows on a shared LAN. In such an environment, no traffic flow separation mechanism exists to protect the RSVP-enabled flows from the best-effort traffic on the same shared media and that raises the question of the utility of such a mechanism outside a topology consisting only of 802.1p-compliant switches. However, we assume that the SBM-based admission control mechanism will still serve a useful purpose in a legacy, shared LAN topology for two reasons. First, assuming that all the nodes that generate Integrated Services traffic flows utilize the SBM-based admission control procedure to request reservation of resources before sending any traffic, the mechanism will restrict the total amount of traffic generated by Integrated Services flows within the bounds desired by a LAN administrator (see discussion of the NonResvSendLimit parameter in Appendix C). Second, the best-effort traffic generated by the TCP/IP-based traffic sources is generally rate adaptive (using a TCP-style "slow start" congestion avoidance mechanism or a feedback-based rate adaptation mechanism used by audio/video streams based on RTP/RTCP protocols) and adapts to stay within the available network bandwidth. Thus, the combination of admission control and rate adaptation should avoid persistent traffic congestion. This does not, however, guarantee that non-Integrated-Services traffic will not interfere with the Integrated Services traffic in the absence of traffic control support in the underlying LAN infrastructure.

3. Organization of the rest of this document

The rest of this document provides a detailed description of the SBM-based admission control procedure(s) for IEEE 802 LAN technologies. The document is organized as follows:

* Section 4 first defines the various terms used in the document and then provides an overview of the admission control procedure with an example of its application to a sample network.

* Section 5 describes the rules for processing and forwarding PATH (and PATH_TEAR) messages at DSBMs (Designated Subnet Bandwidth Managers), SBMs, and DSBM clients.

* Section 6 addresses the inter-operability issues when a DSBM may operate in the absence of RSVP signaling at Layer 3 or when another signaling protocol (such as SNMP) is used to reserve resources on a LAN segment.

* Appendix A describes the details of the DSBM election algorithm used for electing a designated SBM on a LAN segment when more than one SBM is present. It also describes how DSBM clients discover the presence of a DSBM on a managed segment.

* Appendix B specifies the formats of SBM-specific messages used and the formats of new RSVP objects needed for the SBM operation.

* Appendix C describes usage of the DSBM to distribute configuration information to senders on a managed segment.

4. Overview

4.1. Definitions

- Link Layer or Layer 2 or L2: We refer to data-link layer technologies such as IEEE 802.3/Ethernet as L2 or layer 2.

- Link Layer Domain or Layer 2 domain or L2 domain: a set of nodes and links interconnected without passing through a L3 forwarding function. One or more IP subnets can be overlaid on a L2 domain.

- Layer 2 or L2 devices: We refer to devices that only implement Layer 2 functionality as Layer 2 or L2 devices. These include 802.1D bridges or switches.

- Internetwork Layer or Layer 3 or L3: Layer 3 of the ISO 7 layer model. This document is primarily concerned with networks that use the Internet Protocol (IP) at this layer.

- Layer 3 Device or L3 Device or End-Station: these include hosts and routers that use L3 and higher layer protocols or application programs that need to make resource reservations.

- Segment: A L2 physical segment that is shared by one or more senders. Examples of segments include (a) a shared Ethernet or Token-Ring wire resolving contention for media access using CSMA or token passing ("shared L2 segment"), (b) a half duplex link between two stations or switches, (c) one direction of a switched full-duplex link.

- Managed segment: A managed segment is a segment with a DSBM present and responsible for exercising admission control over requests for resource reservation. A managed segment includes those interconnected parts of a shared LAN that are not separated by DSBMs.

- Traffic Class: An aggregation of data flows which are given similar service within a switched network.

- User_priority: User_priority is a value associated with the transmission and reception of all frames in the IEEE 802 service model: it is supplied by the sender that is using the MAC service. It is provided along with the data to a receiver using the MAC service. It may or may not be actually carried over the network: Token-Ring/802.5 carries this value (encoded in its FC octet), basic Ethernet/802.3 does not, 802.12 may or may not depending on the frame format in use. 802.1p defines a consistent way to carry this value over the bridged network on Ethernet, Token Ring, Demand-Priority, FDDI or other MAC-layer media using an extended frame format. The usage of user_priority is fully described in section 2.5 of 802.1D [IEEE8021D] and 802.1p [IEEE8021P] "Support of the Internal Layer Service by Specific MAC Procedures".

- Subnet: used in this memo to indicate a group of L3 devices sharing a common L3 network address prefix along with the set of segments making up the L2 domain in which they are located.

- Bridge/Switch: a layer 2 forwarding device as defined by IEEE 802.1D. The terms bridge and switch are used synonymously in this document.

- DSBM: Designated SBM (DSBM) is a protocol entity that resides in a L2 or L3 device and manages resources on a L2 segment. At most one DSBM exists for each L2 segment.

- SBM: the SBM is a protocol entity that resides in a L2 or L3 device and is capable of managing resources on a segment. However, only a DSBM manages the resources for a managed segment. When more than one SBM exists on a segment, one of the SBMs is elected to be the DSBM.

- Extended segment: An extended segment includes those parts of a network which are members of the same IP subnet and therefore are not separated by any layer 3 devices. Several managed segments, interconnected by layer 2 devices, constitute an extended segment.

- Managed L2 domain: An L2 domain consisting of managed segments is referred to as a managed L2 domain to distinguish it from a L2 domain with no DSBMs present for exercising admission control over resources at segments in the L2 domain.

- DSBM clients: These are entities that transmit traffic onto a managed segment and use the services of a DSBM for the managed segment for admission control over a LAN segment. Only the layer 3 or higher layer entities on L3 devices such as hosts and routers are expected to send traffic that requires resource reservations, and, therefore, DSBM clients are L3 entities.

- SBM transparent devices: A "SBM transparent" device is unaware of SBMs or DSBMs (though it may or may not be RSVP aware) and, therefore, does not participate in the SBM-based admission control procedure over a managed segment. Such a device uses standard forwarding rules appropriate for the device and is transparent with respect to SBM. An example of such a L2 device is a legacy switch that does not participate in resource reservation.

- Layer 3 and layer 2 addresses: We refer to layer 3 addresses of L3/L2 devices as "L3 addresses" and layer 2 addresses as "L2 addresses". This convention will be used in the rest of the document to distinguish between Layer 3 and layer 2 addresses used to refer to RSVP next hop (NHOP) and previous hop (PHOP) devices. For example, in conventional RSVP message processing, RSVP_HOP object in a PATH message carries the L3 address of the previous hop device. We will refer to the address contained in the RSVP_HOP object as the RSVP_HOP_L3 address and the corresponding MAC address of the previous hop device will be referred to as the RSVP_HOP_L2 address.

4.2. Overview of the SBM-based Admission Control Procedure

A protocol entity called "Designated SBM" (DSBM) exists for each managed segment and is responsible for admission control over the resource reservation requests originating from the DSBM clients in that segment. Given a segment, one or more SBMs may exist on the segment. For example, many SBM-capable devices may be attached to a shared L2 segment whereas two SBM-capable switches may share a half-duplex switched segment. In that case, a single DSBM is elected for the segment. The procedure for dynamically electing the DSBM is described in Appendix A. The only other approved method for specifying a DSBM for a managed segment is static configuration at SBM-capable devices.

The presence of a DSBM makes the segment a "managed segment". Sometimes, two or more L2 segments may be interconnected by SBM transparent devices. In that case, a single DSBM will manage the resources for those segments treating the collection of such segments as a single managed segment for the purpose of admission control.

4.2.1. Basic Algorithm

Figure 1 - An Example of a Managed Segment.

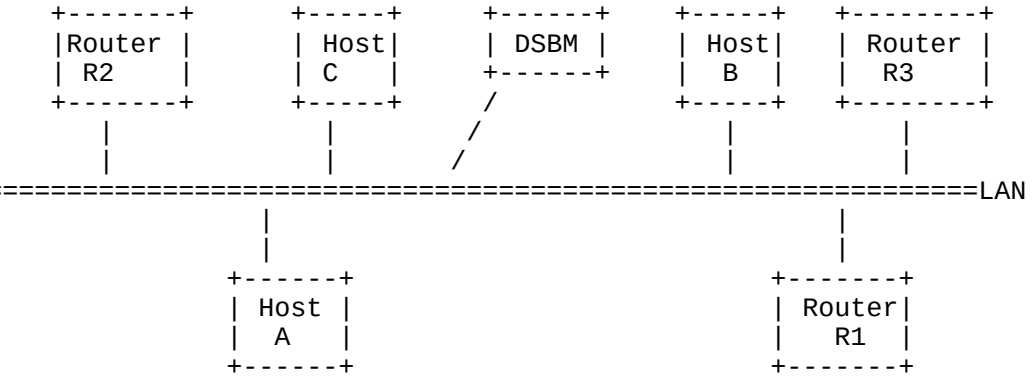

Figure 1 shows an example of a managed segment in a L2 domain that interconnects a set of hosts and routers. For the purpose of this discussion, we ignore the actual physical topology of the L2 domain (assume it is a shared L2 segment and a single managed segment represents the entire L2 domain). A single SBM device is designated to be the DSBM for the managed segment. We will provide examples of operation of the DSBM over switched and shared segments later in the document.

The basic DSBM-based admission control procedure works as follows:

1. DSBM Initialization: As part of its initial configuration, DSBM obtains information such as the limits on fraction of available resources that can be reserved on each managed segment under its control. For instance, bandwidth is one such resource. Even though methods such as auto-negotiation of link speeds and knowledge of link topology allow discovery of link capacity, the configuration may be necessary to limit the fraction of link capacity that can be reserved on a link. Configuration is likely to be static with the current L2/L3 devices. Future work may allow for dynamic discovery of this information. This document does not specify the configuration mechanism.

2. DSBM Client Initialization: For each interface attached, a DSBM client determines whether a DSBM exists on the interface. The procedure for discovering and verifying the existence of the DSBM for an attached segment is described in Appendix A. If the client itself is capable of serving as the DSBM on the segment, it may choose to participate in the election to become the DSBM. At the start, a DSBM client first verifies that a DSBM exists in its L2 domain so that it can communicate with the DSBM for admission control purposes.

   In the case of a full-duplex segment, an election may not be necessary as the SBM at each end will typically act as the DSBM for outgoing traffic in each direction.

3. DSBM-based Admission Control: To request reservation of resources (e.g., LAN bandwidth in a L2 domain), DSBM clients (RSVP-capable L3 devices such as hosts and routers) follow the following steps:

   a) When a DSBM client sends or forwards a RSVP PATH message over an interface attached to a managed segment, it sends the PATH message to the segment's DSBM instead of sending it to the RSVP session destination address (as is done in conventional RSVP processing). After processing (and possibly updating an ADSPEC), the DSBM will forward the PATH message toward its destination address. As part of its processing, the DSBM builds and maintains a PATH state for the session and notes the previous L2/L3 hop that sent it the PATH message.

      Let us consider the managed segment in Figure 1. Assume that a sender to a RSVP session (session address specifies the IP address of host A on the managed segment in Figure 1) resides outside the L2 domain of the managed segment and sends a PATH message that arrives at router R1 which is on the path towards host A.

      DSBM client on Router R1 forwards the PATH message from the sender to the DSBM. The DSBM processes the PATH message and forwards the PATH message towards the RSVP receiver (Detailed message processing and forwarding rules are described in Section 5). In the process, the DSBM builds the PATH state, remembers the router R1 (its L2 and l3 addresses) as the previous hop for the session, puts its own L2 and L3 addresses in the PHOP objects (see explanation later), and effectively inserts itself as an intermediate node between the sender (or R1 in Figure 1) and the receiver (host A) on the managed segment.

b) When an application on host A wishes to make a reservation for the RSVP session, host A follows the standard RSVP message processing rules and sends a RSVP RESV message to the previous hop L2/L3 address (the DSBMs address) obtained from the PHOP object(s) in the previously received PATH message.

c) The DSBM processes the RSVP RESV message based on the bandwidth available and returns an RESV_ERR message to the requester (host A) if the request cannot be granted. If sufficient resources are available and the reservation request is granted, the DSBM forwards the RESV message towards the PHOP(s) based on its local PATH state for the session. The DSBM merges reservation requests for the same session as and when possible using the rules similar to those used in the conventional RSVP processing (except for an additional criterion described in Section 5.8).

d) If the L2 domain contains more than one managed segment, the requester (host A) and the forwarder (router R1) may be separated by more than one managed segment. In that case, the original PATH message would propagate through many DSBMs (one for each managed segment on the path from R1 to A) setting up PATH state at each DSBM. Therefore, the RESV message would propagate hop-by-hop in reverse through the intermediate DSBMs and eventually reach the original forwarder (router R1) on the L2 domain if admission control at all DSBMs succeeds.

4.2.2. Enhancements to the conventional RSVP operation

(D)SBMs and DSBM clients implement minor additions to the standard RSVP protocol. These are summarized in this section. A detailed description of the message processing and forwarding rules follows in section 5.

