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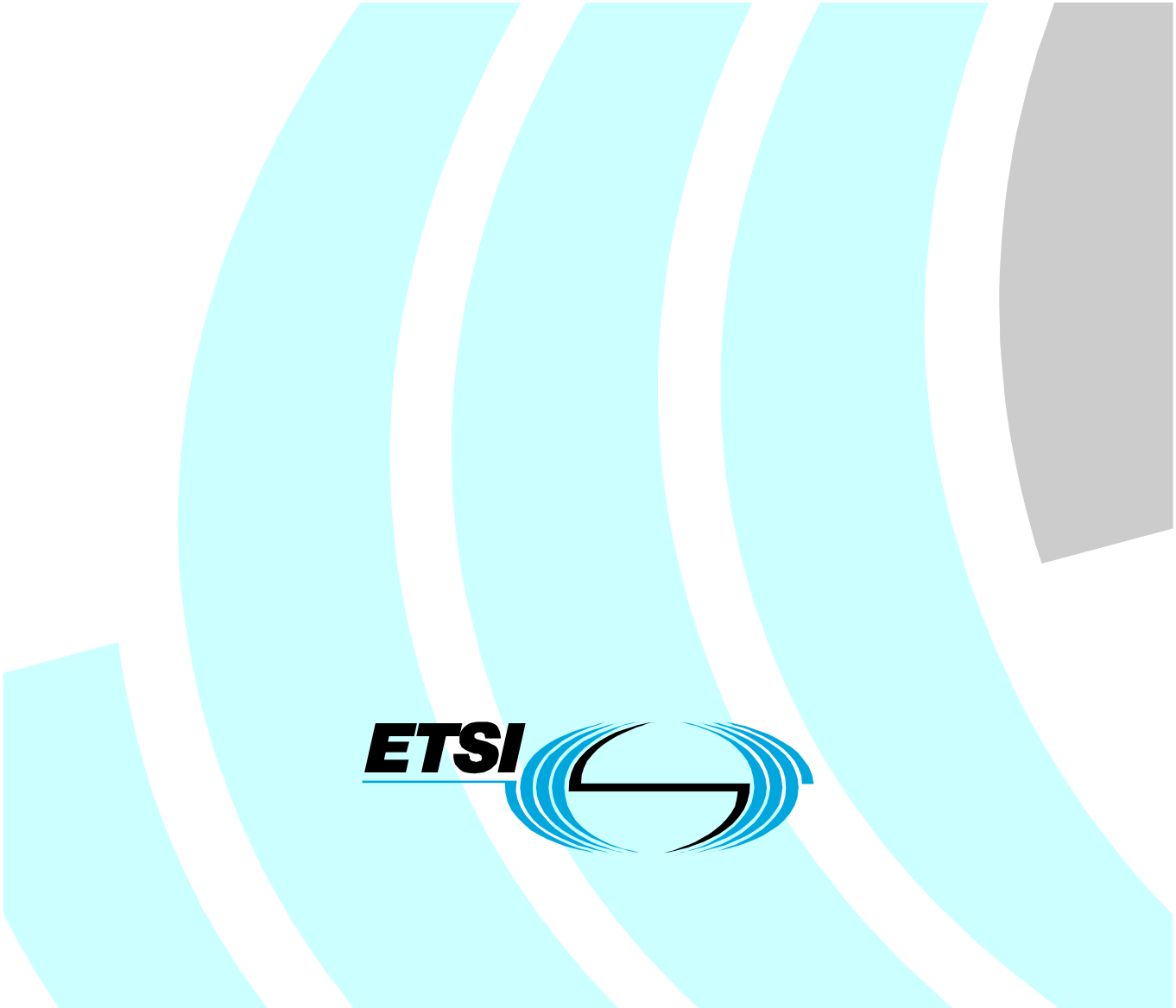
Technical Specification

Digital Broadband Cable Access to the Public Telecommunications Network; IP Multimedia Time Critical Services; Part 17: Inter-domain Quality of Service



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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Access and Terminals (AT).

The present document is part 17 of a multi-part deliverable covering Digital Broadband Cable Access to the Public Telecomunications Network; IP Multimedia Time Critical Services. Full details of the entire series can be found in part 1 [14].

The present document describes a set of Quality of Service (QoS) mechanisms for the IPCableCom project. The objective of the present document is to define an architectural model for end-to-end Quality of Service for IPCableCom Inter-and Intra-Domain environments. The specification describes mechanisms for integrating IPCableCom Dynamic Quality of Service (DQoS) signalling protocols with current IP Core Network QoS models. The present document assumes familiarity with the IPCableCom architecture, specifically with DQoS and call signalling.

Introduction

The cable industry in Europe and across other Global regions has already deployed broadband cable television hybrid fibre coax (HFC) data networks running a standard Cable Modem Protocol. The Cable Industry is in the rapid stages of deploying IP Voice and other time critical multimedia services over these broadband cable television networks.

The cable Industry has recognized the urgent need to develop ETSI Technical Specifications aimed at developing interoperable interface specifications and mechanisms for the delivery of end to end advanced real time IP multimedia time critical services over bi-directional broadband cable networks.

IPCablecom is a set of protocols and associated element functional requirements developed to deliver Quality of Service (QoS) enhanced secure IP multimedia time critical communications services using packetized data transmission technology to a consumer's home over the broadband cable television Hybrid Fibre/Coaxial (HFC) data network running the Cable Modem protocol. IPCablecom utilizes a network superstructure that overlays the two-way data-ready cable television network. While the initial service offerings in the IPCablecom product line are anticipated to be Packet Voice, the long-term project vision encompasses packet video and a large family of other packet-based services.

The Cable Industry is a global market and therefore the ETSI standards are developed to align with standards either already developed or under development in other regions. The ETSI Specifications are consistent with the CableLabs/PacketCable set of specifications as published by the SCTE. An agreement has been established between ETSI and SCTE in the US to ensure, where appropriate, that the release of PacketCable and IPCablecom set of specifications are aligned and to avoid unnecessary duplication. The set of IPCablecom ETSI specifications also refers to ITU-SG9 draft and published recommendations relating to IP Cable Communication.

The whole set of multi-part ETSI deliverables to which the present document belongs specify a Cable Communication Service for the delivery of IP Multimedia Time Critical Services over a HFC Broadband Cable Network to the consumers home cable telecom terminal. 'IPCablecom' also refers to the ETSI working group program that shall define and develop these ETSI deliverables.

1 Scope

The present set of documents specifies IPCablecom, a set of protocols and associated element functional requirements. These have been developed to deliver Quality of Service (QoS), enhanced secure IP multimedia time critical communication services, using packetized data transmission technology to a consumer's home over a cable television Hybrid Fibre/Coaxial (HFC) data network.

NOTE 1: IPCablecom set of documents utilize a network superstructure that overlays the two-way data-ready cable television network, e.g. as specified within ES 201 488 [15] and ES 200 800 [16].

While the initial service offerings in the IPCablecom product line are anticipated to be Packet Voice and Packet Video, the long-term project vision encompasses a large family of packet-based services. This may require in the future, not only careful maintenance control, but also an extension of the present set of documents.

NOTE 2: The present set of documents aims for global acceptance and applicability. It is therefore developed in alignment with standards either already existing or under development in other regions and in International Telecommunications Union (ITU).

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] IETF RFC 3181 (2001): "Signaled Preemption Priority Policy Element".

