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Framework and Requirements for an Access Node Control Mechanism in Broadband Multi-Service Networks

Abstract

The purpose of this document is to define a framework for an Access Node Control Mechanism between a Network Access Server (NAS) and an Access Node (e.g., a Digital Subscriber Line Access Multiplexer (DSLAM)) in a multi-service reference architecture in order to perform operations related to service, quality of service, and subscribers. The Access Node Control Mechanism will ensure that the transmission of the information does not need to go through distinct element managers but rather uses a direct device-device communication. This allows for performing access-link-related operations within those network elements, while avoiding impact on the existing Operational Support Systems.

This document first identifies a number of use cases for which the Access Node Control Mechanism may be appropriate. It then presents the requirements for the Access Node Control Protocol (ANCP) that must be taken into account during protocol design. Finally, it describes requirements for the network elements that need to support ANCP and the described use cases. These requirements should be seen as guidelines rather than as absolute requirements. RFC 2119 therefore does not apply to the nodal requirements.

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Table of Contents

1. Introduction

Digital Subscriber Line (DSL) technology is widely deployed for Broadband Access for Next Generation Networks. Several documents like Broadband Forum TR-058 [TR-058], Broadband Forum TR-059 [TR-059], and Broadband Forum TR-101 [TR-101] describe possible architectures for these access networks. The scope of these specifications consists of the delivery of voice, video, and data services. The framework defined by this document is targeted at DSL-based access (either by means of ATM/DSL or as Ethernet/DSL). The framework shall be open to other access technologies, such as Passive Optical Networks using DSL technology at the Optical Network Unit (ONU), or wireless technologies like IEEE 802.16. Several use cases such as Access Topology Discovery, Remote Connectivity Test, and Multicast may be applied to these access technologies, but the details of this are outside the scope of this document.

Traditional architectures require Permanent Virtual Circuit(s) per subscriber. Such a virtual circuit is configured on layer 2 and terminated at the first layer 3 device (e.g., Broadband Remote Access Server (BRAS)). Beside the data plane, the models define the architectures for element, network, and service management. Interworking at the management plane is not always possible because of the organizational boundaries between departments operating the local loop, departments operating the ATM network, and departments operating the IP network. Besides, management networks are usually not designed to transmit management data between the different entities in real time.

When deploying value-added services across DSL access networks, special attention regarding quality of service and service control is required, which implies a tighter coordination between Network Nodes (e.g., Access Nodes and Network Access Server (NAS)), without burdening the Operational Support System (OSS) with unpractical expectations.

Therefore, there is a need for an Access Node Control Mechanism between a NAS and an Access Node (e.g., a Digital Subscriber Line Access Multiplexer (DSLAM)) in a multi-service reference architecture in order to perform operations related to service, quality of service, and subscribers. The Access Node Control Mechanism will ensure that the transmission of the information does not need to go through distinct element managers but rather using a direct device-device communication. This allows for performing access-link-related operations within those network elements, while avoiding impact on the existing OSSes.

This document provides a framework for such an Access Node Control Mechanism and identifies a number of use cases for which this mechanism can be justified. Next, it presents a number of requirements for the Access Node Control Protocol (ANCP) and the network elements that need to support it.

The requirements spelled out in this document are based on the work that is performed by the Broadband Forum [TR-147].

1.1. Requirements Notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.2. Definitions

- Access Node (AN): network device, usually located at a service provider central office or street cabinet, that terminates access-loop connections from subscribers. In case the access loop is a Digital Subscriber Line (DSL), this is often referred to as a DSL Access Multiplexer (DSLAM).

- Network Access Server (NAS): network device that aggregates multiplexed subscriber traffic from a number of Access Nodes. The NAS plays a central role in per-subscriber policy enforcement and quality of service (QoS). Often referred to as a Broadband Network Gateway (BNG) or Broadband Remote Access Server (BRAS). A detailed definition of the NAS is given in [RFC2881].

- "Net Data Rate": defined by ITU-T G.993.2 [G.993.2], section 3.39, i.e., the portion of the total data rate that can be used to transmit user information (e.g., ATM cells or Ethernet frames). It excludes overhead that pertains to the physical transmission mechanism (e.g., trellis coding in the case of DSL). It includes

TPS-TC (Transport Protocol Specific - Transmission Convergence) encapsulation; this is zero for ATM encapsulation, and non-zero for 64/65 encapsulation.

- "Line Rate": defined by ITU-T G.993.2. It contains the complete overhead including Reed-Solomon and Trellis coding.

- Access Node Control Mechanism: a method for multiple network scenarios with an extensible communication scheme that conveys status and control information between one or more ANs and one or more NASes without using intermediate element managers.

- Control Channel: a bidirectional IP communication interface between the controller function (in the NAS) and the reporting/ enforcement function (in the AN). It is assumed that this interface is configured (rather than discovered) on the AN and the NAS.