4.2.2.1 Sending PATH Messages to the DSBM on a Managed Segment

Normal RSVP forwarding rules apply at a DSBM client when it is not forwarding an outgoing PATH message over a managed segment. However, outgoing PATH messages on a managed segment are sent to the DSBM for the corresponding managed segment (Section 5.2 describes how the PATH messages are sent to the DSBM on a managed segment).

4.2.2.2 The LAN_NHOP Objects

In conventional RSVP processing over point-to-point links, RSVP nodes (hosts/routers) use RSVP_HOP object (NHOP and PHOP info) to keep track of the next hop (downstream node in the path of data packets in a traffic flow) and the previous hop (upstream nodes with respect to

the data flow) nodes on the path between a sender and a receiver. Routers along the path of a PATH message forward the message towards the destination address based on the L3 routing (packet forwarding) tables.

For example, consider the L2 domain in Figure 1. Assume that both the sender (some host X) and the receiver (some host Y) in a RSVP session reside outside the L2 domain shown in the Figure, but PATH messages from the sender to its receiver pass through the routers in the L2 domain using it as a transit subnet. Assume that the PATH message from the sender X arrives at the router R1. R1 uses its local routing information to decide which next hop router (either router R2 or router R3) to use to forward the PATH message towards host Y. However, when the path traverses a managed L2 domain, we require the PATH and RESV messages to go through a DSBM for each managed segment. Such a L2 domain may span many managed segments (and DSBMs) and, typically, SBM protocol entities on L2 devices (such as a switch) will serve as the DSBMs for the managed segments in a switched topology. When R1 forwards the PATH message to the DSBM (an L2 device), the DSBM may not have the L3 routing information necessary to select the egress router (between R2 and R3) before forwarding the PATH message. To ensure correct operation and routing of RSVP messages, we must provide additional forwarding information to DSBMs.

For this purpose, we introduce new RSVP objects called LAN_NHOP address objects that keep track of the next L3 hop as the PATH message traverses an L2 domain between two L3 entities (RSVP PHOP and NHOP nodes).

4.2.2.3 Including Both Layer-2 and Layer-3 Addresses in the LAN_NHOP

When a DSBM client (a host or a router acting as the originator of a PATH message) sends out a PATH message to the DSBM, it must include LAN_NHOP information in the message. In the case of a unicast destination, the LAN_NHOP address specifies the destination address (if the destination is local to its L2 domain) or the address of the next hop router towards the destination. In our example of an RSVP session involving the sender X and receiver Y with L2 domain in Figure 1 acting as the transit subnet, R1 is the ingress node that receives the PATH message. R1 first determines that R2 is the next hop router (or the egress node in the L2 domain for the session address) and then inserts a LAN_NHOP object that specifies R2’s IP address. When a DSBM receives a PATH message, it can now look at the address in the LAN_NHOP object and forward the PATH message towards the egress node after processing the PATH message. However, we expect the L2 devices (such as switches) to act as DSBMs on the path within the L2 domain and it may not be reasonable to expect these devices to have an ARP capability to determine the MAC address (we

call it L2ADDR for Layer 2 address) corresponding to the IP address in the LAN_NHOP object.

Therefore, we require that the LAN_NHOP information (generated by the L3 device) include both the IP address (LAN_NHOP_L3 address) and the corresponding MAC address (LAN_NHOP_L2 address) for the next L3 hop over the L2 domain. The LAN_NHOP_L3 address is used by SBM protocol entities on L3 devices to forward the PATH message towards its destination whereas the L2 address is used by the SBM protocol entities on L2 devices to determine how to forward the PATH message towards the L3 NHOP (egress point from the L2 domain). The exact format of the LAN_NHOP information and relevant objects is described later in Appendix B.

4.2.2.4 Similarities to Standard RSVP Message Processing

- When a DSBM receives a RSVP PATH message, it processes the PATH message according to the PATH processing rules described in the RSVP specification. In particular, the DSBM retrieves the IP address of the previous hop from the RSVP_HOP object in the PATH message and stores the PHOP address in its PATH state. It then forwards the PATH message with the PHOP (RSVP_HOP) object modified to reflect its own IP address (RSVP_HOP_L3 address). Thus, the DSBM inserts itself as an intermediate hop in the chain of nodes in the path between two L3 nodes across the L2 domain.

- The PATH state in a DSBM is used for forwarding subsequent RESV messages as per the standard RSVP message processing rules. When the DSBM receives a RESV message, it processes the message and forwards it to appropriate PHOP(s) based on its PATH state.

- Because a DSBM inserts itself as a hop between two RSVP nodes in the path of a RSVP flow, all RSVP related messages (such as PATH, PATH_TEAR, RESV, RESV_CONF, RESV_TEAR, and RESV_ERR) now flow through the DSBM. In particular, a PATH_TEAR message is routed exactly through the intermediate DSBM(s) as its corresponding PATH message and the local PATH state is first cleaned up at each intermediate hop before the PATH_TEAR message gets forwarded.

- So far, we have described how the PATH message propagates through the L2 domain establishing PATH state at each DSBM along the managed segments in the path. The layer 2 address (LAN_NHOP_L2 address) in the LAN_NHOP object should be used by the L2 devices along the path to decide how to forward the PATH message toward the next L3 hop. Such devices will apply the standard IEEE 802.1D forwarding rules (e.g., send it on a single port based on its filtering database, or flood it on all ports active in the spanning tree if the L2 address does not appear in the filtering

database) to the LAN_NHOP_L2 address as are applied normally to data packets destined to the address.

4.2.2.5 Including Both Layer-2 and Layer-3 Addresses in the RSVP_HOP Objects

In the conventional RSVP message processing, the PATH state established along the nodes on a path is used to route the RESV message from a receiver to a sender in an RSVP session. As each intermediate node builds the path state, it remembers the previous hop (stores the PHOP IP address available in the RSVP_HOP object of an incoming message) that sent it the PATH message and, when the RESV message arrives, the intermediate node simply uses the stored PHOP address to forward the RESV after processing it successfully.

In our case, we expect the SBM entities residing at L2 devices to act as DSBMs (and, therefore, intermediate RSVP hops in an L2 domain) along the path between a sender (PHOP) and receiver (NHOP). Thus, when a RESV message arrives at a DSBM, it must use the stored PHOP IP address to forward the RESV message to its previous hop. However, it may not be reasonable to expect the L2 devices to have an ARP cache or the ARP capability to map the PHOP IP address to its corresponding L2 address before forwarding the RESV message.

To obviate the need for such address mapping at L2 devices, we use a RSVP_HOP_L2 object in the PATH message. The RSVP_HOP_L2 object includes the Layer 2 address (L2ADDR) of the previous hop and complements the L3 address information included in the RSVP_HOP object (RSVP_HOP_L3 address).

When a L3 device constructs and forwards a PATH message over a managed segment, it includes its IP address (IP address of the interface over which PATH is sent) in the RSVP_HOP object and adds a RSVP_HOP_L2 object that includes the corresponding L2 address for the interface. When a device in the L2 domain receives such a PATH message, it remembers the addresses in the RSVP_HOP and RSVP_HOP_L2 objects in its PATH state and then overwrites the RSVP_HOP and RSVP_HOP_L2 objects with its own addresses before forwarding the PATH message over a managed segment.

The exact format of RSVP_HOP_L2 object is specified in Appendix B.

4.2.2.6 Loop Detection

When an RSVP session address is a multicast address and a SBM, DSBM, and DSBM clients share the same L2 segment (a shared segment), it is possible for a SBM or a DSBM client to receive one or more copies of a PATH message that it forwarded earlier when a DSBM on the same wire

forwards it (See Section 5.7 for an example of such a case). To facilitate detection of such loops, we use a new RSVP object called the LAN_LOOPBACK object. DSBM clients or SBMs (but not the DSBMs reflecting a PATH message onto the interface over which it arrived earlier) must overwrite (or add if the PATH message does NOT already include a LAN_LOOPBACK object) the LAN_LOOPBACK object in the PATH message with their own unicast IP address.

Now, a SBM or a DSBM client can easily detect and discard the duplicates by checking the contents of the LAN_LOOPBACK object (a duplicate PATH message will list a device's own interface address in the LAN_LOOPBACK object). Appendix B specifies the exact format of the LAN_LOOPBACK object.

4.2.2.7 802.1p, User Priority and TCLASS

The model proposed by the Integrated Services working group requires isolation of traffic flows from each other during their transit across a network. The motivation for traffic flow separation is to provide Integrated Services flows protection from misbehaving flows and other best-effort traffic that share the same path. The basic IEEE 802.3/Ethernet networks do not provide any notion of traffic classes to discriminate among different flows that request different services. However, IEEE 802.1p defines a way for switches to differentiate among several "user_priority" values encoded in packets representing different traffic classes (see [IEEE802Q, IEEE8021p] for further details). The user_priority values can be encoded either in native LAN packets (e.g., in IEEE 802.5's FC octet) or by using an encapsulation above the MAC layer (e.g., in the case of Ethernet, the user_priority value assigned to each packet will be carried in the frame header using the new, extended frame format defined by IEEE 802.1Q [IEEE8021Q]. IEEE, however, makes no recommendations about how a sender or network should use the user_priority values. An accompanying document makes recommendations on the usage of the user_priority values (see [RFC-MAP] for details).

Under the Integrated Services model, L3 (or higher) entities that transmit traffic flows onto a L2 segment should perform per-flow policing to ensure that the flows do not exceed their traffic specification as specified during admission control. In addition, L3 devices may label the frames in such flows with a user_priority value to identify their service class.

For the purpose of this discussion, we will refer to the user_priority value carried in the extended frame header as the "traffic class" of a packet. Under the ISSLL model, the L3 entities, that send traffic and that use the SBM protocol, may select the appropriate traffic class of outgoing packets [RFC-MAP]. This

selection may be overridden by DSBM devices, in the following manner. once a sender sends a PATH message, downstream DSBMs will insert a new traffic class object (TCLASS object) in the PATH message that travels to the next L3 device (L3 NHOP for the PATH message). To some extent, the TCLASS object contents are treated like the ADSPEC object in the RSVP PATH messages. The L3 device that receives the PATH message must remove and store the TCLASS object as part of its PATH state for the session. Later, when the same L3 device needs to forward a RSVP RESV message towards the original sender, it must include the TCLASS object in the RESV message. When the RESV message arrives at the original sender, the sender must use the user_priority value from the TCLASS object to override its selection for the traffic class marked in outgoing packets.

The format of the TCLASS object is specified in Appendix B. Note that TCLASS and other SBM-specific objects are carried in a RSVP message in addition to all the other, normal RSVP objects per RFC 2205.

4.2.2.8 Processing the TCLASS Object

In summary, use of TCLASS objects requires following additions to the conventional RSVP message processing at DSBMs, SBMs, and DSBM clients:

* When a DSBM receives a PATH message over a managed segment and the PATH message does not include a TCLASS object, the DSBM MAY add a TCLASS object to the PATH message before forwarding it. The DSBM determines the appropriate user_priority value for the TCLASS object. A mechanism for selecting the appropriate user_priority value is described in an accompanying document [RFC-MAP].

* When SBM or DSBM receives a PATH message with a TCLASS object over a managed segment in a L2 domain and needs to forward it over a managed segment in the same L2 domain, it will store it in its path state and typically forward the message without changing the contents of the TCLASS object. However, if the DSBM/SBM cannot support the service class represented by the user_priority value specified by the TCLASS object in the PATH message, it may change the priority value in the TCLASS to a semantically "lower" service value to reflect its capability and store the changed TCLASS value in its path state.

[NOTE: An accompanying document defines the int-serv mappings over IEEE 802 networks [RFC-MAP] provides a precise definition of user_priority values and describes how the user_priority values are compared to determine "lower" of the two values or the "lowest" among all the user_priority values.]

* When a DSBM receives a RESV message with a TCLASS object, it may use the traffic class information (in addition to the usual flowspec information in the RSVP message) for its own admission control for the managed segment.

  Note that this document does not specify the actual algorithm or policy used for admission control. At one extreme, a DSBM may use per-flow reservation request as specified by the flowspec for a fine grain admission control. At the other extreme, a DSBM may only consider the traffic class information for a very coarse-grain admission control based on some static allocation of link capacity for each traffic class. Any combination of the options represented by these two extremes may also be used.

* When a DSBM (at an L2 or L3) device receives a RESV message without a TCLASS object and it needs to forward the RESV message over a managed segment within the same L2 domain, it should first check its path state and check whether it has stored a TCLASS value. If so, it should include the TCLASS object in the outgoing RESV message after performing its own admission control. If no TCLASS value is stored, it must forward the RESV message without inserting a TCLASS object.

* When a DSBM client (residing at an L3 device such as a host or an edge router) receives the TCLASS object in a PATH message that it accepts over an interface, it should store the TCLASS object as part of its PATH state for the interface. Later, when the client forwards a RESV message for the same session on the interface, the client must include the TCLASS object (unchanged from what was received in the previous PATH message) in the RESV message it forwards over the interface.