[2] ETSI TS 101 909-5: "Access and Terminals (AT); Digital Broadband Cable Access to the Public Telecommunications Network; IP Multimedia Time Critical Services; Part 5: Dynamic Quality of Service for the Provision of Real Time Services over Cable Television Networks using Cable Modems".

[3] IETF RFC 2212: "Specification of Guaranteed Quality of Service".

[4] IETF RFC 2474: "Definition of the Differentiated Services Field (DS Field) in the Ipv4 and Ipv6 Headers".

[5] IETF RFC 2998: "A Framework for Integrated Services Operation over Diffserv Networks".

[6] draft-ietf-issll-rsvp-aggr-02.txt (2000): "Aggregation of RSVP for IP4 and IP6 Reservations", http://www.ietf.org/internet-drafts/draft-ietf-rsvp-proxy-02.txt.

[7] IETF RFC 3084: "COPS Usage for Policy Provisioning (COPS-PR)".

[8] IETF RFC 2475 (1998): "An Architecture for Differentiated Service".

[9] IETF RFC 2702 (1999): "Requirements for Traffic Engineering Over MPLS".

[10] IETF RFC 2638 (1999): "A Two-bit Differentiated Services Architecture for the Internet".

[11] IETF RFC 2597 (1999): "Assured Forwarding PHB Group".

[12] IETF RFC 2598 (1999): "An Expedited Forwarding PHB".

[13] draft-ietf-mpls-recovery-frmwrk-00.txt (2000): "Framework for MPLS-based Recovery", http://cell-relay.indiana.edu/mhonarc/mpls/2000-Sep/msg00134.html.

[14] ETSI TS 101 909-1: "Access and Terminals (AT); Digital Broadband Cable Access to the Public Telecommunications Network; IP Multimedia Time Critical Services; Part 1: General".

[15] ETSI ES 201 488: "Data-Over-Cable Service Interface Specifications Radio Frequency Interface Specification".

[16] ETSI ES 200 800: "Digital Video Broadcasting (DVB); DVB interaction channel for Cable TV distribution systems (CATV)".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Access Node (AN): layer two termination device that terminates the network end of the ITU-T Recommendation J.112 connection

NOTE: It is technology specific. In ITU-T Recommendation J.112 annex A it is called the INA while in annex B it is the CMTS.

cable modem: layer two termination device that terminates the customer end of the J.112 connection

endpoint: Terminal, Gateway or MCU

Flow [IP Flow]: unidirectional sequence of packets identified by ISO Layer 3 and Layer 4 header information

NOTE: This information includes source/destination IP addresses, source/destination port numbers, protocol ID. Multiple multimedia streams may be carried in a single IP Flow.

Flow [J.112 Flow]: unidirectional sequence of packets associated with a SID and a QoS. Multiple multimedia streams may be carried in a single J.112 Flow

Gateway: devices bridging between the IPCableCom IP Voice Communication world and the PSTN

NOTE: Examples are the Media Gateway which provides the bearer circuit interfaces to the PSTN and transcodes the media stream, and the Signalling Gateway which sends and receives circuit switched network signalling tot he edge of the IPCableCom network.

IPCablecom: architecture and a series of Specifications that enable the delivery of real time services (such as telephony) over the cable television networks using cable modems

latency: time, expressed in quantity of symbols, taken for a signal element to pass through a device

proxy: facility that indirectly provides some service or acts as a representative in delivering information there by eliminating a host from having to support the services themselves

trunk: analogue or digital connection from a circuit switch which carries user media content and may carry voice signalling (MF, R2, etc.)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AF	Assured Forwarding
AN	Access Node
ATM	Asynchronous Transfer Mode
CMS	Call Management Server
COPS	Common Open Policy Service Protocol
DCS	Distributed Call Signalling
DQoS	Dynamic Quality of Service

DSCP	Diffserv Code Point
EF	Expedited Forwarding
ER	Edge Router
HFC	Hybrid Fibre/Coaxial
IETF	Internet Engineering Task Force
IntServ	Integrated Services
IP	Internet Protocol
MPLS	Multiprotocol Label Switching
MTA	Multimedia Terminal Adapter
PHB	Per Hop Behaviour
PHS	Payload Header Suppression
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RSVP	Resource reSerVation Protocol
UDP	User Datagram Protocol
VoIP	Voice over IP

4 Void

5 Overview

5.1 Solution requirements

There are three basic requirements to providing end-to-end QoS for IPCableCom Sessions:

1) Provide acceptable call setup times, comparable to those in the PSTN.

2) Provide acceptable voice quality by providing mechanisms to guarantee sufficiently small delay, jitter, and packet loss.

3) Ensure high quality is maintained for the entire duration of the session (e.g. block new call attempts when their completion would compromise the quality of existing calls).

In a packet-based network, the second requirement translates to: provide mechanisms to recognize IPCableCom traffic and manage scheduling and buffer allocation in each switch and router so that delay and packet loss are bounded.

The third requirement defines the need for admission control. Depending on the QoS mechanisms chosen, the challenge is to define a satisfactory method to block or admit calls or sessions based-upon resource availability in the backbone.

The following are the general criteria to evaluate solutions for end-to-end QoS for IPCableCom.

- The solution should meet the three requirements above.
- The solution is manageable and implementable.
- The solution is scaleable. QoS mechanisms for voice communication services must be able to grow to accommodate a large number of concurrent IPCableCom sessions without introducing undue implementation costs or complexity.
- The solution should recover gracefully when network failures occur. For example, it is probably unavoidable that some calls are dropped when a network failure occurs, but this event should not negatively influence other calls in the network.

These requirements, in particular the requirement for scalability, lead to a backbone architecture that is based on the IETF's Differentiated Services (Diffserv) approach [4], [7]. Diffserv was specifically designed as a scalable approach to delivering QoS in large backbones. Its application in the IPCableCom environment is described in the following clauses.

5.2 Requirements Phasing

The present document presents several approaches for providing QoS across a managed IPCableCom backbone network. Several of the approaches are complementary and based upon the resource management needs of the network operator these approaches mechanisms may be combined to produce the desired control and management of IPCableCom resources and sessions.

Table 1 illustrates the feasible combinations of approaches described in clauses 7 through 9.

Table 1

Approach	Required clauses		
Diffserv	Clause 7 (Diffserv)		
Per Flow RSVP	Clause 7	Clause 8.1	
Aggregate RSVP	Clause 7	Clause 8.1	Clause 8.2
BW Broker	Clause 7	Clause 8.3	

Diffserv support is REQUIRED for all IPCableCom backbone networks. IPCableCom devices SHALL at a minimum support the DiffServ requirements defined in clause 7.

Per-flow RSVP requirements as defined in clauses 8 and 8.1 are OPTIONAL. However, if per-flow RSVP is supported, the requirements as defined in clauses 8 and 8.1 are REQUIRED.

Clause 8.2 describes an approach for aggregation of RSVP. If RSVP aggregation is supported, all of clause 8.2 is REQUIRED. In addition, all of the per-flow RSVP requirements as defined in clauses 8 and 8.1 are REQUIRED.

MPLS optimizations, as described in clause 9, are OPTIONAL and may be used with any of the approaches described.

5.3 General Objectives

The general objectives of the present document effort are to:

- Define signalling mechanisms for establishment of QoS resources between ANs that are separated by a managed IP backbone network.
- Define signalling mechanisms for establishment of QoS resources between ANs and other IPCableCom elements in the media path such as Edge Routers, Border Routers, Media Gateways, and Media Servers.
- Support end-to-end Dynamic QoS sessions across managed IP backbone networks.
- Define the interfaces for control and delivery of QoS between IPCableCom domains.
- Support Network-based Call Signalling (NCS) and Distributed Call Signalling (DCS) models.
- Support both layer-2 QoS signalling (J.112) and layer-3 QoS signalling (RSVP) on the access network.
- Support multiple backbones with standard QoS implementations for managing scheduling and buffer allocation in switches and routers (e.g. MPLS, DiffServ, ATM, RSVP, etc.).