- Access Node Control Adjacency: the relationship between an Access Node and a NAS for the purpose of exchanging Access Node Control Protocol messages. The adjacency may either be up or down, depending on the result of the Access Node Control Adjacency protocol operation.

- Multicast Flow: designates datagrams sent to a group from a set of sources for which multicast reception is desired. A distinction can be made between Any Source Multicast (ASM) and Source-Specific Multicast (SSM).

- Join: signaling from the user equipment that it wishes to start receiving a new multicast flow. In ASM, it is referred to as a "Join". In SSM [RFC4607], it is referred to as a "subscribe". In IGMPv2, "joins" are indicated through an "IGMPv2 membership report". In IGMPv3 [RFC3376], "join" is indicated through "membership report" using different Filter-Mode-Change (ASM) and Source-List-Change Records.

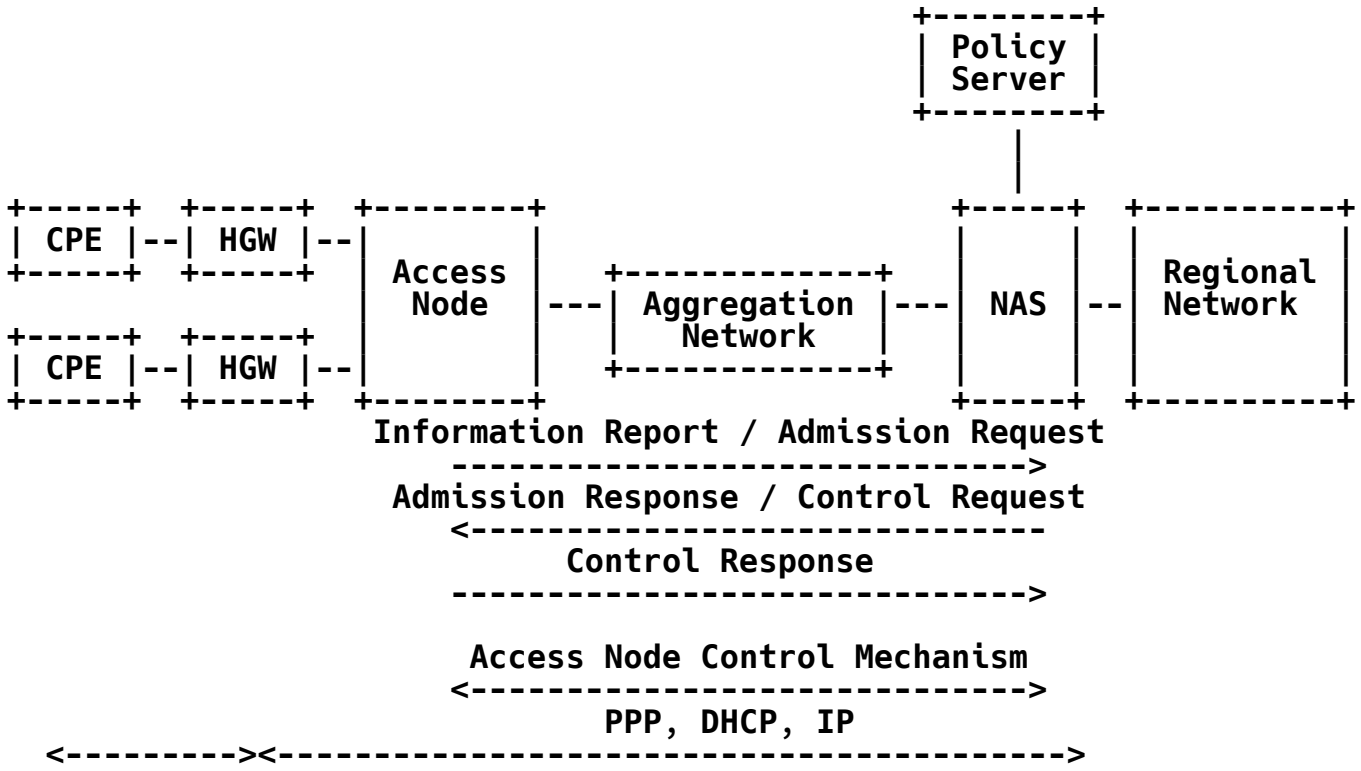
- Leave: signaling from the user equipment that it wishes to stop receiving a multicast flow. With IGMPv2, this is conveyed inside the "Leave Group" message, while in IGMPv3, "leave" is indicated through the "IGMPv3 membership report" message using different Filter-Mode-Change (ASM) and Source-List-Change Records.

2. General Architecture Aspects

This section introduces the basic concept of the Access Node Control Mechanism and describes the reference architecture where it is being applied. Based on the reference architecture, the section then describes how Access Node Control messages are to be prioritized over other data traffic, and the interaction between ANCP and the network management system. Finally, the addressing schemes are described that allow identifying an Access Port in Access Node Control messages.