* When a DSBM client receives a TCLASS object in an incoming RESV message over a managed segment and local admission control succeeds for the session for the outgoing interface over the managed segment, the client must pass the user_priority value in the TCLASS object to its local packet classifier. This will ensure that the data packets in the admitted RSVP flow that are subsequently forwarded over the outgoing interface will contain the appropriate value encoded in their frame header.

* When an L3 device receives a PATH or RESV message over a managed segment in one L2 domain and it needs to forward the PATH/RESV message over an interface outside that domain, the L3 device must remove the TCLASS object (along with LAN_NHOP, RSVP_HOP_L2, and LAN_LOOPBACK objects in the case of the PATH message) before forwarding the PATH/RESV message. If the outgoing interface is on a separate L2 domain, these objects may be regenerated according to the processing rules applicable to that interface.

5. Detailed Message Processing Rules

5.1. Additional Notes on Terminology

* An L2 device may have several interfaces with attached segments that are part of the same L2 domain. A switch in a L2 domain is an example of such a device. A device which has several interfaces may contain a SBM protocol entity that acts in different capacities on each interface. For example, a SBM protocol entity could act as a SBM on interface A, and act as a DSBM on interface B.

* A SBM protocol entity on a layer 3 device can be a DSBM client, and SBM, a DSBM, or none of the above (SBM transparent). Non-transparent L3 devices can implement any combination of these roles simultaneously. DSBM clients always reside at L3 devices.

* A SBM protocol entity residing at a layer 2 device can be a SBM, a DSBM or none of the above (SBM transparent). A layer 2 device will never host a DSBM client.

5.2. Use Of Reserved IP Multicast Addresses

As stated earlier, we require that the DSBM clients forward the RSVP PATH messages to their DSBMs in a L2 domain before they reach the next L3 hop in the path. RSVP PATH messages are addressed, according to RFC-2205, to their destination address (which can be either an IP unicast or multicast address). When a L2 device hosts a DSBM, a simple-to-implement mechanism must be provided for the device to capture an incoming PATH message and hand it over to the local DSBM agent without requiring the L2 device to snoop for L3 RSVP messages.

In addition, DSBM clients need to know how to address SBM messages to the DSBM. For the ease of operation and to allow dynamic DSBM-client binding, it should be possible to easily detect and address the existing DSBM on a managed segment.

To facilitate dynamic DSBM-client binding as well as to enable easy detection and capture of PATH messages at L2 devices, we require that a DSBM be addressed using a logical address rather than a physical address. We make use of reserved IP multicast address(es) for the purpose of communication with a DSBM. In particular, we require that when a DSBM client or a SBM forwards a PATH message over a managed segment, it is addressed to a reserved IP multicast address. Thus, a DSBM on a L2 device needs to be configured in a way to make it easy to intercept the PATH message and forward it to the local SBM protocol entity. For example, this may involve simply adding a static entry in the device's filtering database (FDB) for the corresponding MAC multicast address to ensure the PATH messages get intercepted and are not forwarded further without the DSBM intervention.

Similarly, a DSBM always sends the PATH messages over a managed segment using a reserved IP multicast address and, thus, the SBMs or DSBM clients on the managed segments must simply be configured to intercept messages addressed to the reserved multicast address on the appropriate interfaces to easily receive PATH messages.

RSVP RESV messages continue to be unicast to the previous hop address stored as part of the PATH state at each intermediate hop.

We define use of two reserved IP multicast addresses. We call these the "AllSBM Address" and the "DSBMLogicalAddress". These are chosen from the range of local multicast addresses, such that:

* They are not passed through layer 3 devices.

* They are passed transparently through layer 2 devices which are SBM transparent.

* They are configured in the permanent database of layer 2 devices which host SBMs or DSBMs, such that they are directed to the SBM management entity in these devices. This obviates the need for these devices to explicitly snoop for SBM related control packets.

* The two reserved addresses are 224.0.0.16 (DSBMLogicalAddress) and 224.0.0.17 (AllSBMAddress).

These addresses are used as described in the following table:

Type	DSBMLogicaladdress	AllSBMAddress
DSBM Client	* Sends PATH messages to this address	* Monitors this address to detect the presence of a DSBM

		* Monitors this address to receive PATH messages forwarded by the DSBM
SBM	* Sends PATH messages to this address	* Monitors and sends on this address to participate in election of the DSBM * Monitors this address to receive PATH messages forwarded by the DSBM
DSBM	* Monitors this address for PATH messages directed to it	* Monitors and sends on this to participate in election of the DSBM * Sends PATH messages to this address

The L2 or MAC addresses corresponding to IP multicast addresses are computed algorithmically using a reserved L2 address block (the high order 24-bits are 00:00:5e). The Assigned Numbers RFC [RFC-1700] gives additional details.

5.3. Layer 3 to Layer 2 Address Mapping

As stated earlier, DSBMs or DSBM clients residing at a L3 device must include a LAN_NHOP_L2 address in the LAN_NHOP information so that L2 devices along the path of a PATH message do not need to separately determine the mapping between the LAN_NHOP_L3 address in the LAN_NHOP object and its corresponding L2 address (for example, using ARP).

For the purpose of such mapping at L3 devices, we assume a mapping function called "map_address" that performs the necessary mapping:

```
L2ADDR object = map_addr(L3Addr)
```

We do not specify how the function is implemented; the implementation may simply involve access to the local ARP cache entry or may require performing an ARP function. The function returns a L2ADDR object that need not be interpreted by an L3 device and can be treated as an opaque object. The format of the L2ADDR object is specified in Appendix B.

5.4. Raw vs. UDP Encapsulation

We assume that the DSBMs, DSBM clients, and SBMs use only raw IP for encapsulating RSVP messages that are forwarded onto a L2 domain. Thus, when a SBM protocol entity on a L3 device forwards a RSVP message onto a L2 segment, it will only use RAW IP encapsulation.

5.5. The Forwarding Rules

The message processing and forwarding rules will be described in the context of the sample network illustrated in Figure 2.

Figure 2 - A sample network or L2 domain consisting of switched and shared L2 segments

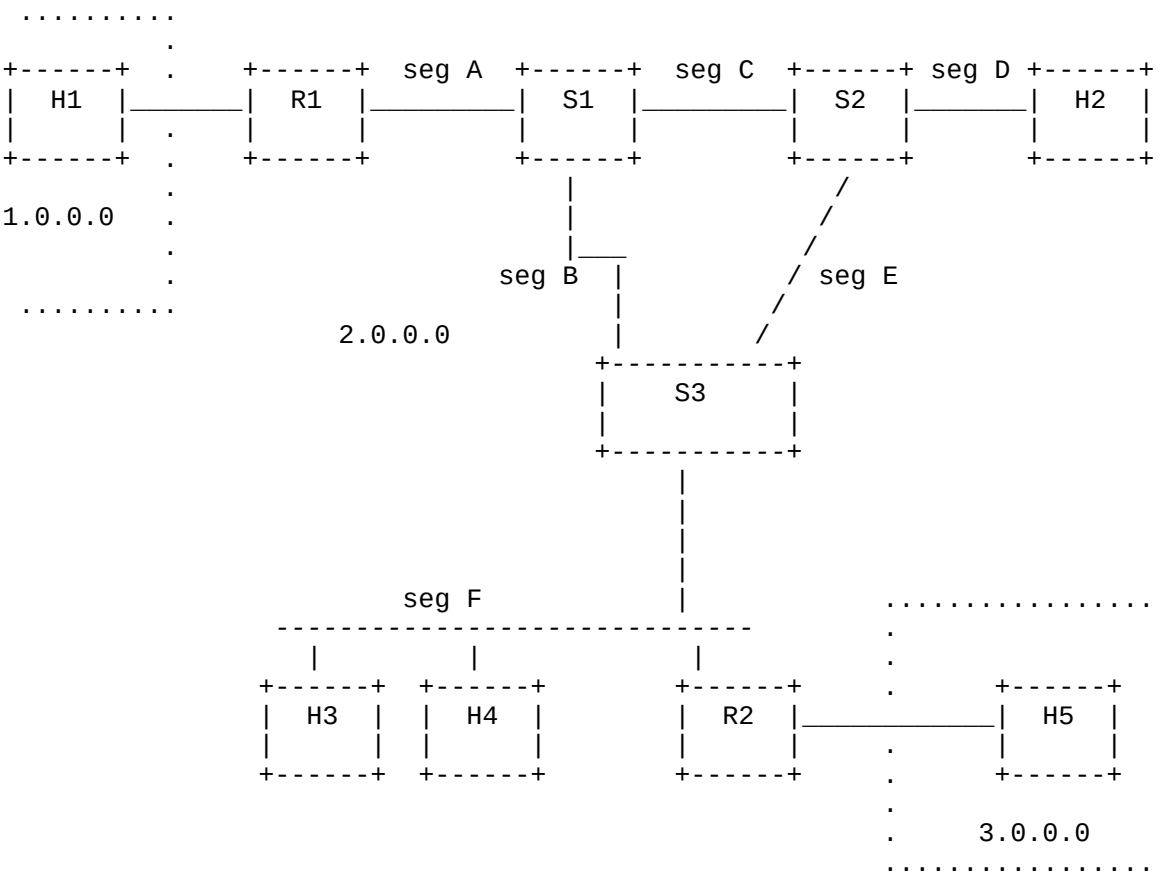

Figure 2 illustrates a sample network topology consisting of three IP subnets (1.0.0.0, 2.0.0.0, and 3.0.0.0) interconnected using two routers. The subnet 2.0.0.0 is an example of a L2 domain consisting of switches, hosts, and routers interconnected using switched segments and a shared L2 segment. The sample network contains the following devices:

Device	Type	SBM Type
H1, H5	Host (layer 3)	SBM Transparent
H2-H4	Host (layer 3)	DSBM Client
R1	Router (layer 3)	SBM
R2	Router (layer 3)	DSBM for segment F
S1	Switch (layer 2)	DSBM for segments A, B
S2	Switch (layer 2)	DSBM for segments C, D, E
S3	Switch (layer 2)	SBM

The following paragraphs describe the rules, which each of these devices should use to forward PATH messages (rules apply to PATH_TEAR messages as well). They are described in the context of the general network illustrated above. While the examples do not address every scenario, they do address most of the interesting scenarios. Exceptions can be discussed separately.

The forwarding rules are applied to received PATH messages (routers and switches) or originating PATH messages (hosts), as follows:

1. Determine the interface(s) on which to forward the PATH message using standard forwarding rules:

   * If there is a LAN_LOOPBACK object in the PATH message, and it carries the address of this device, silently discard the message. (See the section below on "Additional notes on forwarding the PATH message onto a managed segment).

   * Layer 3 devices use the RSVP session address and perform a routing lookup to determine the forwarding interface(s).

   * Layer 2 devices use the LAN_NHOP_L2 address in the LAN_NHOP information and MAC forwarding tables to determine the forwarding interface(s). (See the section below on "Additional notes on forwarding the PATH message onto a managed segment")

2. For each forwarding interface:

   * If the device is a layer 3 device, determine whether the interface is on a managed segment managed by a DSBM, based on the presence or absence of I_AM_DSBM messages. If the interface is not on a managed segment, strip out RSVP_HOP_L2, LAN_NHOP, LAN_LOOPBACK, and TCLASS objects (if present), and forward to the unicast or multicast destination.

(Note that the RSVP Class Numbers for these new objects are chosen so that if an RSVP message includes these objects, the nodes that are RSVP-aware, but do not participate in the SBM protocol, will ignore and silently discard such objects.)

* If the device is a layer 2 device or it is a layer 3 device *and* the interface is on a managed segment, proceed to rule #3.

3. Forward the PATH message onto the managed segment:

* If the device is a layer 3 device, insert LAN_NHOP address objects, a LAN_LOOPBACK, and a RSVP_HOP_L2 object into the PATH message. The LAN_NHOP objects carry the LAN_NHOP_L3 and LAN_NHOP_L2 addresses of the next layer 3 hop. The RSVP_HOP_L2 object carries the device's own L2 address, and the LAN_LOOPBACK object contains the IP address of the outgoing interface.

  An L3 device should use the map_addr() function described earlier to obtain an L2 address corresponding to an IP address.

* If the device hosts the DSBM for the segment to which the forwarding interface is attached, do the following:

  - Retrieve the PHOP information from the standard RSVP HOP object in the PATH message, and store it. This will be used to route RESV messages back through the L2 network. If the PATH message arrived over a managed segment, it will also contain the RSVP_HOP_L2 object; then retrieve and store also the previous hop's L2 address in the PATH state.

  - Copy the IP address of the forwarding interface (layer 2 devices must also have IP addresses) into the standard RSVP HOP object and the L2 address of the forwarding interface into the RSVP_HOP_L2 object.

  - If the PATH message received does not contain the TCLASS object, insert a TCLASS object. The user_priority value inserted in the TCLASS object is based on service mappings internal to the device that are configured according to the guidelines listed in [RFC-MAP]. If the message already contains the TCLASS object, the user_priority value may be changed based again on the service mappings internal to the device.