6 Network Model

The overall IPCableCom network architecture is depicted in figure 1. An IPCableCom backbone network consists of a general topology managed IP network that may comprise multiple administrative domains.

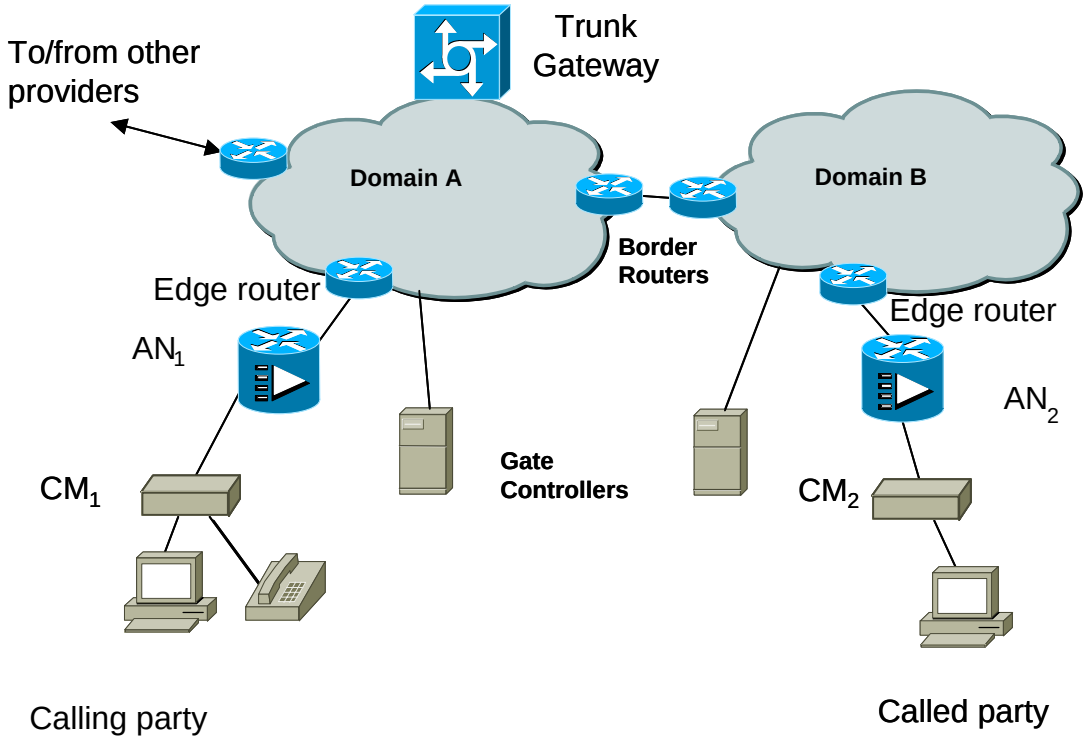

Figure 1: Interdomain QoS Architecture

The architecture assumes the existence of IPCableCom Service Agreement (PSA) between service providers that defines the level of trust between IPCableCom domains as well as requirements for QoS, call signalling, transport and interconnection requirements, and other such details.

The architecture also supports the transport of media and signalling between domains may pass through one or more intermediate or Transit IP networks. IPCableCom assumes that operators will have an "IP Transport Agreement" with all transit networks to which they are directly connected.

In this architecture, we assume that DQoS signalling is used in the access network. The access portion of the network is defined to be between the Multimedia Terminal Adapter (MTA) and the Access Node (AN), and includes the J.112/HFC network.

At a minimum, the backbone and transit IP networks are expected to be compliant with the Diffserv architecture. The backbone portion of the network is defined to be all of the IP network elements between the two ANs. This includes all edge, border, and core routers. For sessions that terminate on the PSTN, the backbone network may be further defined to include all resources between the AN and media gateway.

The following clauses describe a number of approaches that can be taken which offer different degrees of assurance and levels of complexity.

Note that the AN may be at the edge of the Diffserv backbone or not, depending on various factors described below. Also note that there may be intermediate devices (not shown in this figure) between the AN and the edge of the Diffserv backbone.

Border routers are those that sit at the boundaries between providers. They have specific roles in a Diffserv environment (such as aggregate policing and re-marking) that are discussed in more detail in clauses 7.3 and 8.1.

7 Diffserv usage in backbone

In this clause, we assume a simple Diffserv backbone with no signalling of resource requirements beyond those specified in DQoS. In this case the AN functions as the Diffserv edge device. In later clauses we build on the foundation of a Diffserv backbone by adding signalling capabilities to control access to resources in the backbone. We assume here a common backbone for data and voice; other possibilities include using a physically or logically separate network for voice.

7.1 Media traffic

IPCableCom media traffic is defined as packets originating or terminating on an IPCableCom endpoint for which QoS has been requested using DQoS. (Note that this explicitly excludes call and QoS signalling packets such as DQoS gate coordination messages, DCS/SIP Invite messages, etc., which are discussed in clause 7.2). In the backbone, at least one Per Hop Behaviour (PHB) SHOULD be dedicated for IPCableCom media traffic. This PHB MAY be EF, one of the AF PHBs, one of the Class Selector (CS) PHBs, or a "private" PHB. The only restrictions are:

- It SHALL NOT be the default (best effort) PHB.
- The only packets which are assigned this PHB SHOULD be those for which QoS was requested using DQoS.
- If an AF PHB is used, it SHOULD be Afx1, i.e., it should offer the lowest drop probability.

It is not required that all domains use the same PHB for IPCableCom media packets. It is also possible to use more than one PHB within a single domain for IPCableCom media packets, in which case it is necessary to provide some policy at the AN to determine which of the possible PHBs to use for a given packet. We return to this issue below.

7.2 Signalling traffic

Signalling traffic is defined to include call signalling messages between IPCableCom call control elements (e.g. DCS or NCS messages, DQoS Gate Coordination messages, RSVP messages, etc.). In order to control the latency and loss experienced by signalling traffic, one or more PHBs MAY be dedicated to IPCableCom signalling traffic. For example, the PHB CS6 has traditionally been used for routing traffic. If a PHB is dedicated to signalling messages, the following guidelines apply:

- The PHB for signalling messages SHOULD be distinct from the default best-effort PHB.
- The only packets which are assigned this PHB SHOULD be signalling messages.
- The PHB for signalling messages SHALL be distinct from the PHB that is used for routing messages.
- The PHB for signalling messages SHOULD be distinct from the PHB that is used for media messages.
- The amount of traffic generated with the PHB SHOULD be limited.

This last guideline may be difficult to achieve. A possible approach is to limit the amount of traffic that a single user may generate that is marked with the DSCP for this PHB to a configured value. This value needs to be just large enough to accommodate the expected signalling load from the user. This limit may be enforced by policing packets bearing the designated DSCP at the AN, with excess packets being remarked "best effort". Excess packets SHOULD NOT be dropped. By remarking excess packets, users are prevented from sending significant amounts of data traffic with the DSCP that is reserved for signalling. At the same time, if the offered load of signalling traffic temporarily exceeds the expected level, the excess is still transmitted into the network with a reasonable chance of timely delivery, thus avoiding serious degradation in signalling performance.