2.1. Concept of an Access Node Control Mechanism

The high-level communication framework for an Access Node Control Mechanism is defined in Figure 1. The Access Node Control Mechanism defines a quasi-real-time, general-purpose method for multiple network scenarios with an extensible communication scheme, addressing the different use cases that are described throughout this document.



CPE: Customer Premises Equipment
HGW: Home Gateway

Figure 1: Access Network Architecture

A number of functions can be identified:

- A controller function: this function is used either to send out requests for information to be used by the network element where the controller function resides, or to trigger a certain behavior in the network element where the reporting and/or enforcement function resides.

- A reporting function: this function is used to convey status information to the controller function. An example of this is the transmission of the access-loop data rate from an Access Node to a Network Access Server (NAS) tasked with shaping traffic to that rate.

- An enforcement function: this function is contacted by the controller function to trigger a remote action on the Access Node. An example is the initiation of a port-testing mechanism on an Access Node. Another example is enforcing whether a multicast join is to be honored or denied.

The messages shown in Figure 1 show the conceptual message flow. The actual use of these flows, and the times or frequencies when these messages are generated depends on the actual use cases, which are described in Section 3.

The use cases in this document are described in an abstract way, independent from any actual protocol mapping. The actual protocol specification is out of scope of this document, but there are certain characteristics of the protocol that are required to simplify specification, implementation, debugging and troubleshooting, and to extend support for additional use cases.

2.2. Reference Architecture

The reference architecture used in this document can be based on ATM or Ethernet access/aggregation. Specifically:

- In case of a legacy ATM aggregation network that is to be used for the introduction of new QoS-enabled IP services, the architecture builds on the reference architecture specified in the Broadband Forum [TR-059];

- In case of an Ethernet aggregation network that supports new QoS-enabled IP services (including Ethernet multicast replication), the architecture builds on the reference architecture specified in the Broadband Forum [TR-101].

Given the industry's move towards Ethernet as the new access and aggregation technology for triple-play services, the primary focus throughout this document is on a TR-101 architecture. However the concepts are equally applicable to an ATM architecture based on TR-059.

2.2.1. Home Gateway

The Home Gateway (HGW) connects the different Customer Premises Equipment (CPE) to the Access Node and the access network. In case of DSL, the HGW is a DSL Network Termination (NT) that could either operate as a layer 2 bridge or as a layer 3 router. In the latter case, such a device is also referred to as a Routing Gateway (RG).

2.2.2. Access Loop

The access loop ensures physical connectivity between the HGW at the customer premises and the Access Node. In case of DSL, the access-loop physical layer could be, e.g., ADSL, ADSL2+, VDSL, VDSL2, or SHDSL. In order to increase bandwidth, it is also possible that multiple DSL links are grouped together to form a single virtual link; this process is called "DSL bonding". The protocol encapsulation on the access loop could be based on multi-protocol encapsulation over ATM Adaption Layer 5 (AAL5) defined in [RFC2684]. This covers PPP over Ethernet (PPPoE, defined in [RFC2516]), bridged IP (IP over Ethernet (IPoE), defined in [RFC894]) and routed IP (IP over ATM (IPoA), defined in [RFC2225]). Next to this, PPP over AAL5 (PPPoA) as defined in [RFC2364] can be used. Future scenarios include cases where the access loop supports direct Ethernet encapsulation (e.g., when using VDSL or VDSL2).

2.2.3. Access Node

The Access Node (AN) may support one or more access-loop technologies and allow them to interwork with a common aggregation network technology. Besides the access-loop termination, the AN can also aggregate traffic from other Access Nodes using ATM or Ethernet.

The framework defined by this document is targeted at DSL-based access (either by means of ATM/DSL or as Ethernet/DSL). The framework shall be open to non-DSL technologies, like Passive Optical Networks (PONs) and IEEE 802.16 (WiMAX), but the details of this are outside the scope of this document.

The reporting and/or enforcement function defined in Section 2.1 typically resides in an Access Node.

2.2.4. Access Node Uplink

The fundamental requirements for the Access Node uplink are to provide traffic aggregation, Class of Service (CoS) distinction, and customer separation and traceability. This can be achieved using an ATM- or Ethernet-based technology.

2.2.5. Aggregation Network

The aggregation network provides traffic aggregation towards the NAS. The aggregation technology can be based on ATM (in case of a TR-059 architecture) or Ethernet (in case of a TR-101 architecture).

2.2.6. Network Access Server

The Network Access Server (NAS) interfaces to the aggregation network by means of standard ATM or Ethernet interfaces, and towards the Regional Network by means of transport interfaces for Ethernet frames (e.g., Gigabit Ethernet (GigE), Ethernet over Synchronous Optical Network (SONET)). The NAS functionality corresponds to the BNG functionality described in Broadband Forum TR-101. In addition to this, the NAS supports the Access Node Control functionality defined for the respective use cases throughout this document.

The controller function defined in Section 2.1 typically resides in a NAS.