* If the device is a layer 3 device and hosts a SBM for the segment to which the forwarding interface is attached, it *is required* to retrieve and store the PHOP info.

  If the device is a layer 2 device and hosts a SBM for the segment to which the forwarding interface is attached, it is *not* required to retrieve and store the PHOP info. If it does not do so, the SBM must leave the standard RSVP HOP object and the RSVP_HOP_L2 objects in the PATH message intact and it will not receive RESV messages.

  If the SBM on a L2 device chooses to overwrite the RSVP HOP and RSVP_HOP_L2 objects with the IP and L2 addresses of its forwarding interface, it will receive RESV messages. In this case, it must store the PHOP address info received in the standard RSVP_HOP field and RSVP_HOP_L2 objects of the incident PATH message.

  In both the cases mentioned above (L2 or L3 devices), the SBM must forward the TCLASS object in the received PATH message unchanged.

* Copy the IP address of the forwarding interface into the LAN_LOOPBACK object, unless the SBM protocol entity is a DSBM reflecting a PATH message back onto the incident interface. (See the section below on "Additional notes on forwarding a PATH message onto a managed segment").

* If the SBM protocol entity is the DSBM for the segment to which the forwarding interface is attached, it must send the PATH message to the AllSBMAddress.

* If the SBM protocol entity is a SBM or a DSBM Client on the segment to which the forwarding interface is attached, it must send the PATH message to the DSBMLogicalAddress.

5.5.1. Additional notes on forwarding a PATH message onto a managed segment

Rule #1 states that normal IEEE 802.1D forwarding rules should be used to determine the interfaces on which the PATH message should be forwarded. In the case of data packets, standard forwarding rules at a L2 device dictate that the packet should not be forwarded on the interface from which it was received. However, in the case of a DSBM that receives a PATH message over a managed segment, the following exception applies:

E1. If the address in the LAN_NHOP object is a unicast address, consult the filtering database (FDB) to determine whether the destination address is listed on the same interface over which the message was received. If yes, follow the rule below on "reflecting a PATH message back onto an interface" described below; otherwise, proceed with the rest of the message processing as usual.

E2. If there are members of the multicast group address (specified by the addresses in the LAN_NHOP object), on the segment from which the message was received, the message should be forwarded back onto the interface from which it was received and follow the rule on "reflecting a PATH message back onto an interface" described below.

*** Reflecting a PATH message back onto an interface ***

Under the circumstances described above, when a DSBM reflects the PATH message back onto an interface over which it was received, it must address it using the AllSBMAddress.

Since it is possible for a DSBM to reflect a PATH message back onto the interface from which it was received, precautions must be taken to avoid looping these messages indefinitely. The LAN_LOOPBACK object addresses this issue. All SBM protocol entities (except DSBMs reflecting a PATH message) overwrite the LAN_LOOPBACK object in the PATH message with the IP address of the outgoing interface. DSBMs which are reflecting a PATH message, leave the LAN_LOOPBACK object unchanged. Thus, SBM protocol entities will always be able to recognize a reflected multicast message by the presence of their own address in the LAN_LOOPBACK object. These messages should be silently discarded.

5.6. Applying the Rules -- Unicast Session

Let’s see how the rules are applied in the general network illustrated previously (see Figure 2).

Assume that H1 is sending a PATH for a unicast session for which H5 is the receiver. The following PATH message is composed by H1:

	RSVP Contents
RSVP session IP address	IP address of H5 (3.0.0.35)
Sender Template	IP address of H1 (1.0.0.11)
PHOP	IP address of H1 (1.0.0.11)
RSVP_HOP_L2	n/a (H1 is not sending onto a managed segment)
LAN_NHOP	n/a (H1 is not sending onto a managed

	segment)
LAN_LOOPBACK	n/a (H1 is not sending onto a managed segment)
	IP Header
Source address	IP address of H1 (1.0.0.11)
Destn address	IP addr of H5 (3.0.0.35, assuming raw mode & router alert)
	MAC Header
Destn address	The L2 addr corresponding to R1 (determined by map_addr() and routing tables at H1)

Since H1 is not sending onto a managed segment, the PATH message is composed and forwarded according to standard RSVP processing rules.

Upon receipt of the PATH message, R1 composes and forwards a PATH message as follows:

	RSVP Contents
RSVP session IP address	IP address of H5
Sender Template	IP address of H1
PHOP	IP address of R1 (2.0.0.1) (seed the return path for RESV messages)
RSVP_HOP_L2	L2 address of R1
LAN_NHOP	LAN_NHOP_L3 (2.0.0.2) and LAN_NHOP_L2 address of R2 (L2ADDR) (this is the next layer 3 hop)
LAN_LOOPBACK	IP address of R1 (2.0.0.1)
	IP Header
Source address	IP address of H1
Destn address	DSBMLogical IP address (224.0.0.16)
	MAC Header
Destn address	DSBMLogical MAC address

* R1 does a routing lookup on the RSVP session address, to determine the IP address of the next layer 3 hop, R2.

* It determines that R2 is accessible via seg A and that seg A is managed by a DSBM, S1.

* Therefore, it concludes that it is sending onto a managed segment, and composes LAN_NHOP objects to carry the layer 3 and layer 2 next hop addresses. To compose the LAN_NHOP L2ADDR object, it invokes the L3 to L2 address mapping function

("map_address") to find out the MAC address for the next hop L3 device, and then inserts a LAN_NHOP_L2ADDR object (that carries the MAC address) in the message.

* Since R1 is not the DSBM for seg A, it sends the PATH message to the DSBMLogicalAddress.

Upon receipt of the PATH message, S1 composes and forwards a PATH message as follows:

	RSVP Contents
RSVP session IP address	IP address of H5
Sender Template	IP address of H1
PHOP	IP addr of S1 (seed the return path for RESV messages)
RSVP_HOP_L2	L2 address of S1
LAN_NHOP	LAN_NHOP_L3 (IP) and LAN_NHOP_L2 address of R2 (layer 2 devices do not modify the LAN_NHOP)
LAN_LOOPBACK	IP addr of S1
	IP Header
Source address	IP address of H1
Destn address	AllSBMIPaddr (224.0.0.17, since S1 is the DSBM for seg B).
	MAC Header
Destn address	All SBM MAC address (since S1 is the DSBM for seg B).

* S1 looks at the LAN_NHOP address information to determine the L2 address towards which it should forward the PATH message.

* From the bridge forwarding tables, it determines that the L2 address is reachable via seg B.

* S1 inserts the RSVP_HOP_L2 object and overwrites the RSVP HOP object (PHOP) with its own addresses.

* Since S1 is the DSBM for seg B, it addresses the PATH message to the AllSBMAddress.

Upon receipt of the PATH message, S3 composes and forwards a PATH message as follows:

	RSVP Contents
RSVP session IP addr	IP address of H5
Sender Template	IP address of H1
PHOP	IP addr of S3 (seed the return path for RESV messages)
RSVP_HOP_L2	L2 address of S3
LAN_NHOP	LAN_NHOP_L3 (IP) and LAN_NHOP_L2 (MAC) address of R2 (L2 devices don't modify LAN_NHOP)
LAN_LOOPBACK	IP address of S3

	IP Header
Source address	IP address of H1
Destn address	DSBMLogical IP addr (since S3 is not the DSBM for seg F)

	MAC Header
Destn address	DSBMLogical MAC address

* S3 looks at the LAN_NHOP address information to determine the L2 address towards which it should forward the PATH message.

* From the bridge forwarding tables, it determines that the L2 address is reachable via segment F.

* It has discovered that R2 is the DSBM for segment F. It therefore sends the PATH message to the DSBMLogicalAddress.

* Note that S3 may or may not choose to overwrite the PHOP objects with its own IP and L2 addresses. If it does so, it will receive RESV messages. In this case, it must also store the PHOP info received in the incident PATH message so that it is able to forward the RESV messages on the correct path.

Upon receipt of the PATH message, R2 composes and forwards a PATH message as follows:

	RSVP Contents
RSVP session IP addr	IP address of H5
Sender Template	IP address of H1
PHOP	IP addr of R2 (seed the return path for RESV messages)
RSVP_HOP_L2	Removed by R2 (R2 is not sending onto a managed segment)
LAN_NHOP	Removed by R2 (R2 is not sending onto a managed segment)

	IP Header
Source address	IP address of H1
Destn address	IP address of H5, the RSVP session address

	MAC Header
Destn address	L2 addr corresponding to H5, the next layer 3 hop

* R2 does a routing lookup on the RSVP session address, to determine the IP address of the next layer 3 hop, H5.

* It determines that H5 is accessible via a segment for which there is no DSBM (not a managed segment).

* Therefore, it removes the LAN_NHOP and RSVP_HOP_L2 objects and places the RSVP session address in the destination address of the IP header. It places the L2 address of the next layer 3 hop, into the destination address of the MAC header and forwards the PATH message to H5.

5.7. Applying the Rules - Multicast Session

The rules described above also apply to multicast (m/c) sessions. For the purpose of this discussion, it is assumed that layer 2 devices track multicast group membership on each port individually. Layer 2 devices which do not do so, will merely generate extra multicast traffic. This is the case for L2 devices which do not implement multicast filtering or GARP/GMRP capability.

Assume that H1 is sending a PATH for an m/c session for which H3 and H5 are the receivers. The rules are applied as they are in the unicast case described previously, until the PATH message reaches R2, with the following exception. The RSVP session address and the LAN_NHOP carry the destination m/c addresses rather than the unicast addresses carried in the unicast example.

Now let’s look at the processing applied by R2 upon receipt of the PATH message. Recall that R2 is the DSBM for segment F. Therefore, S3 will have forwarded its PATH message to the DSBMLogicalAddress, to be picked up by R2. The PATH message will not have been seen by H3 (one of the m/c receivers), since it monitors only the AllSBMAddress, not the DSBMLogicalAddress for incoming PATH messages. We rely on R2 to reflect the PATH message back onto seg f, and to forward it to H5. R2 forwards the following PATH message onto seg f:

	RSVP Contents
RSVP session addr	m/c session address
Sender Template	IP address of H1

PHOP	IP addr of R2 (seed the return path for RESV messages)
RSVP_HOP_L2	L2 addr of R2
LAN_NHOP	m/c session address and corresponding L2 address
LAN_LOOPBACK	IP addr of S3 (DSBMs reflecting a PATH message don't modify this object)

IP Header

Source address	IP address of H1
Destn address	AllSBMIP address (since R2 is the DSBM for seg F)

MAC Header

Destn address	AllSBMMAC address (since R2 is the DSBM for seg F)

Since H3 is monitoring the All SBM Address, it will receive the PATH message reflected by R2. Note that R2 violated the standard forwarding rules here by sending an incoming message back onto the interface from which it was received. It protected against loops by leaving S3's address in the LAN_LOOPBACK object unchanged.

R2 forwards the following PATH message on to H5:

RSVP Contents

RSVP session addr	m/c session address
Sender Template	IP address of H1
PHOP	IP addr of R2 (seed the return path for RESV messages)
RSVP_HOP_L2	Removed by R2 (R2 is not sending onto a managed segment)
LAN_NHOP	Removed by R2 (R2 is not sending onto a managed segment)
LAN_LOOPBACK	Removed by R2 (R2 is not sending onto a managed segment)

IP Header

Source address	IP address of H1
Destn address	m/c session address

MAC Header

Destn address	MAC addr corresponding to the m/c session address

* R2 determines that there is an m/c receiver accessible via a segment for which there is no DSBM. Therefore, it removes the LAN_NHOP and RSVP_HOP_L2 objects and places the RSVP session address in the destination address of the IP header. It

places the corresponding L2 address into the destination address of the MAC header and multicasts the message towards H5.

5.8. Merging Traffic Class objects

When a DSBM client receives TCLASS objects from different senders (different PATH messages) in the same RSVP session and needs to combine them for sending back a single RESV message (as in a wild-card style reservation), the DSBM client must choose an appropriate value that corresponds to the desired-delay traffic class. An accompanying document discusses the guidelines for traffic class selection based on desired service and the TSpec information [RFC-MAP].

In addition, when a SBM or DSBM needs to merge RESVs from different next hops at a merge point, it must decide how to handle the TCLASS values in the incoming RESVs if they do not match. Consider the case when a reservation is in place for a flow at a DSBM (or SBM) with a successful admission control done for the TCLASS requested in the first RESV for the flow. If another RESV (not the refresh of the previously admitted RESV) for the same flow arrives at the DSBM, the DSBM must first check the TCLASS value in the new RESV against the TCLASS value in the already installed RESV. If the two values are same, the RESV requests are merged and the new, merged RESV installed and forwarded using the normal rules of message processing. However, if the two values are not identical, the DSBM must generate and send a RESV_ERR message towards the sender (NHOP) of the newer, RESV message. The RESV_ERR must specify the error code corresponding to the RSVP "traffic control error" (RESV_ERR code 21) that indicates failure to merge two incompatible service requests (sub-code 01 for the RSVP traffic control error) [RFC-2205]. The RESV_ERR message may include additional objects to assist downstream nodes in recovering from this condition. The definition and usage of such objects is beyond the scope of this memo.