Note that the use of different PHBs for media and signalling traffic does not need to imply a relative prioritization of media over signalling or vice versa. The intent is simply to allow resources to be allocated for media and signalling independently to meet the desired loss and latency goals for each traffic type.

7.3 PHB selection and DSCP setting

The AN is required to set or police the DSCP for IPCableCom media and signalling packets. The IPCableCom DQoS specification [2] provides a means by which a Gate Controller can tell an AN which DSCP to use on a call-by-call basis, via the GATE-SET message. The AN SHALL ensure that the DSCP for all media packets for a given call is set to the value contained in the GATE-SPEC for that call. The AN SHALL ensure that the amount of media traffic generated for a given call that is marked with the desired DSCP does not exceed the token bucket specification that was provided by DQoS signalling.

Each domain MAY employ its own DSCP(s) for whichever PHB(s) it uses independently of other domains, as long as the choice is consistent across a single domain. If a standard PHB is used, the IETF recommended code point SHOULD be used as defined in [11] and [12]. If different DSCPs are used for IPCableCom media and signalling packets in neighbouring domains, DSCP remarking SHALL be performed by a border router on packets that leave one domain and enter another. The required capabilities of border routers are described below.

Routers at the domain borders SHALL also be able to set or police the DSCP for packets which are destined to an IPCableCom endpoint and for which QoS has been requested using DQoS. In the absence of explicit signalling at domain boundaries, it is not possible to authoritatively identify IPCableCom media packets arriving at a border router on a per flow basis. Thus, border routers must rely on the DSCP to identify such packets. For this reason, the border router SHOULD provide the following capabilities:

- It SHOULD be possible to configure the border router to impose a limit on the total amount of traffic entering the domain that is marked with a certain DSCP.
- It SHOULD be possible to configure the border router to modify the DSCP of traffic entering the domain. This capability is used if it is known that a different DSCP is in use for IPCableCom media packets in a domain from which packets are received. That is, a router may be configured to recognize packets arriving on one interface with DSCP = x as IPCableCom media packets and then transmit them on another interface with DSCP = y (where x != y). This mapping from one DSCP to another SHOULD be negotiated between the operators of the peer networks.

Trunk gateways SHOULD also set the appropriate DSCP on packets they generate that are destined for a DQoS endpoint. For example, this may be achieved by signalling the desired DSCP in TGCP [11] (note that the obsolete term Type of Service is used in the TGCP specification). It may also be acceptable for a gateway to set the same DSCP value on all packets that it generates. If the trunk gateway cannot correctly mark packets that it generates, another device located between the gateway and the backbone (e.g. a router) SHOULD be configured to set the DSCP for IPCableCom media packets entering the backbone from the gateway.

It is RECCOMENDED that other IPCableCom elements in the media path (e.g. audio/announcement servers, anonymizers, conferencing bridges, etc.) are able to mark packets that they generate that are destined for QoS endpoints.

Within a single domain, all devices that either set or police the DSCP for IPCableCom media packets, or provide QoS to packets by examining their DSCP, SHOULD have consistent configuration. This may be accomplished by using COPS provisioning [7] or by other means.

It is possible to use multiple PHBs for different types of service. For example, it may be appropriate to use a different PHB for video than for voice, or it may be desired to use different PHBs for calls with tighter delay requirements due to the distance between endpoints or other factors. The mechanisms for signalling the appropriate choice of PHB in this case are described above.

7.4 PHB support by AN

Based on the criteria discussed above, one or more PHBs are selected for use in the backbone. The AN SHOULD implement all of these PHBs on its upstream links (i.e. those links connecting it to the backbone) in order to deliver appropriate QoS to packets entering the backbone. Alternatively, it may be possible to over-provision the upstream links on the AN rather than relying on Diffserv support on these links. It is important to note that over-provisioning solutions, while viable approaches to QoS, may not always be the most cost effective or resource efficient solutions.

7.5 Resource allocation

It is necessary to ensure that enough resources are allocated to the chosen PHBs at all network elements in the backbone. In the absence of signalling in the backbone, this is essentially a provisioning problem. COPS provisioning [7] or other means may be used to distribute provisioning information to network elements.

7.6 Admission control

Even in a statically provisioned Diffserv backbone it is possible to perform admission control at certain points in the network. One option is to perform admission control at the AN; another is to perform admission control at the CMS. One, both, or none of these options may be appropriate. For example, if the upstream bandwidth from the AN to the backbone is large relative to the capacity of the J.112 links it serves, it may not be required to perform admission control on the AN's upstream links.

If admission control is to be performed at the AN, each AN SHALL be configured with a maximum amount of bandwidth for each PHB that is to be used for IPCableCom media traffic on each of its upstream (non-J.112) interfaces. Each AN SHALL also keep track of the amount of bandwidth that has been admitted into each PHB on each interface. When a AN receives a DQoS request to admit a call, it determines which PHB the call will use by consulting the DSCP-PHB mapping with which it is configured, and using the DSCP provided in the GATE-SET. It SHALL check to see if the amount of bandwidth available in that PHB on the outgoing interface that this call will use is sufficient to accommodate the resources required by this call. Thus the total amount of traffic of a given PHB that will be injected into the network by any AN is bounded.

It may also be possible to perform CMS-based admission control under some circumstances. If a CMS can be provided with enough knowledge of network resources and topology, it may be able to perform admission control based on the destination of calls. For example, CMS X may know that calls which are destined to destinations handled by CMS Y must pass through a link of known capacity and can thus reject calls to that destination once the capacity is exhausted.

The admission control approaches described in this clause may have certain limitations. Notably, they may not take account of the full path through the backbone that the packets for a given call will take. Nor do they necessarily take account of the possibility of link failures affecting available capacity. Thus there is the risk that some links will become oversubscribed. Approaches to address these issues are discussed in the following clauses.

8 Admission control for a single domain

8.1 Per-flow RSVP control plane

It is possible to use per-flow RSVP as the admission control protocol for a Diffserv cloud. An overview of this approach is provided in [5]. This clause describes the application of per-flow RSVP signalling to a Diffserv backbone in the IPCableCom environment. The approach described is more scalable than traditional per-flow RSVP because all classification and scheduling (i.e. all operations in the forwarding plane) are performed on Diffserv behaviour aggregates.

In order to support the capabilities described in this clause, the basic Diffserv functionality described in clause 7 SHALL be provided in the AN and the backbone network. Additional requirements are presented in the following paragraphs.

To support a per-flow RSVP control plane, a AN participating in DQoS signalling SHALL support the two following modes of operation:

- End-to-end RSVP mode. In this mode, the MTA signals with RSVP messages as described in [2] clause 6, and the AN SHALL forward such RSVP messages towards the MTA at the far end of the call.
- Embedded signalling mode. In this mode, the embedded MTA uses MAC-layer signalling, and the AN SHALL originate RSVP messages to the far end MTA.

In either mode, the result is that per-flow RSVP is used between the two ANs involved in a call. It may be true end-to-end (MTA-MTA) RSVP or it may be only between the ANs acting as proxies for the MTAs; this has no effect on the backbone QoS mechanisms.

With per-flow RSVP in operation between the two ANs, a network operator has considerable flexibility as to where to place the edge of the Diffserv region. As shown in figure 1, the edge of the Diffserv network need not necessarily be the AN, although it may be. That is, per-flow RSVP with per-flow classification and scheduling may be used from the AN to the edge of the Diffserv region; alternatively, the AN may be at the edge of the Diffserv region, in which case aggregate scheduling and classification is used on all traffic that is upstream of the AN.