2.2.7. Regional Network

The Regional Network connects one or more NAS and associated Access Networks to Network Service Providers (NSPs) and Application Service Providers (ASPs). The NSP authenticates access and provides and manages the IP address to subscribers. It is responsible for overall service assurance and includes Internet Service Providers (ISPs). The ASP provides application services to the application subscriber (gaming, video, content on demand, IP telephony, etc.).

The Regional Network supports aggregation of traffic from multiple Access Networks and hands off larger geographic locations to NSPs and ASPs -- relieving a potential requirement for them to build infrastructure to attach more directly to the various Access Networks.

2.3. Prioritizing Access Node Control Traffic

When sending Access Node Control messages across the aggregation network, care is needed that messages won't get lost. The connectivity between the Access Node and the NAS may differ depending on the actual layer 2 technology used (ATM or Ethernet). This section briefly outlines how network connectivity can be established.

In case of an ATM access/aggregation network, a typical practice is to send the Access Node Control Protocol messages over a dedicated Permanent Virtual Circuit (PVC) configured between the AN and the NAS. These ATM PVCs would then be given a high priority so that at times of network congestion, loss of the ATM cells carrying the Access Node Control Protocol is avoided or minimized. It is discouraged to route the Access Node Control Protocol messages within the Virtual Path (VP) that also carries the customer connections, if that VP is configured with a best-effort QoS class (e.g., Unspecified Bitrate (UBR)). The PVCs of multiple Access Node Control Adjacencies can be aggregated into a VP that is given a high priority and runs across the aggregation network. This requires the presence of a VC cross-connect in the aggregation node that terminates the VP.

In case of an Ethernet access/aggregation network, a typical practice is to send the Access Node Control Protocol messages over a dedicated Ethernet Virtual LAN (VLAN) using a separate VLAN identifier (VLAN ID). This can be achieved using a different VLAN ID for each Access Node, or, in networks with many Access Nodes and a high degree of aggregation, one Customer VLAN (C-VLAN) per Access Node and one Service VLAN (S-VLAN) for the Access Node Control Adjacencies of all Access Nodes. The traffic should be given a high priority (e.g., by using a high CoS value) so that the frame loss of Ethernet frames carrying the Access Node Control Protocol messages is minimized in the event of network congestion.

In both cases, the Control Channel between NAS and Access Node could use the same physical network and routing resources as the subscriber traffic. This means that the connection is an inband connection between the involved network elements. Therefore, there is no need for an additional physical interface to establish the Control Channel.

Note that these methods for transporting Access Node Control Protocol messages are typical examples; they do not rule out other methods that achieve the same behavior.

The Access Node Control Adjacency interactions must be reliable. In addition to this, some of the use cases described in Section 3 require the interactions to be performed in a transactional fashion,

i.e., using a "request/response" mechanism. This is required so that the network elements always remain in a known state, irrespective of whether or not the transaction is successful.

2.4. Interaction with Management Systems

When introducing an Access Node Control Mechanism, care is needed to ensure that the existing management mechanisms remain operational as before.

Specifically, when using the Access Node Control Mechanism for performing a configuration action on a network element, one gets confronted with the challenge of supporting multiple managers for the same network element: both the Element Manager as well as the Access Node Control Mechanism may now perform configuration actions on the same network element. Therefore, conflicts need to be avoided.

Using the Access Node Control Mechanism, the NAS retrieves and controls a number of subscriber-related parameters. The NAS may decide to communicate this information to a central Policy or AAA Server so that it can keep track of the parameters and apply policies on them. The Server can then enforce those policies on the NAS. For instance, in case a subscriber is connected to more than one NAS, the policy server could be used to coordinate the bandwidth available on a given Access Port for use amongst the different NAS devices.

Guidelines related to management will be addressed in Section 5.

2.5. Circuit Addressing Scheme

In order to associate subscriber parameters to a particular Access Port, the NAS needs to be able to uniquely identify the Access Port (or a specific circuit on an Access Port) using an addressing scheme.

In deployments using an ATM aggregation network, the ATM PVC on an access loop connects the subscriber to a NAS. Based on this property, the NAS typically includes a NAS-Port-Id, NAS-Port, or Calling-Station-Id attribute in RADIUS authentication and accounting packets sent to the RADIUS server(s). Such attribute includes the identification of the ATM VC for this subscriber, which allows in turn identifying the access loop.

In an Ethernet-based aggregation network, a new addressing scheme is defined in [TR-101]. Two mechanisms can be used:

- A first approach is to use a one-to-one VLAN assignment model for all Access Ports (e.g., a DSL port) and circuits on an Access Port (e.g., an ATM PVC on an ADSL port). This enables directly deriving the port and circuit identification from the VLAN tagging information, i.e., S-VLAN ID or <S-VLAN ID, C-VLAN ID> pair.

- A second approach is to use a many-to-one VLAN assignment model and to encode the Access Port and circuit identification in the "Agent Circuit ID" sub-option to be added to a DHCP or PPPoE message. The details of this approach are specified in [TR-101].