5.9. Operation of SBM Transparent Devices

SBM transparent devices are unaware of the entire SBM/DSBM protocol. They do not intercept messages addressed to either of the SBM related local group addresses (the DSBMLogicalAddrss and the ALLSBMAddress), but instead, pass them through. As a result, they do not divide the DSBM election scope, they do not explicitly participate in routing of PATH or RESV messages, and they do not participate in admission control. They are entirely transparent with respect to SBM operation.

According to the definitions provided, physical segments interconnected by SBM transparent devices are considered a single managed segment. Therefore, DSBMs must perform admission control on such managed segments, with limited knowledge of the segment's topology. In this case, the network administrator should configure the DSBM for each managed segment, with some reasonable approximation of the segment's capacity. A conservative policy would configure the DSBM for the lowest capacity route through the managed segment. A liberal policy would configure the DSBM for the highest capacity route through the managed segment. A network administrator will likely choose some value between the two, based on the level of guarantee required and some knowledge of likely traffic patterns.

This document does not specify the configuration mechanism or the choice of a policy.

5.10. Operation of SBMs Which are NOT DSBMs

In the example illustrated, S3 hosts a SBM, but the SBM on S3 did not win the election to act as DSBM on any segment. One might ask what purpose such a SBM protocol entity serves. Such SBMs actually provide two useful functions. First, the additional SBMs remain passive in the background for fault tolerance. They listen to the periodic announcements from the current DSBM for the managed segment (Appendix A describes this in more detail) and step in to elect a new DSBM when the current DSBM fails or ceases to be operational for some reason. Second, such SBMs also provide the important service of dividing the election scope and reducing the size and complexity of managed segments. For example, consider the sample topology in Figure 3 again. the device S3 contains an SBM that is not a DSBM for any f the segments, B, E, or F, attached to it. However, if the SBM protocol entity on S3 was not present, segments B and F would not be separate segments from the point of view of the SBM protocol. Instead, they would constitute a single managed segment, managed by a single DSBM. Because the SBM entity on S3 divides the election scope, seg B and seg F are each managed by separate DSBMs. Each of these segments have a trivial topology and a well defined capacity. As a result, the DSBMs for these segments do not need to perform admission control based on approximations (as would be the case if S3 were SBM transparent).

Note that, SBM protocol entities which are not DSBMs, are not required to overwrite the PHOP in incident PATH messages with their own address. This is because it is not necessary for RESV messages to be routed through these devices. RESV messages are only required to be routed through the correct sequence of DSBMs. SBMs may not process RESV messages that do pass through them, other than to forward them towards their destination address, using standard

forwarding rules.

SBM protocol entities which are not DSBMs are required to overwrite the address in the LAN_LOOPBACK object with their own address, in order to avoid looping multicast messages. However, no state need be stored.

6. Inter-Operability Considerations

There are a few interesting inter-operability issues related to the deployment of a DSBM-based admission control method in an environment consisting of network nodes with and without RSVP capability. In the following, we list some of these scenarios and explain how SBM-aware clients and nodes can operate in those scenarios:

6.1. An L2 domain with no RSVP capability.

It is possible to envisage L2 domains that do not use RSVP signaling for requesting resource reservations, but, instead, use some other (e.g., SNMP or static configuration) mechanism to reserve bandwidth at a particular network device such as a router. In that case, the question is how does a DSBM-based admission control method work and interoperate with the non-RSVP mechanism. The SBM-based method does not attempt to provide an admission control solution for such an environment. The SBM-based approach is part of an end to end signaling approach to establish resource reservations and does not attempt to provide a solution for SNMP-based configuration scenario.

As stated earlier, the SBM-based approach can, however, co-exist with any other, non-RSVP bandwidth allocation mechanism as long as resources being reserved are either partitioned statically between the different mechanisms or are resolved dynamically through a common bandwidth allocator so that there is no over-commitment of the same resource.

6.2. An L2 domain with SBM-transparent L2 Devices.

This scenario has been addressed earlier in the document. The SBM-based method is designed to operate in such an environment. When SBM-transparent L2 devices interconnect SBM-aware devices, the resulting managed segment is a combination of one or more physical segments and the DSBM for the managed segment may not be as efficient in allocating resources as it would if all L2 devices were SBM-aware.

6.3. An L2 domain on which some RSVP-based senders are not DSBM clients.

All senders that are sourcing RSVP-based traffic flows onto a managed segment MUST be SBM-aware and participate in the SBM protocol. Use of the standard, non-SBM version of RSVP may result in over-allocation of resources, as such use bypasses the resource management function of the DSBM. All other senders (i.e., senders that are not sending streams subject to RSVP admission control) should be elastic applications that send traffic of lower priority than the RSVP traffic, and use TCP-like congestion avoidance mechanisms.

All DSBMs, SBMs, or DSBM clients on a managed segment (a segment with a currently active DSBM) must not accept PATH messages from senders that are not SBM-aware. PATH messages from such devices can be easily detected by SBMs and DSBM clients as they would not be multicast to the ALLSBMAddress (in case of SBMs and DSBM clients) or the DSBMLogicalAddress (in case of DSBMs).

6.4. A non-SBM router that interconnects two DSBM-managed L2 domains.

Multicast SBM messages (e.g., election and PATH messages) have local scope and are not intended to pass between the two domains. A correctly configured non-SBM router will not pass such messages between the domains. A broken router implementation that does so may cause incorrect operation of the SBM protocol and consequent over- or under-allocation of resources.

6.5. Interoperability with RSVP clients that use UDP encapsulation and are not capable of receiving/sending RSVP messages using RAW_IP

This document stipulates that DSBMs, DSBM clients, and SBMs use only raw IP for encapsulating RSVP messages that are forwarded onto a L2 domain. RFC-2205 (the RSVP Proposed Standard) includes support for both raw IP and UDP encapsulation. Thus, a RSVP node using only the UDP encapsulation will not be able to interoperate with the DSBM unless DSBM accepts and supports UDP encapsulated RSVP messages.

7. Guidelines for Implementers

In the following, we provide guidelines for implementers on different aspects of the implementation of the SBM-based admission control procedure including suggestions for DSBM initialization, etc.

7.1. DSBM Initialization

As stated earlier, DSBM initialization includes configuration of maximum bandwidth that can be reserved on a managed segment under its control. We suggest the following guideline.

In the case of a managed segment consisting of L2 devices interconnected by a single shared segment, DSBM entities on such devices should assume the bandwidth of the interface as the total link bandwidth. In the case of a DSBM located in a L2 switch, it might additionally need to be configured with an estimate of the device's switching capacity if that is less than the link bandwidth, and possibly with some estimate of the buffering resources of the switch (see [RFC-FRAME] for the architectural model assumed for L2 switches). Given the total link bandwidth, the DSBM may be further configured to limit the maximum amount of bandwidth for RSVP-enabled flows to ensure spare capacity for best-effort traffic.

7.2. Operation of DSBMs in Different L2 Topologies

Depending on a L2 topology, a DSBM may be called upon to manage resources for one or more segments and the implementers must bear in mind efficiency implications of the use of DSBM in different L2 topologies. Trivial L2 topologies consist of a single "physical segment". In this case, the 'managed segment' is equivalent to a single segment. Complex L2 topologies may consist of a number of Admission control on such an L2 extended segment can be performed from a single pool of resources, similar to a single shared segment, from the point of view of a single DSBM.

This configuration compromises the efficiency with which the DSBM can allocate resources. This is because the single DSBM is required to make admission control decisions for all reservation requests within the L2 topology, with no knowledge of the actual physical segments affected by the reservation.

We can realize improvements in the efficiency of resource allocation by subdividing the complex segment into a number of managed segments, each managed by their own DSBM. In this case, each DSBM manages a managed segment having a relatively simple topology. Since managed segments are simpler, the DSBM can be configured with a more accurate estimate of the resources available for all reservations in the managed segment. In the ultimate configuration, each physical segment is a managed segment and is managed by its own DSBM. We make no assumption about the number of managed segments but state, simply, that in complex L2 topologies, the efficiency of resource allocation improves as the granularity of managed segments increases.

8. Security Considerations

The message formatting and usage rules described in this note raise security issues, identical to those raised by the use of RSVP and Integrated Services. It is necessary to control and authenticate

access to enhanced qualities of service enabled by the technology described in this RFC. This requirement is discussed further in [RFC-2205], [RFC-2211], and [RFC-2212].

[RFC-RSVPMD5] describes the mechanism used to protect the integrity of RSVP messages carrying the information described here. A SBM implementation should satisfy the requirements of that RFC and provide the suggested mechanisms just as though it were a conventional RSVP implementation. It should further use the same mechanisms to protect the additional, SBM-specific objects in a message.

Finally, it is also necessary to authenticate DSBM candidates during the election process, and a mechanism based on a shared secret among the DSBM candidates may be used. The mechanism defined in [RFC-RSVPMD5] should be used.

9. References

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A.1. Introduction

To simplify the rest of this discussion, we will assume that there is a single DSBM for the entire L2 domain (i.e., assume a shared L2 segment for the entire L2 domain). Later, we will discuss how a DSBM is elected for a half-duplex or full-duplex switched segment.

To allow for quick recovery from the failure of a DSBM, we assume that additional SBMs may be active in a L2 domain for fault tolerance. When more than one SBM is active in a L2 domain, the SBMs use an election algorithm to elect a DSBM for the L2 domain. After the DSBM is elected and is operational, other SBMs remain passive in the background to step in to elect a new DSBM when necessary. The protocol for electing and discovering DSBM is called the "DSBM election protocol" and is described in the rest of this Appendix.

A.1.1. How a DSBM Client Detects a Managed Segment

Once elected, a DSBM periodically multicasts an I_AM_DSBM message on the AllSBMAddress to indicate its presence. The message is sent every period (e.g., every 5 seconds) according to the RefreshInterval timer value (a configuration parameter). Absence of such a message over a certain time interval (called "DSBMDeadInterval"; another configuration parameter typically set to a multiple of RefreshInterval) indicates that the DSBM has failed or terminated and triggers another round of the DSBM election. The DSBM clients always listen for periodic DSBM advertisements. The advertisement includes the unicast IP address of the DSBM (DSBMAddress) and DSBM clients send their PATH/RESV (or other) messages to the DSBM. When a DSBM client detects the failure of a DSBM, it waits for a subsequent I_AM_DSBM advertisement before resuming any communication with the DSBM. During the period when a DSBM is not present, a DSBM client may forward outgoing PATH messages using the standard RSVP forwarding rules.

The exact message formats and addresses used for communication with (and among) SBM(s) are described in Appendix B.

A.2. Overview of the DSBM Election Procedure

When a SBM first starts up, it listens for incoming DSBM advertisements for some period to check whether a DSBM already exists in its L2 domain. If one already exists (and no new election is in progress), the new SBM stays quiet in the background until an election of DSBM is necessary. All messages related to the DSBM election and DSBM advertisements are always sent to the AllSBMAddress.

If no DSBM exists, the SBM initiates the election of a DSBM by sending out a DSBM_WILLING message that lists its IP address as a candidate DSBM and its "SBM priority". Each SBM is assigned a priority to determine its relative precedence. When more than one SBM candidate exists, the SBM priority determines who gets to be the DSBM based on the relative priority of candidates. If there is a tie based on the priority value, the tie is broken using the IP addresses of tied candidates (one with the higher IP address in the lexicographic order wins). The details of the election protocol start in Section A.4.

A.2.1 Summary of the Election Algorithm

For the purpose of the algorithm, a SBM is in one of the four states (Idle, DetectDSBM, ElectDSBM, IAMDSBM).

A SBM (call it X) starts up in the DetectDSBM state and waits for a ListenInterval for incoming I_AM_DSBM (DSBM advertisement) or DSBM_WILLING messages. If an I_AM_DSBM advertisement is received during this state, the SBM notes the current DSBM (its IP address and priority) and enters the Idle state. If a DSBM_WILLING message is received from another SBM (call it Y) during this state, then X enters the ElectDSBM state. Before entering the new state, X first checks to see whether it itself is a better candidate than Y and, if so, sends out a DSBM_WILLING message and then enters the ElectDSBM state.

When a SBM (call it X) enters the ElectDSBM state, it sets a timer (called ElectionIntervalTimer, and typically set to a value at least equal to the DSBMDeadInterval value) to wait for the election to finish and to discover who is the best candidate. In this state, X keeps track of the best (or better) candidate seen so far (including itself). Whenever it receives another DSBM_WILLING message it updates its notion of the best (or better) candidate based on the priority (and tie-breaking) criterion. During the ElectionInterval, X sends out a DSBM_WILLING message every RefreshInterval to (re)assert its candidacy.