For generality, we use the concept of an Edge Router (ER) as defined in [5]. This device is able to perform per-flow RSVP and to perform admission control on traffic that will enter the Diffserv network. The AN MAY perform the ER function or the function may be assigned to a router upstream of the AN, i.e. a router closer to the backbone.

In the following clauses, the behaviour of ANs, Border Routersedge routers, and core routers (those Diffserv routers in the backbone which are not Border Routers) are described.

8.1.1 AN behaviour

A AN may operate in one of two modes, depending on whether the MTA that it serves is using embedded signalling or RSVP signalling. Both modes SHALL be supported. We treat each mode in turn below. In either case, the AN runs per-flow RSVP on its upstream (non-HFC network) interfaces, and uses standard RSVP/Intserv procedures to perform admission control, classification and scheduling for packets sent on those interfaces.

Note that, regardless of which mode an AN operates in, it is responsible for forwarding (or originating) both PATH and RESV messages towards the far end. A bi-directional reservation is established between two ANs when a pair of RESV messages have been exchanged between them.

8.1.1.1 Embedded signalling

When using embedded signalling as defined in DQoS [2] annexes A and B, a AN detects the need to make a backbone reservation when a MAC-layer signalling message indicating the request to establish a new flow with QoS assignment arrives and when a gate has been established for the corresponding call. In this case, the AN MUST send a PATH message to the far end MTA, using parameters derived from the MAC message. It then waits for a RESV from the far end AN or MTA. When it has received a RESV from the far end, it knows the reservation has succeeded and MUST respond to the MTA with a MAC-layer signalling message indicating the success.

When an AN receives a PATH from a far end AN or MTA, and the PATH is destined to an MTA that does not support RSVP, the AN MUST first verify that it has a gate established for the corresponding call. If so, it MUST respond with a RESV sent back to the previous hop (PHOP) contained in that PATH message. The parameters in the RESV are determined from the received PATH message.

The type and format of MAC-layer signalling messages to be used to set up flows depends on the layer 2 protocol implemented in the HFC network. Further details on MAC signalling can be found in ES 200 800 [16] or ES 201 488 [15], respectively

8.1.1.1.1 Determining RSVP PATH parameters

In order to generate an RSVP PATH message (at the receipt of a MAC-layer message indicating the need to make a backbone reservation), the AN needs to construct the session object, sender template object and the sender Tspec object. The Session object consists of the protocol, destination address and destination port number. The sender template consists of the sender address and the sender port number. The mapping of the RSVP parameters to the parameters contained in the MAC message is shown in table 2.

Table 2

RSVP parameter	ES 200 800 RESC-REQ parameter	ES 201 488 DSA-REQ parameter
Session object		
Protocol Id	Session_Binding_US. Upstream_internet_protocol	Upstream packet classifier. IP protocol
Destination Address	Session_Binding_US. NIU_client_destination_IP_add	Upstream packet classifier. IP Destination Address
Destination Port	Session_Binding_US. NIU_client_destination_port	Upstream packet classifier. TCP/UDP Destination Port Start
Sender Template object		
Source Address	Session_Binding_US. NIU_client_source_IP_add	Upstream packet classifier. IP Source Address
Source Port	Session_Binding_US. NIU_client_source_port	Upstream packet classifier. TCP/UDP Source Port Start

The sender Tspec parameters are derived from the upstream QoS parameter encodings contained in the MAC-layer signalling message requesting the establishment of the new flow. An example for mapping the MAC QoS parameters to the Tspec object to construct the RSVP PATH message is given below. For further details refer to ES 200 800 [16] or ES 201 488 [15], respectively.

The PATH message should also carry the updated Adspec object, which conveys the additional delay introduced by the AN to the RSVP routers downstream. Due to strict latency bound requirements, it is expected that hosts generating VoIP traffic would indicate their resource requirements using the guaranteed service QoS parameters as defined by the IntServ architecture. Hence, the guaranteed service block of the Adspec object should contain the appropriate C (rate dependent component) and D (rate independent component) terms. The value of D must take into account the fixed delay (for instance message processing delay, codec delay, etc.).

Constructing the Tspec object from ES 200 800 QoS parameters

To accommodate the CBR characteristics typically exhibited by voice sources, either fixed-rate or reservation access mode may be used.

Details are for further study.

Constructing the Tspec object from ES 201 488 QoS parameters

Since voice sources typically exhibit CBR characteristics, it is expected that MTAs will request an unsolicited grant service (UGS) on the HFC link. If the "service flow scheduling type" in the DSA-REQ message is set to UGS then the sender Tspec is determined as follows. Let:

- G - grant size (bytes);
- I - grant interval (seconds).

For VoIP flows the "grants per interval" parameter would typically be set to 1 (if it is more than 1, G has to be calculated accordingly). Given above, the IntServ parameters for token bucket are:

- M (maximum datagram size) = G - Ethernet overhead - ES 201 488 overhead;
- r (bucket rate) = M/I.

The Ethernet header overhead is 18 bytes and the ES 201 488 header overhead could be up to 13 bytes. Since VoIP sources exhibit CBR characteristics:

- p (peak rate) = r, b (bucket depth) = M and m = M.

The ES 201 488 overhead includes only the MAC layer overhead (standard MAC header, BPI extended header etc.) It does not include the physical layer overhead.

If payload header suppression is being used in the upstream direction, M (as calculated above) MUST be further modified to reflect the suppressed bytes. "PHS size" parameter from the DSA-REQ MUST be used to modify M as follows:

- M' = M - 2 + PHS size,

where two bytes constitute the ES 201 488 extended header, containing the value for the PHS index. Since the grant size includes this overhead as well, it MUST be substracted to compute M'.

The other Tspec parameters are modified accordingly:

- r = M'/I, p = r, b = M', m = M'.

With regard to the updated Adspec object, the advertised value of C for a UGS service would be M (or M').

8.1.1.1.2 Determining RSVP RESV parameters

When an AN receives a PATH message from the remote AN, it SHALL send RESV message to reserve appropriate resources on the backbone. The RESV message SHALL include the session object, flowspec and the filterspec. The session object and filterspec are derived from the PATH message. VoIP traffic should use Guaranteed Service flow specifications, which consist of a Tspec and an Rspec. The Tspec parameters are obtained from the sender Tspec object in the PATH message. The Rspec parameters are derived from the downstream QoS parameters of the flow to be established on the HFC link, the Rspec parameters are computed as follows:

- R = "Downstream Maximum Sustained Traffic Rate";
- S = 0.

The value of zero for S (slack) is the recommended value from [3] when no slack is specified.

8.1.1.2 RSVP signalling

When the MTA uses RSVP signalling as defined in DQOS [2] clause 3, and per flow RSVP signalling is to be supported in the backbone, the AN SHALL be able to forward RSVP messages into the backbone rather than simply intercepting them when received from the MTA. The AN SHALL support a configurable parameter on each of its non-HFC network interfaces that defines whether RSVP message forwarding is enabled for the interface. When that parameter has the value "enabled" on a given interface, and the AN receives a PATH message from an MTA that SHOULD be sent out over that interface according to the forwarding table of the AN, the AN SHALL forward the PATH message over that interface. When forwarding such PATH message that was received from the MTA, the AN SHALL remove all DQoS-specific objects (e.g. reverse Tspec, etc.) before forwarding the message on towards its destination. In this configuration, The AN SHOULD NOT proxy RESV messages back towards the MTA, but SHOULD instead wait for a RESV message to be received from the backbone and then process and forward it according to standard RSVP processing rules. Similarly, it SHOULD NOT proxy PATH messages towards the MTA, but SHOULD await a PATH message from the far end of the call instead, which it SHALL process according to standard RSVP rules.