This document reuses the addressing scheme specified in TR-101. It should be noted however that the use of such a scheme does not imply the actual existence of a PPPoE or DHCP session, nor the presence of the specific interworking function in the Access Node. In some cases, no PPPoE or DHCP session may be present, while port and circuit addressing would still be desirable.

3. Use Cases for Access Node Control Mechanism

3.1. Access Topology Discovery

[TR-059] and [TR-101] discuss various queuing/scheduling mechanisms to avoid congestion in the access network while dealing with multiple flows with distinct QoS requirements. One technique that can be used on a NAS is known as "Hierarchical Scheduling" (HS). This option is applicable in a single NAS scenario (in which case the NAS manages all the bandwidth available on the access loop) or in a dual NAS scenario (in which case the NAS manages some fraction of the access loop's bandwidth). The HS must, at a minimum, support 3 levels modeling the NAS port, Access Node uplink, and access-loop sync rate. The rationale for the support of HS is as follows:

- Provide fairness of network resources within a class.

- Allow for a better utilization of network resources. Drop traffic early at the NAS rather than letting it traverse the aggregation network just to be dropped at the Access Node.

- Enable more flexible CoS behaviors than only strict priority.

- The HS system could be augmented to provide per-application admission control.

- Allow fully dynamic bandwidth partitioning between the various applications (as opposed to static bandwidth partitioning).

- Support "per-user weighted scheduling" to allow differentiated Service Level Agreements (e.g., business services) within a given traffic class.

Such mechanisms require that the NAS gains knowledge about the topology of the access network, the various links being used, and their respective rates. Some of the information required is somewhat dynamic in nature (e.g., DSL line rate -- thus also the net data rate); hence, it cannot come from a provisioning and/or inventory management OSS system. Some of the information varies less frequently (e.g., capacity of a DSLAM uplink), but nevertheless needs to be kept strictly in sync between the actual capacity of the uplink and the image the BRAS has of it.

OSS systems are typically not designed to enforce the consistency of such data in a reliable and scalable manner across organizational boundaries. The Access Topology Discovery function is intended to allow the NAS to perform these functions without having to rely on an integration with an OSS system.

Communicating access-loop attributes is specifically important in case the rate of the access loop changes overtime. The DSL actual data rate may be different every time the DSL NT is turned on. In this case, the Access Node sends an Information Report message to the NAS after the DSL line has resynchronized.

Additionally, during the time the DSL NT is active, data rate changes can occur due to environmental conditions (the DSL access loop can get "out of sync" and can retrain to a lower value, or the DSL access loop could use Seamless Rate Adaptation making the actual data rate fluctuate while the line is active). In this case, the Access Node sends an additional Information Report to the NAS each time the access-loop attributes change above a threshold value.

The hierarchy and the rates of the various links to enable the NAS hierarchical scheduling and policing mechanisms are the following:

- The identification and speed (data rate) of the DSL access loop (i.e., the net data rate)

- The identification and speed (data rate) of the Remote Terminal (RT) / Access Node uplink (when relevant)

The NAS can adjust downstream shaping to the Access Loop's current actual data rate, and more generally reconfigure the appropriate nodes of its hierarchical scheduler (support of advanced capabilities according to TR-101).

This use case may actually include more information than link identification and corresponding data rates. In case of DSL access loops, the following access-loop characteristics can be sent to the NAS (cf. ITU-T Recommendation G.997.1 [G.997.1]):

- DSL Type (e.g., ADSL1, ADSL2, SDSL, ADSL2+, VDSL, VDSL2)
- Framing mode (e.g., ATM, ITU-T Packet Transfer Mode (PTM), IEEE 802.3 Ethernet in the First Mile (EFM))
- DSL port state (e.g., synchronized/showtime, low power, no power/ idle)
- Actual net data rate (upstream/downstream)
- Maximum achievable/attainable net data rate (upstream/downstream)
- Minimum net data rate configured for the access loop (upstream/ downstream)
- Maximum net data rate configured for the access loop (upstream/ downstream)
- Minimum net data rate in low power state configured for the access loop (upstream/downstream)
- Maximum achievable interleaving delay (upstream/downstream)
- Actual interleaving delay (upstream/downstream)

The NAS MUST be able to receive access-loop characteristics information, and share such information with AAA/policy servers.

3.2. Access-Loop Configuration

access-loop rates are typically configured in a static way. When a subscriber wants to change its access-loop rate, the network operator needs to reconfigure the Access Port configuration, possibly implying a business-to-business transaction between an Internet Service Provider (ISP) and an Access Provider. From an Operating Expenditures (OPEX) perspective this is a costly operation.

Using the Access Node Control Mechanism to change the access-loop rate from the NAS avoids those cross-organization business-to-business interactions and allows to centralize subscriber-related service data in e.g., a policy server. More generally, several access-loop parameters (e.g., minimum data rate, interleaving delay) could be changed by means of the Access Node Control Mechanism.