At the end of the ElectionInterval, X checks whether it is the best candidate so far. If so, it declares itself to be the DSBM (by sending out the I_AM_DSBM advertisement) and enters the IAMDSBM state; otherwise, it decides to wait for the best candidate to declare itself the winner. To wait, X re-initializes its ElectDSBM state and continues to wait for another round of election (each round lasts for an ElectionTimerInterval duration).

A SBM is in Idle state when no election is in progress and the DSBM is already elected (and happens to be someone else). In this state, it listens for incoming I_AM_DSBM advertisements and uses a DSBMDeadIntervalTimer to detect the failure of DSBM. Every time the advertisement is received, the timer is restarted. If the timer fires, the SBM goes into the DetectDSBM state to prepare to elect the new DSBM. If a SBM receives a DSBM_WILLING message from the current DSBM in this state, the SBM enters the ElectDSBM state after sending out a DSBM_WILLING message (to announce its own candidacy).

In the IAMDSBM state, the DSBM sends out I_AM_DSBM advertisements every refresh interval. If the DSBM wishes to shut down (gracefully terminate), it sends out a DSBM_WILLING message (with SBM priority value set to zero) to initiate the election procedure. The priority value zero effectively removes the outgoing DSBM from the election procedure and makes way for the election of a different DSBM.

A.3. Recovering from DSBM Failure

When a DSBM fails (DSBMDeadIntervalTimer fires), all the SBMs enter the ElectDSBM state and start the election process.

At the end of the ElectionInterval, the elected DSBM sends out an I_AM_DSBM advertisement and the DSBM is then operational.

A.4. DSBM Advertisements

The I_AM_DSBM advertisement contains the following information:

1. DSBM address information -- contains the IP and L2 addresses of the DSBM and its SBM priority (a configuration parameter -- priority specified by a network administrator). The priority value is used to choose among candidate SBMs during the election algorithm. Higher integer values indicate higher priority and the value is in the range 0..255. The value zero indicates that the SBM is not eligible to be the DSBM. The IP address is required and used for breaking ties. The L2 address is for the interface of the managed segment.

2. RegreshInterval -- contains the value of RefreshInterval in seconds. Value zero indicates the parameter has been omitted in the message. Receivers may substitute their own default value in this case.

3. DSBMDeadInterval -- contains the value of DSBMDeadInterval in seconds. If the value is omitted (or value zero is specified), a default value (from initial configuration) should be used.

4. Miscellaneous configuration information to be advertised to senders on the managed segment. See Appendix C for further details.

A.5. DSBM_WILLING Messages

When a SBM wishes to declare its candidacy to be the DSBM during an election phase, it sends out a DSBM_WILLING message. The DSBM_WILLING message contains the following information:

1. DSBM address information -- Contains the SBM's own addresses (IP and L2 address), if it wishes to be the DSBM. The IP address is required and used for breaking ties. The L2 address is the address of the interface for the managed segment in question. Also, the DSBM address information includes the corresponding priority of the SBM whose address is given above.

A.6. SBM State Variables

For each network interface, a SBM maintains the following state variables related to the election of the DSBM for the L2 domain on that interface:

a) LocalDSBMAddrInfo -- current DSBM's IP address (initially, 0.0.0.0) and priority. All IP addresses are assumed to be in network byte order. In addition, current DSBM's L2 address is also stored as part of this state information.

b) OwnAddrInfo -- SBM's own IP address and L2 address for the interface and its own priority (a configuration parameter).

c) RefreshInterval in seconds. When the DSBM is not yet elected, it is set to a default value specified as a configuration parameter.

d) DSBMDeadInterval in seconds. When the DSBM is not yet elected, it is initially set to a default value specified as a configuration parameter.

f) ListenInterval in seconds -- a configuration parameter that decides how long a SBM spends in the DetectDSBM state (see below).

g) ElectionInterval in seconds -- a configuration parameter that decides how long a SBM spends in the ElectDSBM state when it has declared its candidacy.

Figure 3 shows the state transition diagram for the election protocol and the various states are described below. A complete description of the state machine is provided in Section A.10.

A.7. DSBM Election States

DOWN -- SBM is not operational.

DetectDSBM -- typically, the initial state of a SBM when it starts up. In this state, it checks to see whether a DSBM already exists in its domain.

Idle -- SBM is in this state when no election is in progress and it is not the DSBM. In this state, SBM passively monitors the state of the DSBM.

ElectDSBM -- SBM is in this state when a DSBM election is in progress.

IAMDSBM -- SBM is in this state when it is the DSBM for the L2 domain.

A.8. Events that cause state changes

StartUp -- SBM starts operation.

ListenInterval Timeout -- The ListenInterval timer has fired. This means that the SBM has monitored its domain to check for an existing DSBM or to check whether there are candidates (other than itself) willing to be the DSBM.

DSBM_WILLING message received -- This means that the SBM received a DSBM_WILLING message from some other SBM. Such a message is sent when a SBM wishes to declare its candidacy to be the DSBM.

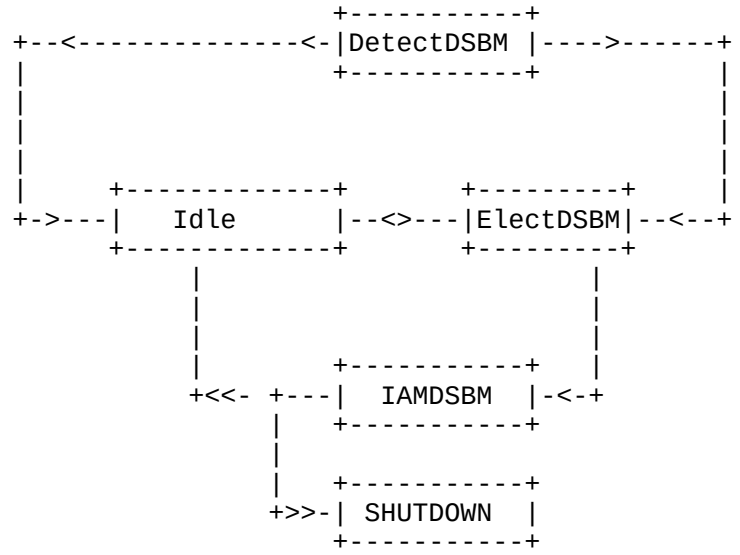
I_AM_DSBM message received -- SBM received a DSBM advertisement from the DSBM in its L2 domain.

DSBMDeadInterval Timeout -- The DSBMDeadIntervalTimer has fired. This means that the SBM did not receive even one DSBM advertisement during this period and indicates possible failure of the DSBM.

RefreshInterval Timeout -- The RefreshIntervalTimer has fired. In the IAMDSBM state, this means it is the time for sending out the next DSBM advertisement. In the ElectDSBM state, the event means that it is the time to send out another DSBM_WILLING message.

ElectionInterval Timeout -- The ElectionIntervalTimer has fired. This means that the SBM has waited long enough after declaring its candidacy to determine whether or not it succeeded.

A.9. State Transition Diagram (Figure 3)



A.10. Election State Machine

Based on the events and states described above, the state changes at a SBM are described below. Each state change is triggered by an event and is typically accompanied by a sequence of actions. The state machine is described assuming a single threaded implementation (to avoid race conditions between state changes and timer events) with no timer events occurring during the execution of the state machine.

The following routines will be frequently used in the description of the state machine:

ComparePrio(FirstAddrInfo, SecondAddrInfo)
-- determines whether the entity represented by the first parameter is better than the second entity using the priority information and the IP address information in the two parameters. If any address is zero, that entity automatically loses; then first priorities are compared; higher priority candidate wins. If there is a tie based on the priority value, the tie is broken using the IP addresses of tied candidates (one with the higher IP address in the lexicographic order wins). Returns TRUE if first entity is a better choice. FALSE otherwise.

```
   SendDSBMWilling Message()
   Begin
       Send out DSBM_WILLING message listing myself as a candidate for
       DSBM (copy OwnAddr and priority into appropriate fields)
       start RefreshIntervalTimer
       goto ElectDSBM state
   End

   AmIBetterDSBM(OtherAddrInfo)
   Begin
       if (ComparePrio(OwnAddrInfo, OtherAddrInfo))
           return TRUE

       change LocalDSBMInfo = OtherDSBMAddrInfo
       return FALSE
   End

   UpdateDSBMInfo()
   /* invoked in an assignment such as LocalDSBMInfo = OtherAddrInfo */
   Begin
       update LocalDSBMInfo such as  IP addr, DSBM L2 address,
       DSBM priority, RefreshIntervalTimer, DSBMDeadIntervalTimer
   End
```

A.10.1 State Changes

In the following, the action "continue" or "continue in current state" means an "exit" from the current action sequence without a state transition.

```
 State:      DOWN
 Event:      StartUp
 New State:  DetectDSBM
 Action:     Initialize the local state variables (LocalDSBMADDR and
             LocalDSBMAddrInfo set to 0). Start the ListenIntervalTimer.

 State:      DetectDSBM
 New State:  Idle
 Event:      I_AM_DSBM message received
 Action:     set LocalDSBMAddrInfo = IncomingDSBMAddrInfo
             start DeadDSBMInterval timer
             goto Idle State

 State:      DetectDSBM
 Event:      ListenIntervalTimer fired
 New State:  ElectDSBM
 Action:     Start ElectionIntervalTimer
             SendDSBMWillingMessage();
```

```
State:      DetectDSBM
Event:      DSBM_WILLING message received
New State:  ElectDSBM
Action:     Cancel any active timers

            Start ElectionIntervalTimer
            /* am I a better choice than this dude? */
            If (ComparePrio(OwnAddrInfo, IncomingDSBMInfo)) {
                /* I am better */
                SendDSBMWillingMessage()
            } else {
                Change LocalDSBMAddrInfo = IncomingDSBMAddrInfo
                goto ElectDSBM state
            }

State:      Idle
Event:      DSBMDeadIntervalTimer fired.
New State:  ElectDSBM
Action:     start ElectionIntervalTimer
            set LocalDSBMAddrInfo = OwnAddrInfo
            SendDSBMWiliingMessage()

State:      Idle
Event:      I_AM_DSBM message received.
New State:  Idle
Action:     /* first check whether anything has changed */
            if (!ComparePrio(LocalDSBMAddrInfo, IncomingDSBMAddrInfo))
                change LocalDSBMAddrInfo to reflect new info
            endif
            restart DSBMDeadIntervalTimer;
            continue in current state;

State:      Idle
Event:      DSBM_WILLING Message is received
New State:  Depends on action (ElectDSBM or Idle)
Action:     /* check whether it is from the DSBM itself (shutdown) */
            if (IncomingDSBMAddr == LocalDSBMAddr) {
                cancel active timers
                Set LocalDSBMAddrInfo = OwnAddrInfo
                Start ElectionIntervalTimer
                SendDSBMWillingMessage() /* goto ElectDSBM state */
            }

            /* else, ignore it */
            continue in current state

State:      ElectDSBM
Event:      ElectionIntervalTimer Fired
```

```
New State:  depends on action (IAMDSBM or Current State)
Action:     If (LocalDSBMAddrInfo == OwnAddrInfo) {
                /* I won */
                send I_AM_DSBM message
                start RefreshIntervalTimer
                goto IAMDSBM state
            } else {   /* someone else won, so wait for it to declare
                          itself to be the DSBM */
                set LocalDSBMAddressInfo = OwnAddrInfo
                start ElectionIntervalTimer
                SendDSBMWillingMessage()
                continue in current state
            }

State:      ElectDSBM
Event:      I_AM_DSBM message received
New State:  Idle
Action:     set LocalDSBMAddrInfo = IncomingDSBMAddrInfo
            Cancel any active timers
            start DeadDSBMInterval timer
            goto Idle State

State:      ElectDSBM
Event:      DSBM_WILLING message received
New State:  ElectDSBM
Action:     Check whether it's a loopback and if so, discard, continue;
            if (!AmIBetterDSBM(IncomingDSBMAddrInfo)) {
                Change LocalDSBMAddrInfo = IncomingDSBMAddrInfo
                Cancel RefreshIntervalTimer
            } else if (LocalDSBMAddrInfo == OwnAddrInfo) {
                SendDSBMWillingMessage()
            }
            continue in current state

State:      ElectDSBM
Event:      RefreshIntervalTimer fired
New State:  ElectDSBM
Action:     /* continue to send DSBMWilling messages until
              election interval ends */
            SendDSBMWillingMessage()

State:      IAMDSBM
Event:      DSBM_WILLING message received
New State:  depends on action (IAMDSBM or SteadyState)
Action:     /* check whether other guy is better */
            If (ComparePrio(OwnAddrInfo, IncomingAddrInfo))  {
            /* I am better */
                send I_AM_DSBM message
```

```
                restart RefreshIntervalTimer
               continue in current state
            } else {
               Set LocalDSBMAddrInfo = IncomingAddrInfo
               cancel active timers
               start DSBMDeadIntervalTimer
               goto SteadyState
            }

 State:      IAMDSBM
 Event:      RefreshIntervalTimer fired
 New State:  IAMDSBM
 Action:     send I_AM_DSBM message
             restart RefreshIntervalTimer

 State:      IAMDSBM
 Event:      I_AM_DSBM message received
 New State:  depends on action (IAMDSBM or Idle)
 Action:     /* check whether other guy is better */
             If (ComparePrio(OwnAddrInfo, IncomingAddrInfo))  {
                 /* I am better */
                 send I_AM_DSBM message
                 restart RefreshIntervalTimer
                 continue in current state
            } else {
                 Set LocalDSBMAddrInfo = IncomingAddrInfo
                 cancel active timers
                 start DSBMDeadIntervalTimer
                 goto Idle State
           }

 State:      IAMDSBM
 Event:      Want to shut myself down
 New State:  DOWN
 Action:     send DSBM_WILLING message with My address filled in, but
             priority set to zero
             goto Down State
```

A.10.2 Suggested Values of Interval Timers

To avoid DSBM outages for long period, to ensure quick recovery from DSBM failures, and to avoid timeout of PATH and RESV state at the edge devices, we suggest the following values for various timers.