Note that the decision to forward PATH messages into the backbone rather than to perform as a proxy as described in DQOS [2] clause 6 is based on per-interface configuration. Thus all flows of IPCableCom media packets traversing an interface that is configured as described above will be subject to admission control. This behaviour is desirable as it ensures that all flows entering the network over a given interface are subject to admission control, thus permitting intelligent admission control decisions to be made.

NOTE: An alternative approach would be to decide on a per-flow basis whether to forward PATH messages for each flow. This would raise the issue of how such a decision should be made, but more importantly it would present the risk that some subset of flows would inject traffic into the backbone without being subject to admission control, compromising the overall accuracy of admission control.

8.1.2 Location of Diffserv edge

When a per-flow RSVP control plane is used across the backbone, it is not necessary for the AN to be the edge of the Diffserv cloud. Instead, the Diffserv edge function may reside in an edge router that is upstream of the AN. In this case, there exists a network between the AN and the edge router, which may be as simple as a point-to-point link (as shown in figure 1) or may be a general topology IP network. The required QoS may be provided between the AN and the edge router either through the use of Integrated Services or by over-provisioning of the bandwidth, and the choice between these options may be made on a link-by-link basis.

8.1.3 Edge Router behaviour

Whether the edge router is the AN or some other router upstream of the AN, it SHALL participate in per-flow RSVP. In addition, an Edge Router (ER) has some set of interfaces that are "interior" to the Diffserv cloud and some that are "exterior". The ER is responsible for marking packets that pass from an outside interface to an interior interface with an appropriately chosen DSCP, unless it is able to trust that the DSCP was set correctly at the AN. The ER SHALL perform admission control on all its interfaces. In order to do this on interior interfaces, each interior interface must be configured with a pool of resources available for each PHB that is to be used for IPCableCom media traffic. The ER performs admission control over this set of resources for each RSVP request it receives. The ER must also be able to determine which PHB and DSCP to use for a given RSVP request. This may be determined by local configuration or as a matter of policy provided from some outside source, e.g. a policy server.

An ER MAY perform microflow classification, policing and scheduling on its exterior interfaces but SHALL perform aggregate classification, policing and scheduling on its interior interfaces. If the ER does not perform microflow classification and policing on flows that are passing through it into the backbone, those functions SHALL be performed by the ANs that send traffic to the ER. Performing microflow policing at the AN may provide better scalability than doing so at the ER, as the number of flows is likely to be larger at the ER.

8.1.4 Other terminating devices (media gateways, anonymizers, announcement servers, conference bridges)

In order for per-flow RSVP signalling to operate effectively across the backbone, all devices that can terminate a media stream SHOULD be able to support per-flow RSVP signalling. Such devices include media gateways, anonymizers, announcement servers, conference bridges, etc. Any device terminating an IPCableCom media stream SHOULD:

- Send PATH messages toward the far end(s) of the call.
- Receive PATH and RESV messages from the far end(s) of the call.
- Send RESV messages toward the far end(s) of the call in response to received PATH messages.

These devices derive the contents of the PATH messages from call signalling in the same way that an MTA does in normal DQoS operation. The contents of the RESV messages can be derived from PATH messages in the same manner as described in clause 8.1.1.

Note that, like an AN, the devices mentioned in this clause may or may not function as Edge routers, in that they may be on the edge of the Diffserv cloud or not.

8.1.5 Core Router Behaviour

A router behaves as a core router when it receives packets on an interior interface and forwards them on an interior interface. Note that a single router may behave as an ER with regard to some flows and as a core router with regard to other flows.

A core router does not perform remarking of the DSCP in packets that it forwards. It performs admission control over the resources allocated to the appropriate PHB for each reservation. It performs aggregate classification, policing and scheduling. Thus, the forwarding behaviour of a core router is just like any Diffserv router, even though it uses RSVP for admission control.

8.1.6 Signalling latency

The approach to bandwidth reservation described in this clause requires end-to-end RSVP messages to traverse the backbone. Clearly this may have an impact on total signalling latency and thus post-dial delay. To meet a provider's post-dial delay targets, the following techniques may be used:

- RSVP refresh reduction and reliability enhancement;
- Choice of a low latency PHB and corresponding DSCP for RSVP control messages.

The same situation applies for the approach defined in clause 8.1.7.

8.1.7 Pre-emption

This clause describes mechanisms that may be used to support pre-emption of reservations (e.g. to provide resources to emergency calls in preference to previously admitted calls).

The pre-emption priority element defined for use in RSVP and COPS [1] MAY be used in the backbone. It is not expected that this object would be provided by the MTA, since end users cannot generally be trusted to determine their own pre-emption priority. However, the Gate Controller provides a Session class to the AN which MAY be used by the AN to generate a valid pre-emption priority element. In this case, the AN SHOULD use the following mapping from session class values to pre-emption priority values.

Session Type	Session Class Value	Pre-emption priority value
Normal	0x01	32767
High Priority (Emergency)	0x02	64911

This mapping SHOULD be configurable. The pre-emption priority element contains both a defending priority field and a pre-emption priority field. These SHOULD both be set to the same value.

It is also possible that RSVP-capable routers in the backbone will use COPS to outsource policy decisions. In this case the pre-emption priority element MAY be carried inside a COPS decision and its interpretation at the routers SHALL be as defined in IETF RFC 3181 [1].

8.2 Aggregate RSVP

Aggregated RSVP [6] is a logical extension to per-flow RSVP across a Diffserv backbone. To support this functionality, the AN, edge router and core router functions described in clause 8.1 SHALL be provided. Additional functionality is provided by aggregating and de-aggregating routers, as defined below. RSVP signalling is performed between call endpoints (either the MTAs or AN acting on behalf of MTAs) as in the preceding clause. In addition to the functionality of clause 8.1, aggregate RSVP defines a way in which many per-flow RSVP reservations may be combined to form a single aggregate reservation. Two or more per-flow RSVP reservations may be aggregated when their paths pass through a common pair of routers. We refer to routers which are able to aggregate and de-aggregate reservations as aggregation routers (which are defined more formally in draft-ietf-issll-rsvp-aggr-02.txt [6]).

The aggregation routers have the responsibility of creating aggregate reservations across an aggregation region, which may be the entire Diffserv cloud or a defined aggregation region within the cloud. Each aggregate reservation represents an aggregate flow of traffic from an ingress router (or aggregator) to an egress router (the de-aggregator). Aggregate reservations may be configured statically based on the expected load from an ingress to an egress router, or they may be automatically established and re-sized as described in draft-ietf-issll-rsvp-aggr-02.txt [6]. Each aggregate reservation carries the traffic from a number of "end-to-end" RSVP reservations that share a common ingress/egress router pair. An end-to-end reservation represents a single microflow, and signalling for such a reservation is accomplished using standard RSVP. "End-to-end" RSVP messages may be originated by the MTA or by the AN on behalf of the MTA in the case of embedded signalling, as described above. Such E2E RSVP messages are "tunnelled" across the aggregation region by setting the IP protocol number in the Path message to "RSVP-E2E-IGNORE".

Note that the aggregator and de-aggregator may or may not also be Edge Routers as defined above. We define the relationship between these devices in clause 8.2.4.