Triggered by the communication of the access-loop attributes described in Section 3.1, the NAS could query a Policy or AAA Server to retrieve access-loop configuration data. The best way to change access-loop parameters is by using profiles. These profiles (e.g., DSL profiles for different services) are pre-configured by the Element Manager managing the Access Nodes. The NAS may then use the Configure Request message to send a reference to the right profile to the Access Node. The NAS may also update the access-loop configuration due to a subscriber service change (e.g., triggered by the policy server).

The access-loop configuration mechanism may also be useful for configuration of parameters that are not specific to the access-loop technology. Examples include the QoS profile to be used for an access loop, or the per-subscriber multicast channel entitlement information, used for IPTV applications where the Access Node is performing IGMP snooping or IGMP proxy function. The latter is also discussed in Section 3.4.

It may be possible that a subscriber wants to change its access-loop rate, and that the operator wants to enforce this updated access-loop rate on the Access Node using ANCP, but that the Access Node Control Adjacency is down. In such a case, the NAS will not be able to request the configuration change on the Access Node. The NAS should then report this failure to the external management system, which could use application-specific signaling to notify the subscriber of the fact that the change could not be performed at this time.

3.3. Remote Connectivity Test

Traditionally, ATM circuits are point-to-point connections between the BRAS and the DSLAM or DSL NT. In order to test the connectivity on layer 2, appropriate Operations, Administration, and Maintenance (OAM) functionality is used for operation and troubleshooting. An end-to-end OAM loopback is performed between the edge devices (NAS and HGW) of the broadband access network.

When migrating to an Ethernet-based aggregation network (as defined by TR-101), end-to-end ATM OAM functionality is no longer applicable. Ideally in an Ethernet aggregation network, end-to-end Ethernet OAM (as specified in IEEE 802.1ag and ITU-T Recommendation Y.1730/1731) can provide access-loop connectivity testing and fault isolation. However, most HGWs do not yet support these standard Ethernet OAM procedures. Also, various access technologies exist such as ATM/DSL, Ethernet in the First Mile (EFM), etc. Each of these access technologies have their own link-based OAM mechanisms that have been or are being standardized in different standard bodies.

In a mixed Ethernet and ATM access network (including the local loop), it is desirable to keep the same ways to test and troubleshoot connectivity as those used in an ATM-based architecture. To reach consistency with the ATM-based approach, an Access Node Control Mechanism between NAS and Access Node can be used until end-to-end Ethernet OAM mechanisms are more widely available.

Triggered by a local management interface, the NAS can use the Access Node Control Mechanism to initiate an access-loop test between Access Node and HGW. In case of an ATM-based access loop, the Access Node Control Mechanism can trigger the Access Node to generate ATM (F4/F5) loopback cells on the access loop. In case of Ethernet, the Access Node can perform a port synchronization and administrative test for the access loop. The Access Node can send the result of the test to the NAS via a Control Response message. The NAS may then send the result via a local management interface. Thus, the connectivity between the NAS and the HGW can be monitored by a single trigger event.

3.4. Multicast

With the rise of supporting IPTV services in a resource efficient way, multicast services are getting increasingly important.

In case of an ATM access/aggregation network, such as the reference architecture specified in Broadband Forum [TR-059], multicast traffic replication is performed in the NAS. In this model, typically IGMP is used to control the multicast replication process towards the subscribers. The NAS terminates and processes IGMP signaling messages sent by the subscribers; towards the Regional Network, the NAS typically uses a multicast routing protocol such as Protocol Independent Multicast (PIM). The ATM Access Nodes and aggregation switches don't perform IGMP processing, nor do they perform multicast traffic replication. As a result, network resources are wasted within the access/aggregation network.

To overcome this resource inefficiency, the Access Node, aggregation node(s), and the NAS must all be involved in the multicast replication process. This prevents several copies of the same stream from being sent within the access/aggregation network. In case of an Ethernet-based access/aggregation network, this may, for example, be achieved by means of IGMP snooping or IGMP proxy in the Access Node and aggregation node(s).

By introducing IGMP processing in the access/aggregation nodes, the multicast replication process is now divided between the NAS, the aggregation node(s), and Access Nodes. In order to ensure backward compatibility with the ATM-based model, the NAS, aggregation node,

and Access Node need to behave as a single logical device. This logical device must have exactly the same functionality as the NAS in the ATM access/aggregation network. The Access Node Control Mechanism can be used to make sure that this logical/functional equivalence is achieved by exchanging the necessary information between the Access Node and the NAS.

Another option is for the subscriber to communicate the "join/leave" information with the NAS. This can for instance be done by terminating all subscriber IGMP signaling on the NAS. Another example could be a subscriber using some form of application-level signaling, which is redirected to the NAS. In any case, this option is transparent to the access and aggregation network. In this scenario, the NAS can use ANCP to create replication state in the AN for efficient multicast replication. The NAS sends a single copy of the multicast stream towards the AN. The NAS can perform conditional access and multicast admission control on multicast joins, and create replication state in the AN if the flow is admitted by the NAS.