Assuming that the RSVP implementations use a 30 second timeout for PATH and RESV refreshes, we suggest that the RefreshIntervalTimer should be set to about 5 seconds with DSBMDeadIntervalTimer set to 15 seconds (K=3, K*RefreshInterval). The DetectDSBMTimer should be set

to a random value between (DSBMDeadIntervalTimer, 2*DSBMDeadIntervalTimer). The ElectionIntervalTimer should be set at least to the value of DSBMDeadIntervalTimer to ensure that each SBM has a chance to have its DSBM_WILLING message (sent every RefreshInterval in ElectDSBM state) delivered to others.

A.10.3. Guidelines for Choice of Values for SBM_PRIORITY

Network administrators should configure SBM protocol entity at each SBM-capable device with the device's "SBM priority" for each of the interfaces attached to a managed segment. SBM_PRIORITY is an 8-bit, unsigned integer value (in the range 0-255) with higher integer values denoting higher priority. The value zero for an interface indicates that the SBM protocol entity on the device is not eligible to be a DSBM for the segment attached to the interface.

A separate range of values is reserved for each type of SBM-capable device to reflect the relative priority among different classes of L2/L3 devices. L2 devices get higher priority followed by routers followed by hosts. The priority values in the range of 128..255 are reserved for L2 devices, the values in the range of 64..127 are reserved for routers, and values in the range of 1..63 are reserved for hosts.

A.11. DSBM Election over switched links

The election algorithm works as described before in this case except each SBM-capable L2 device restricts the scope of the election to its local segment. As described in Section B.1 below, all messages related to the DSBM election are sent to a special multicast address (AllSBMAddress). AllSBMAddress (its corresponding MAC multicast address) is configured in the permanent database of SBM-capable, layer 2 devices so that all frames with AllSBMAddress as the destination address are not forwarded and instead directed to the SBM management entity in those devices. Thus, a DSBM can be elected separately on each point-to-point segment in a switched topology. For example, in Figure 2, DSBM for "segment A" will be elected using the election algorithm between R1 and S1 and none of the election-related messages on this segment will be forwarded by S1 beyond "segment A". Similarly, a separate election will take place on each segment in this topology.

When a switched segment is a half-duplex segment, two senders (one sender at each end of the link) share the link. In this case, one of the two senders will win the DSBM election and will be responsible for managing the segment.

If a switched segment is full-duplex, exactly one sender sends on the link in each direction. In this case, either one or two DSBMs can exist on such a managed segment. If a sender at each end wishes to serve as a DSBM for that end, it can declare itself to be the DSBM by sending out an I_AM_DSBM advertisement and start managing the resources for the outgoing traffic over the segment. If one of the two senders does not wish itself to be the DSBM, then the other DSBM will not receive any DSBM advertisement from its peer and assume itself to be the DSBM for traffic traversing in both directions over the managed segment.

Appendix B Message Encapsulation and Formats

To minimize changes to the existing RSVP implementations and to ensure quick deployment of a SBM in conjunction with RSVP, all communication to and from a DSBM will be performed using messages constructed using the current rules for RSVP message formats and raw IP encapsulation. For more details on the RSVP message formats, refer to the RSVP specification (RFC 2205). No changes to the RSVP message formats are proposed, but new message types and new L2-specific objects are added to the RSVP message formats to accommodate DSBM-related messages. These additions are described below.

B.1 Message Addressing

For the purpose of DSBM election and detection, AllSBMAddress is used as the destination address while sending out both DSBM_WILLING and I_AM_DSBM messages. A DSBM client first detects a managed segment by listening to I_AM_DSBM advertisements and records the DSBMAddress (unicast IP address of the DSBM).

B.2. Message Sizes

Each message must occupy exactly one IP datagram. If it exceeds the MTU, such a datagram will be fragmented by IP and reassembled at the recipient node. This has a consequence that a single message may not exceed the maximum IP datagram size, approximately 64K bytes.

B.3. RSVP-related Message Formats

All RSVP messages directed to and from a DSBM may contain various RSVP objects defined in the RSVP specification and messages continue to follow the formatting rules specified in the RSVP specification. In addition, an RSVP implementation must also recognize new object classes that are described below.

B.3.1. Object Formats

All objects are defined using the format specified in the RSVP specification. Each object has a 32-bit header that contains length (of the object in bytes including the object header), the object class number, and a C-Type. All unused fields should be set to zero and ignored on receipt.

B.3.2. SBM Specific Objects

Note that the Class-Num values for the SBM specific objects (LAN_NHOP, LAN_LOOPBACK, and RSVP_HOP_L2) are chosen from the codespace 10XXXXXX. This coding assures that non-SBM aware RSVP nodes will ignore the objects without forwarding them or generating an error message.

Within the SBM specific codespace, note the following interpretation of the third most significant bit of the Class-Num:

a) Objects of the form 100XXXXX are to be silently discarded by SBM nodes that do not recognize them.

b) Objects of the form 101XXXXX are to be silently forwarded by SBM nodes that do not recognize them.

B.3.3. IEEE 802 Canonical Address Format

The 48-bit MAC Addresses used by IEEE 802 were originally defined in terms of wire order transmission of bits in the source and destination MAC address fields. The same wire order applied to both Ethernet and Token Ring. Since the bit transmission order of Ethernet and Token Ring data differ - Ethernet octets are transmitted least significant bit first, Token Ring most significant first - the numeric values naturally associated with the same address on different 802 media differ. To facilitate the communication of address values in higher layer protocols which might span both token ring and Ethernet attached systems connected by bridges, it was necessary to define one reference format - the so called canonical format for these addresses. Formally the canonical format defines the value of the address, separate from the encoding rules used for transmission. It comprises a sequence of octets derived from the original wire order transmission bit order as follows. The least significant bit of the first octet is the first bit transmitted, the next least significant bit the second bit, and so on to the most significant bit of the first octet being the 8th bit transmitted; the least significant bit of the second octet is the 9th bit transmitted, and so on to the most significant bit of the sixth octet of the canonical format being the last bit of the address transmitted.

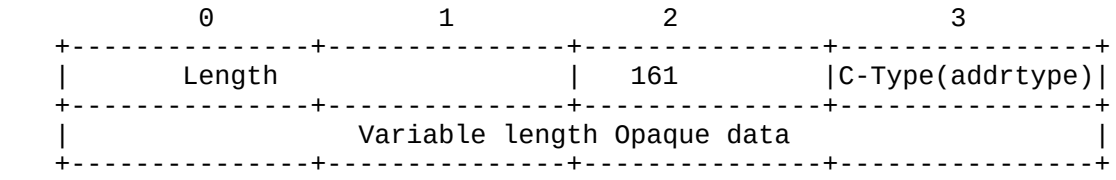
This canonical format corresponds to the natural value of the address octets for Ethernet. The actual transmission order or formal encoding rules for addresses on media which do not transmit bit serially are derived from the canonical format octet values.

This document requires that all L2 addresses used in conjunction with the SBM protocol be encoded in the canonical format as a sequence of 6 octets. In the following, we define the object formats for objects that contain L2 addresses that are based on the canonical representation.

B.3.4. RSVP_HOP_L2 object

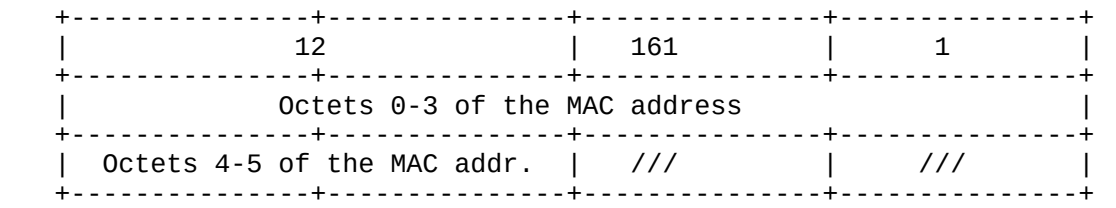
RSVP_HOP_L2 object uses object class = 161; it contains the L2 address of the previous hop L3 device in the IEEE Canonical address format discussed above.

RSVP_HOP_L2 object: class = 161, C-Type represents the addressing format used. In our case, C-Type=1 represents the IEEE Canonical Address format.



C-Type = 1 (IEEE Canonical Address format)

When C-Type=1, the object format is:



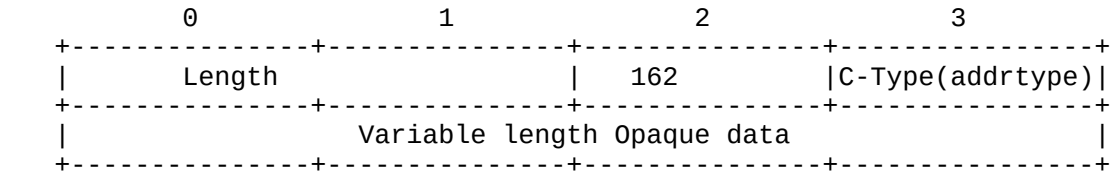
/// -- unused (set to zero)

B.3.5. LAN_NHOP object

LAN_NHOP object represents two objects, namely, LAN_NHOP_L3 address object and LAN_NHOP_L2 address object.

<LAN_NHOP object> ::= <LAN_NHOP_L2 object> <LAN_NHOP_L3 object>

LAN_NHOP_L2 address object uses object class = 162 and uses the same format (but different class number) as the RSVP_HOP_L2 object. It provides the L2 or MAC address of the next hop L3 device.

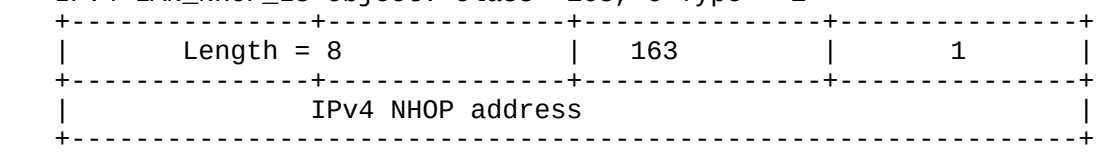


C-Type = 1 (IEEE 802 Canonical Address Format as defined below) See the RSVP_HOP_L2 address object for more details.

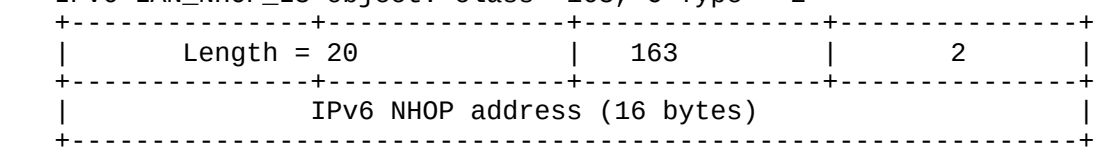
LAN_NHOP_L3 object uses object class = 163 and gives the L3 or IP address of the next hop L3 device.

LAN_NHOP_L3 object: class = 163, C-Type specifies IPv4 or IPv6 address family used.