8.2.1 Provisioned aggregate reservations

It is possible to provision an aggregate reservation from an ingress (aggregating) router to an egress (de-aggregating) router. This requires prior knowledge of the expected load between the routers in order to determine the size of the reservation. In this case, the ingress router sends an aggregate PATH message to the egress router, and the egress router responds with an aggregate RESV back towards the ingress. This establishes an aggregate reservation for traffic flowing from the ingress to the egress that is marked with the appropriate DSCP as identified in the aggregate RSVP messages.

Once an aggregate reservation has been established between a pair of routers, it may be treated as a logical link for the purposes of admission control. Admission control for an individual call is performed when an end-to-end RESV arrives at the egress router. Before that can happen, an E2E Path SHALL be sent from the ingress to the egress. The ingress swaps the protocol ID to RSVP-E2E-IGNORE, which means that the Path is ignored by all routers between the ingress and the egress. When the egress receives the E2E Path, the PHOP (previous hop) identifies the ingress router. The egress router stores this information and then forwards the Path towards its destination.

When an E2E RESV arrives at the egress router, it determines which aggregate reservation this E2E reservation belongs to by examining the PHOP information in the Path state that matches the RESV. That PHOP is the ingress router for the appropriate aggregate reservation. The egress router SHALL track the resources allocated to a particular aggregate reservation as they are consumed by admitted E2E reservations and SHALL reject an E2E reservation that cannot be accommodated in the appropriate aggregate reservation.

8.2.2 Dynamic aggregate reservations

The obvious drawbacks of statically provisioning aggregate reservations is that they must be sized appropriately, and that oversizing wastes resources while undersizing will lead to excessive call blocking. These drawbacks are avoided by dynamically creating and resizing aggregate reservations in response to the arrival and departure of E2E reservations. The details of automatic creation, resizing, and removal of aggregate reservations are described in [6].

One consideration when dynamically resizing reservations is the amount of signalling overhead that may result. If the aggregate reservation is adjusted in size for every arriving or departing E2E reservation, then the signalling overhead remains equal to what it would be without RSVP aggregation, although the stored reservation state is nevertheless reduced. If excessive signalling overhead is expected to be a problem, it is preferable to use heuristics to size the aggregate reservation, e.g. by rounding up the reserved aggregate bandwidth to something greater than the sum of the current E2E reservations.

8.2.3 Hierarchical aggregation

As defined in [6], aggregate reservations may themselves be aggregated. This may enable further reduction in the total number of reservations that need to be made through the backbone of the network, although the actual reduction clearly depends much on topology.

8.2.4 Location of aggregation points and DiffServ edge

As in clause 8.1.2, the DiffServ edge may be at the AN or further upstream into the backbone, and the same options apply here for provision of QoS between the AN and the DiffServ edge. Providers have considerable flexibility as to where aggregation points (aggregating and de-aggregating routers) are located. An aggregation point may coincide with the DiffServ edge (i.e. an edge router MAY perform aggregation) or it may be placed inside the DiffServ cloud. Aggregation points SHALL NOT be placed outside the DiffServ cloud.

One extreme is to make the AN both the DiffServ edge router and the aggregation point. In this case the AN performs the edge router function and also performs aggregation and de-aggregation. While it may be theoretically possible to dispense with end-to-end RSVP signalling of individual flows in this configuration, end-to-end RSVP signalling provides two benefits:

It provides a simple way to discover which aggregate reservation among many candidates is the one to which a given flow belongs.

It provides a mechanism by which the end-points can recognize the need to dynamically create an aggregate reservation or to increase or decrease the size of an aggregate reservation.

The second benefit does not apply to statically provisioned aggregate reservations, and there are, in some cases, other ways to determine the aggregate reservation to which a single flow belongs. For example, if the aggregating and de-aggregating AN are in the same area of a network using link-state routing, the link-state database can be used to find the de-aggregator given the address of the far end MTA.

Performing aggregation at the AN leads to a potentially large number of aggregate reservations in the backbone, on the order of the square of the number of AN. If the number of calls in place between a pair of AN is typically small, then it is more useful to aggregate further into the backbone.

A given aggregation point may choose to aggregate traffic to some destinations and not to others based on a local policy (e.g. aggregate only when number of calls to that destination exceeds a configured threshold).

As in clause 8.1.3, microflow policing SHALL be performed before a flow's packets enter the DiffServ cloud. This function may be performed by the AN or the edge router.

8.3 Bandwidth broker

The notion of a bandwidth broker is introduced in IETF RFC 2638 [10] and has been the subject of considerable research. A bandwidth broker is a centralized admission control agent from which requests for bandwidth can be made. Such requests may be made by hosts, by other brokers in neighbouring domains, or by edge routers. In the IPCableCom environment, it would be possible for each AN or CMS to make requests for bandwidth from a bandwidth broker that was responsible for managing access to the bandwidth for a domain. These requests would also specify the PHB for which the request is being made. The bandwidth broker for each domain is then responsible for making requests for bandwidth from neighbouring domains.

There is considerable flexibility in the admission control algorithm and mechanisms that the bandwidth broker may use. Each broker must reject any request for bandwidth for a given PHB that would result in over-commitment of resources and degradation of the quality of calls already in progress. In order to perform this admission control function, a bandwidth broker may simply bound the total amount of traffic that is allowed to enter the domain without regard to the paths that calls will traverse. In this case, the network operator may make some statistical assumptions about the distribution of calls (e.g. that it is very unlikely that all calls will converge on a single link) in order to determine the amount of bandwidth that may safely be granted. A more conservative approach would be to assume the worst case in which all calls converge on the most resource constrained link can happen, and to use the capacity of that link for the request PHB as the bound on admitted bandwidth requests.

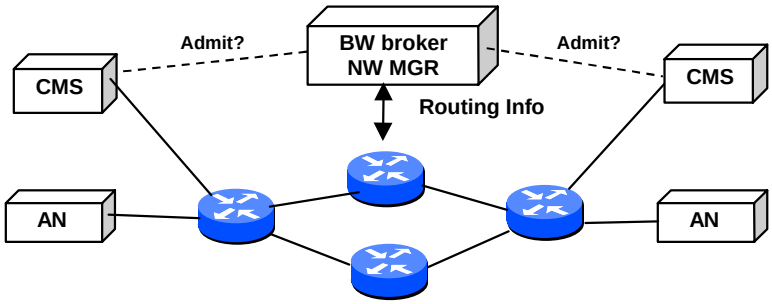

Figure 2: Bandwidth Broker Example

A more sophisticated approach to admission control would rely on the bandwidth broker having some understanding of the network topology and the route to be taken by a call. A bandwidth broker could be configured with knowledge of the network topology (perhaps limited to the location of the most resource-constrained links), or it could dynamically learn the topology, e.g. by listening to link-state routing advertisements, enhanced with resource information. The requests for bandwidth made to the broker in this case must include enough information about the destination of the call to allow the broker to determine which resource-constrained links this call will traverse and thus whether the call can safely be admitted.

As with aggregated RSVP, it is not strictly necessary for per-call signalling to take place - it may be possible for an AN to aggregate requests for calls with similar destinations. Note, however, that this would require some topology knowledge in the AN.

There does not currently exist a standard protocol for communication with or between bandwidth brokers.

9 Use of MPLS

MPLS MAY be used in the backbone, with label switched paths (LSPs) being used to represent aggregate reservations or aggregate traffic flows. This offers the following potential benefits:

- Ability to perform traffic engineering more precisely than without MPLS;
- Recovery mechanisms around link and node failures;
- Constraint-based routing of aggregate reservations;
- Consistent routing of aggregate control messages and data.