The following subsections describe the different use cases related to multicast.

3.4.1. Multicast Conditional Access

In a DSL broadband access scenario, service providers may want to dynamically control, at the network level, access to some multicast flows on a per-user basis. This may be used in order to differentiate among multiple Service Offers or to realize/reinforce conditional access for sensitive content. Note that, in some environments, application-layer conditional access by means of Digital Rights Management (DRM) may provide sufficient control, so that Multicast Conditional Access may not be needed.

Where Multicast Conditional Access is required, it is possible, in some cases, to provision the necessary conditional access information into the AN so the AN can then perform the conditional access decisions autonomously. For these cases, the NAS can use ANCP to provision the necessary information in the AN so that the AN can decide locally to honor a join or to not honor a join. This can be done with the Control Request and Control Response messages.

Provisioning the conditional access information on the AN can be done using a "white list", "grey list", and/or a "black list". A white list associated with an Access Port identifies the multicast flows that are allowed to be replicated to that port. A black list associated with an Access Port identifies the multicast flows that are not allowed to be replicated to that port. A grey list associated with an Access Port identifies the multicast flows for

which the AN on receiving a join message, before starting traffic replication queries the NAS for further authorization. Each list contains zero, one, or multiple entries, and each entry may specify a single flow or contain ranges (i.e., mask on Group address and/or mask on Source address).

Upon receiving a join message on an Access Port, the Access Node will first check if the requested multicast flow is part of a white, grey, or a black list associated with that Access Port. If it is part of a white list, the AN autonomously starts replicating multicast traffic. If it is part of a black list, the AN autonomously discards the message because the request is not authorized, and may thus inform the NAS and log the request accordingly. If it is part of a grey list the AN uses ANCP to query the NAS, that in turn will respond to the AN indicating whether the join is to be honored (and hence replication performed by the AN) or denied (and hence replication not performed by the AN).

If the requested multicast flow is part of multiple lists associated with the Access Port, then the most specific match will be used. If the most specific match occurs in multiple lists, the black list entry takes precedence over the grey list, which takes precedence over the white list.

If the requested multicast flow is not part of any list, the message should be discarded. This default behavior can easily be changed by means of a "catch-all" statement in either the white list or the grey list. For instance, adding (<S=*,G=*>) in the white list would make the default behavior to accept join messages for a multicast flow that has no other match on any list. Similarly, if the default behavior should be to send a request to the NAS, then adding (<S=*,G=*>) in the grey list accomplishes that.

The white list, black list, and grey list can contain entries allowing:

- an exact match for a (*,G) ASM group (e.g., <G=g.h.i.l>);
- an exact match for a (S,G) SSM channel (e.g., <S=s.t.u.v,G=g.h.i.l>);
- a mask-based range match for a (*,G) ASM group (e.g., <G=g.h.i.l/Mask>);
- a mask-based range match for a (S,G) SSM channel (e.g., <S=s.t.u.v/Mask,G=g.h.i.l/Mask>);

The following are some example configurations:

- Scenario 1: reject all messages
  - black list = {<S=*,G=*>}
- Scenario 2: reject all messages, except Join (S=*,G=Gi) (1<=i<=n)
  - white list = { <S=*,G=G1> , <S=*,G=G2>, ... <S=*,G=Gn>}
  - black list = {<S=*,G=*>}
- Scenario 3: AN performs autonomous decisions for some channels, and asks the NAS for other channels
  - white list = { <S=*,G=G1> , <S=*,G=G2>, ... <S=*,G=Gn>}
  - grey list = { <S=s,G=Gm>} for m>n
  - black list = {<S=*,G=*>}
  - ==> Join (S=*,G=Gi) gets honored by AN (1<=i<=n)
  - ==> Join (S=s,G=Gm) triggers ANCP Admission Request to NAS
  - ==> everything else gets rejected by AN

The use of a white list and black list may be applicable, for instance, to regular IPTV services (i.e., broadcast TV) offered by an Access Provider to broadband (e.g., DSL) subscribers. For this application, the IPTV subscription is typically bound to a specific DSL line, and the multicast flows that are part of the subscription are well-known beforehand. Furthermore, changes to the conditional access information are infrequent, since they are bound to the subscription. Hence, the Access Node can be provisioned with the conditional access information related to the IPTV service.

In some other cases, it may be desirable to have the conditional access decision being taken by the NAS or a Policy Server. This may be the case when conditional access information changes frequently, or when the multicast groups are not known to a client application in advance. The conditional access control could be tied to a more complex policy/authorization mechanism, e.g., time-of-day access, location-based access, or to invoke a remote authorization server. For these cases, the AN can use ANCP to query the NAS that in turn will respond to the AN indicating whether the join is to be denied or honored (and hence replication performed by the AN). This can be done with the Admission Request and Admission Response messages.