IPv4 LAN_NHOP_L3 object: class =163, C-Type = 1



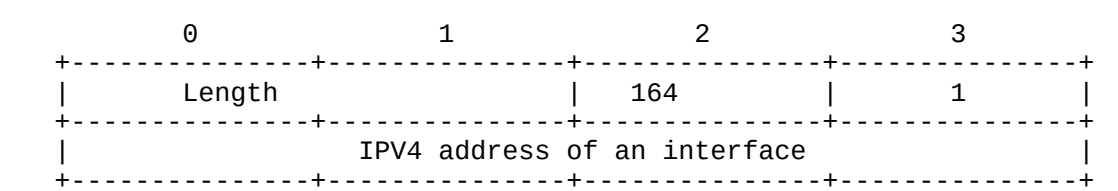
IPv6 LAN_NHOP_L3 object: class =163, C-Type = 2



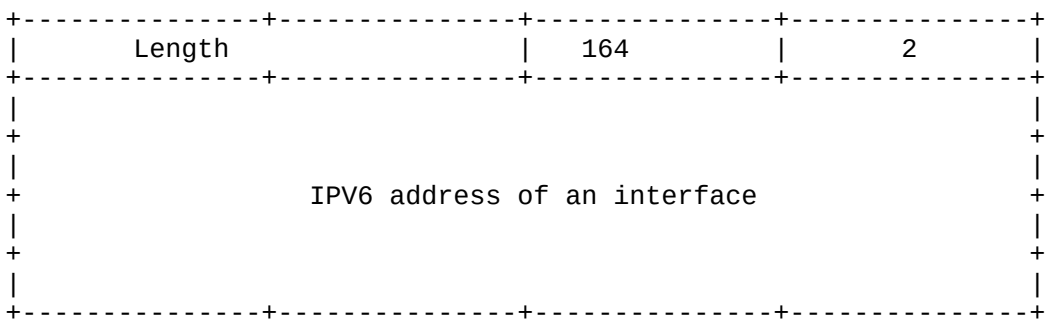
B.3.6. LAN_LOOPBACK Object

The LAN_LOOPBACK object gives the IP address of the outgoing interface for a PATH message and uses object class=164; both IPv4 and IPv6 formats are specified.

IPv4 LAN_LOOPBACK object: class = 164, C-Type = 1

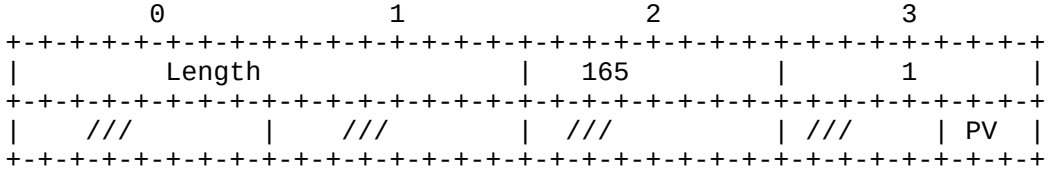


IPv6 LAN_LOOPBACK object: class = 164, C-Type = 2



B.3.7. TCLASS Object

TCLASS object (traffic class based on IEEE 802.1p) uses object class = 165.



Only 3 bits in data contain the user_priority value (PV).

B.4. RSVP PATH and PATH_TEAR Message Formats

As specified in the RSVP specification, a PATH and PATH_TEAR messages contain the RSVP Common Header and the relevant RSVP objects.

For the RSVP Common Header, refer to the RSVP specification (RFC 2205). Enhancements to an RSVP_PATH message include additional objects as specified below.

<PATH Message> ::= <RSVP Common Header> [<INTEGRITY>]
<RSVP_HOP_L2> <LAN_NHOP>
<LAN_LOOPBACK> [<TCLASS>] <SESSION><RSVP_HOP>
<TIME_VALUES> [<POLICY DATA>] <sender descriptor>

<PATH_TEAR Message> ::= <RSVP Common Header> [<INTEGRITY>]
<LAN_LOOPBACK> <LAN_NHOP> <SESSION> <RSVP_HOP>
[<sender descriptor>]

If the INTEGRITY object is present, it must immediately follow the RSVP common header. L2-specific objects must always precede the SESSION object.

B.5. RSVP RESV Message Format

As specified in the RSVP specification, an RSVP_RESV message contains the RSVP Common Header and relevant RSVP objects. In addition, it may contain an optional TCLASS object as described earlier.

B.6. Additional RSVP message types to handle SBM interactions

New RSVP message types are introduced to allow interactions between a DSBM and an RSVP node (host/router) for the purpose of discovering and binding to a DSBM. New RSVP message types needed are as follows:

RSVP Msg Type (8 bits)	Value
DSBM_WILLING	66
I_AM_DSBM	67

All SBM-specific messages are formatted as RSVP messages with an RSVP common header followed by SBM-specific objects.

<SBMP_MESSAGE> ::= <SBMP common header> <SBM-specific objects>

where <SBMP common header> ::= <RSVP common Header> [<INTEGRITY>]

For each SBM message type, there is a set of rules for the permissible choice of object types. These rules are specified using

Backus-Naur Form (BNF) augmented with square brackets surrounding optional sub-sequences. The BNF implies an order for the objects in a message. However, in many (but not all) cases, object order makes no logical difference. An implementation should create messages with the objects in the order shown here, but accept the objects in any permissible order. Any exceptions to this rule will be pointed out in the specific message formats.

DSBM_WILLING Message

```
<DSBM_WILLING message> ::= <SBM Common Header> <DSBM IP ADDRESS>
                           <DSBM L2 address> <SBM PRIORITY>
```

I_AM_DSBM Message

```
<I_AM_DSBM> ::= <SBM Common Header> <DSBM IP ADDRESS> <DSBM L2 address>
                           <SBM PRIORITY> <DSBM Timer Intervals>
                           [<NON_RESV_SEND_LIMIT>]
```

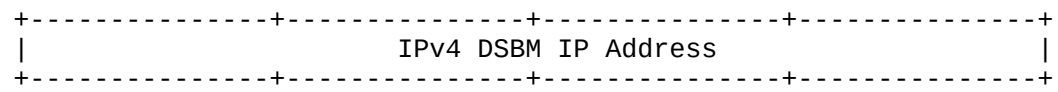
For compatibility reasons, receivers of the I_AM_DSBM message must be prepared to receive additional objects of the Unknown Class type [RFC-2205].

All I_AM_DSBM messages are multicast to the well known AllSBMAddress. The default priority of a SBM is 1 and higher priority values represent higher precedence. The priority value zero indicates that the SBM is not eligible to be the DSBM.

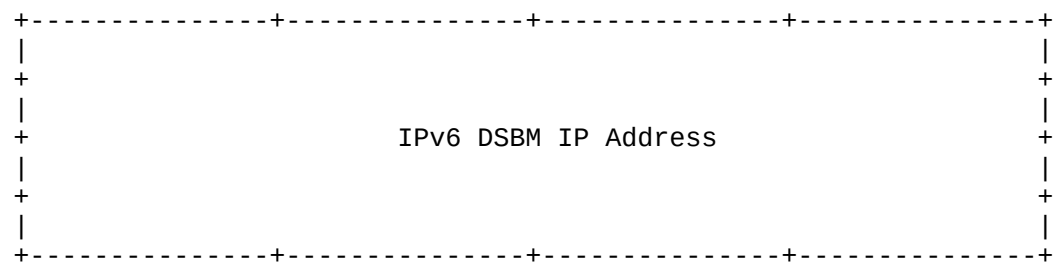
Relevant Objects

DSBM IP ADDRESS objects use object class = 42; IPv4 DSBM IP ADDRESS object uses <Class=42, C-Type=1> and IPv6 DSBM IP ADDRESS object uses <Class=42, C-Type=2>.

IPv4 DSBM IP ADDRESS object: class = 42, C-Type =1



IPv6 DSBM IP ADDRESS object: Class = 42, C-Type = 2

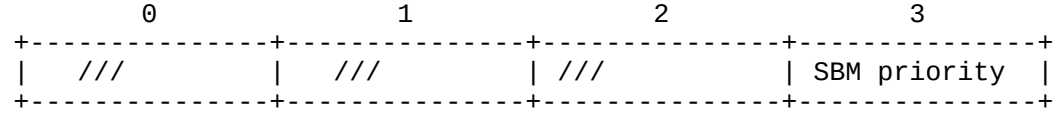


<DSBM L2 address> Object is the same as <RSVP_HOP_L2> object with C-Type = 1 for IEEE Canonical Address format.

<DSBM L2 address> ::= <RSVP_HOP_L2>

A SBM may omit this object by including a NULL L2 address object. For C-Type=1 (IEEE Canonical address format), such a version of the L2 address object contains value zero in the six octets corresponding to the MAC address (see section B.3.4 for the exact format).

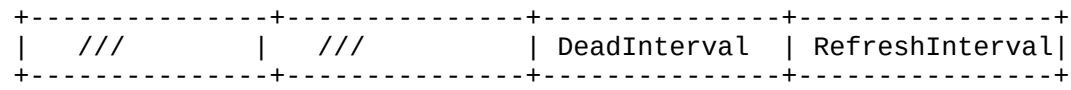
SBM_PRIORITY Object: class = 43, C-Type =1



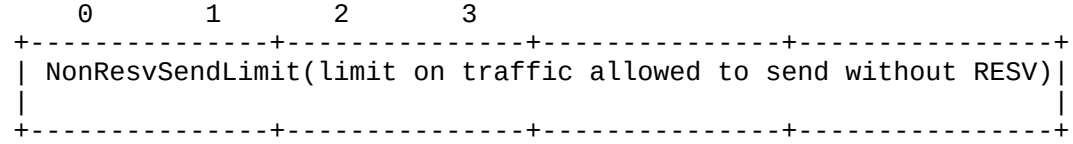
TIMER INTERVAL VALUES.

The two timer intervals, namely, DSBM Dead Interval and DSBM Refresh Interval, are specified as integer values each in the range of 0..255 seconds. Both values are included in a single "DSBM Timer Intervals" object described below.

DSBM Timer Intervals Object: class = 44, C-Type =1



NON_RESV_SEND_LIMIT Object: class = 45, C-Type = 1



<NonResvSendLimit> ::= <Intserv Sender_TSPEC object>
(class=12, C-Type =2)

The NON_RESV_SEND_LIMIT object specifies a per-flow limit on the profile of traffic which a sending host is allowed to send onto a managed segment without a valid RSVP reservation (see Appendix C for further details on the usage of this object). The object contains the NonResvSendLimit parameter. This parameter is equivalent to the Intserv SENDER_TSPEC (see RFC 2210 for contents and encoding rules). The SENDER_TSPEC includes five parameters which describe a traffic profile (r, b, p, m and M). Sending hosts compare the SENDER_TSPEC describing a sender traffic flow to the SENDER_TSPEC advertised by the DSBM. If the SENDER_TSPEC of the traffic flow in question is less than or equal to the SENDER_TSPEC advertised by the DSBM, it is allowable to send traffic on the corresponding flow without a valid RSVP reservation in place. Otherwise it is not.

The network administrator may configure the DSBM to disallow any sent traffic in the absence of an RSVP reservation by configuring a NonResvSendLimit in which r = 0, b = 0, p = 0, m = infinity and M =

0. Similarly the network administrator may allow any traffic to be sent in the absence of an RSVP reservation by configuring a NonResvSendLimit in which r = infinity, b = infinity, p = infinity, m = 0 and M = infinity. Of course, any of these parameters may be set to values between zero and infinity to advertise finite per-flow limits.

The NON_RESV_SEND_LIMIT object is optional. Senders on a managed segment should interpret the absence of the NON_RESV_SEND_LIMIT object as equivalent to an infinitely large SENDER_TSPEC (it is permissible to send any traffic profile in the absence of an RSVP reservation).

Appendix C The DSBM as a Source of Centralized Configuration Information

There are certain configuration parameters which it may be useful to distribute to layer-3 senders on a managed segment. The DSBM may serve as a centralized management point from which such parameters can easily be distributed. In particular, it is possible for the network administrator configuring a DSBM to cause certain configuration parameters to be distributed as objects appended to the I_AM_DSBM messages. The following configuration object is defined at this time. Others may be defined in the future. See Appendix B for further details regarding the NON_RESV_SEND_LIMIT object.

C.1. NON_RESV_SEND_LIMIT

As we QoS enable layer 2 segments, we expect an evolution from subnets comprised of traditional shared segments (with no means of traffic separation and no DSBM), to subnets comprised of dedicated segments switched by sophisticated switches (with both DSBM and 802.1p traffic separation capability).

A set of intermediate configurations consists of a group of QoS enabled hosts sending onto a traditional shared segment. A layer-3 device (or a layer-2 device) acts as a DSBM for the shared segment, but cannot enforce traffic separation. In such a configuration, the DSBM can be configured to limit the number of reservations approved for senders on the segment, but cannot prevent them from sending. As a result, senders may congest the segment even though a network administrator has configured an appropriate limit for admission control in the DSBM.

One solution to this problem which would give the network administrator control over the segment, is to require applications (or operating systems on behalf of applications) not to send until they have obtained a reservation. This is problematic as most applications are used to sending as soon as they wish to and expect to get whatever service quality the network is able to grant at that time. Furthermore, it may often be acceptable to allow certain applications to send before a reservation is received. For example, on a segment comprised of a single 10 Mbps ethernet and 10 hosts, it may be acceptable to allow a 16 Kbps telephony stream to be transmitted but not a 3 Mbps video stream.

A more pragmatic solution then, is to allow the network administrator to set a per-flow limit on the amount of non-adaptive traffic which a sender is allowed to generate on a managed segment in the absence of a valid reservation. This limit is advertised by the DSBM and received by sending hosts. An API on the sending host can then approve or deny an application’s QoS request based on the resources

requested.

The NON_RESV_SEND_LIMIT object can be used to advertise a Flowspec which describes the shape of traffic that a sender is allowed to generate on a managed segment when its RSVP reservation requests have either not yet completed or have been rejected.

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