The first benefit applies to all of the approaches described in the preceding clauses. By traffic engineering we mean the ability to control the paths taken by aggregate flows of traffic, with the general goal of avoiding over- or under-utilization of links. MPLS traffic engineering and its benefits are described in [9].

As described in IETF RFC 2597 [13], MPLS also provides facilities to protect against the failure of links or nodes in a network. For example, backup paths can be pre-established to bypass, and thus protect against the failure of, a link or node. By routing packets onto a backup LSP from a node upstream of the point of failure, it is possible to avoid the delay associated with waiting for IP routing to re-converge after a failure. Thus, the period of time for which forwarding of packets is interrupted due to either link failure, node failure, or packet loss arising from inconsistent routing, can be significantly reduced.

Constraint-based routing of aggregate reservations enables paths to be selected based on their ability to satisfy constraints, notably the availability of sufficient bandwidth to accommodate a particular reservation request, as described in IETF RFC 2475 [9]. This will typically allow more reservations to be established than would be possible if all reservation requests followed the shortest path as determined by conventional IP routing.

The fourth benefit, as discussed in draft-ietf-issll-rsvp-aggr-02.txt [6], primarily applies when traffic is split across equal cost paths, introducing the risk that an aggregate PATH message would take one path while the data requiring a reservation would take another. This issue is avoided if the data is "tunnelled" from ingress to egress, and MPLS provides a suitable tunnelling technology.

An additional benefit of MPLS is that it can be deployed incrementally on a node-by node basis via software upgrades. This is beneficial in that existing routing and QoS mechanisms can be preserved and supported during a phased MPLS roll-out.

The choice of whether to run MPLS in any domain can be made independently from other domains and depends on whether the provider needs or wishes to address the three issues listed above.

Note that MPLS may be used with any of the approaches described in clauses 7 and 8. In a purely (non-signalled) Diffserv backbone, the primary benefits would be traffic engineering and fast reroute. Constraint-based routing of reservations is useful for either of the approaches in clauses 8.1 and 8.2, while the consistent routing of control and data messages is only significant for aggregate RSVP (see clause 8.2).

10 Admission control over multiple domains

It is expected that individual IPCableCom domain networks will have their own policies and operational procedures. It is also expected that IPCableCom network operators may use a variety of IP transport providers to carry their IPCableCom traffic, each of which may employ different network topologies. It is therefore difficult to assume that consistent QoS mechanisms will be available end-to-end for calls that cross the backbones of multiple providers. As described in IETF RFC 2998 [5], it is possible to use RSVP end-to-end without requiring that all intervening domains be RSVP-aware. For example, one domain might use a pure provisioned Diffserv model, another might use RSVP aggregation, and another might use per-flow RSVP. One observation that can be made is that there is no reason per-flow or aggregate RSVP reservations cannot traverse domain boundaries if two adjacent domains agree to honour each others' RSVP requests. In such an environment, stronger assurances may be obtained than would be possible if some domains do not support RSVP. In addition, the effect of aggregation on scalability may be improved if aggregate reservations are able to traverse domain boundaries, as this avoids the need to de-aggregate the RSVP requests at the border router.

It is also possible for different providers to choose widely varying technological approaches for providing QoS in their backbones. For example, one provider may choose to implement its backbone using ATM, and RSVP reservations (individual or aggregated) may be satisfied by establishing ATM VCs with appropriate QoS characteristics. Other providers may use SDH links to directly connect routers. Providers have similar flexibility in deciding whether or not to use MPLS as discussed above.

Annex A (informative): Call Flow Examples

EXAMPLE 1: Both MTAs use DQoS RSVP signalling, RSVP aggregation performed by ERs, unidirectional message exchange only is shown for clarity.

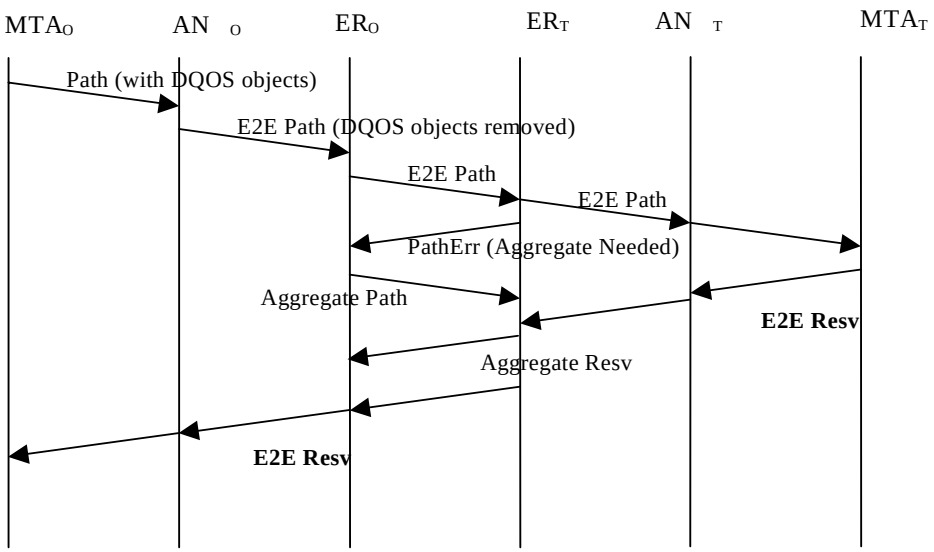

Figure A.1

EXAMPLE 2: Increase in size of an existing aggregate reservation in response to a new E2E reservation.

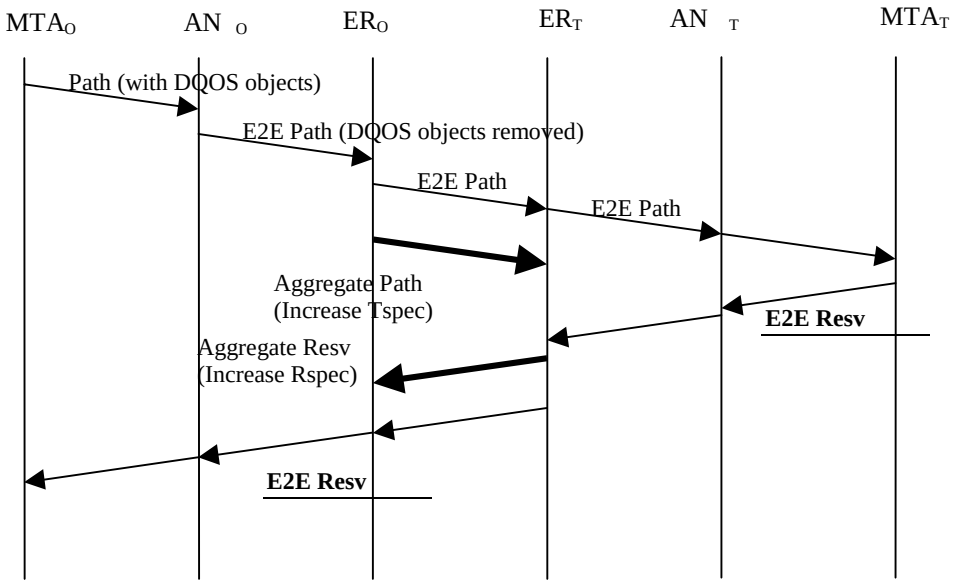

Figure A.2

Annex B (informative): Bibliography

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History

Document history		
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