Some examples of using NAS querying are the following:

- Roaming users: a subscriber that logs in on different wireless hotspots and would like to receive multicast content he is entitled to receive;
- Mobility or seamless handover (a related example): in both cases, the burden of (re)configuring access nodes with white lists or black lists may be too high;
- "Over-the-top video partnerships": service providers may choose to partner with Internet video providers to provide video content. In this case, the multicast group mappings may not be known in advance, or may be reused for different content in succession.
- "Pay Per View": a subscriber chooses a specific IPTV channel which is made available for a given amount of time.

3.4.2. Multicast Admission Control

The successful delivery of triple-play broadband services is quickly becoming a big capacity planning challenge for most of the Service Providers nowadays. Solely increasing available bandwidth is not always practical, cost-economical, and/or sufficient to satisfy end-user experience given not only the strict requirements of unicast delay sensitive applications like VoIP and video, but also the fast growth of multicast interactive applications such as videoconferencing, digital TV, digital audio, online movies, and networked gaming. These applications are typically characterized by a delay-sensitive nature, an extremely loss-sensitive nature, and intensive bandwidth requirements. They are also typically "non-elastic", which means that they operate at a fixed bandwidth that cannot be dynamically adjusted to the currently available bandwidth.

Therefore, a Connection Admission Control (CAC) mechanism covering admission of video traffic over the DSL broadband access is required, in order to avoid oversubscribing the available bandwidth and negatively impacting the end-user experience.

Considering specifically admission control over the access line, before honoring a user request to join a new multicast flow, the combination of AN and NAS must ensure admission control is performed to validate that there is sufficient bandwidth remaining on the access line to carry the new video stream (in addition to all other multicast and unicast video streams sent over the access line). The solution needs to cope with multiple flows per access line and needs

to allow access-line bandwidth to be dynamically shared across multicast and unicast traffic (the unicast CAC is performed either by the NAS or by some off-path policy server).

Thus, supporting CAC for the access line requires some form of synchronization between the entity performing multicast CAC (e.g., the NAS or the AN), the entity performing unicast CAC (e.g., the policy server), and the entity actually enforcing the multicast replication (i.e., the AN). This synchronization can be achieved in a number of ways:

- One approach is for the AN to query the NAS so that Admission Control for the access line is performed by the NAS, or by the policy server which interacts with the AN via NAS. The AN can use ANCP to query the NAS that in turn performs a multicast Admission Control check for the new multicast flow and responds to the AN indicating whether the join is to be denied or honored (and hence replication performed by the AN). The NAS may locally keep track of the portion of the access-loop net data rate that is available for (unicast or multicast) video flows and perform video bandwidth accounting for the access loop. Upon receiving an Admission Request from the AN, the NAS can check available access-loop bandwidth before admitting or denying the multicast flow. In the process, the NAS may communicate with the policy server. For unicast video services such as Video on Demand (VoD), the NAS may also be queried (by a policy server or via on-path CAC signaling), so that it can perform admission control for the unicast flow and update the remaining available access-loop bandwidth. The ANCP requirements to support this approach are specified in this document.

- The above model could be enhanced with the notion of "Delegation of Authorization". In such a model, the NAS or the policy server delegates authority to the Access Node to perform multicast Admission Control on the access loop. This is sometimes referred to as "Bandwidth Delegation", referring to the portion of the total access-loop bandwidth that can be used by the Access Node for multicast Admission Control. In this model, the NAS or the policy server manages the total access-line bandwidth, performs unicast admission control, and uses ANCP to authorize the Access Node to perform multicast Admission Control within the bounds of the "delegated bandwidth". Upon receiving a request for a multicast flow replication that matches an entry in the white or grey list, the AN performs the necessary bandwidth admission control check for the new multicast flow, before starting the multicast flow replication. At this point, there is typically no

need for the Access Node to communicate with the NAS or the policy server via the NAS. The ANCP requirements to support this approach are also specified in this document.

- In case the subscriber communicates the "join/leave" information with the NAS (e.g., by terminating all subscriber IGMP signaling on the NAS or by using some form of application-level signaling), the approach is very similar. In this case, the NAS may locally keep track of the portion of the access-loop bandwidth that is available for video flows, perform CAC for unicast and multicast flows, and perform video bandwidth management. The NAS can set the replication state on the AN using ANCP if the flow is admitted. For unicast video services, the NAS may be queried (by a policy server or via on-path CAC signaling) to perform admission control for the unicast flow, and update the remaining available access-loop bandwidth. The ANCP requirements to support this approach are specified in this document.

- In the last approach, the policy server queries the AN directly or indirectly via the NAS, so that both unicast and multicast CAC for the access line are performed by the AN. In this case, a subscriber request for a unicast flow (e.g., a Video on Demand session) will trigger a resource request message towards a policy server; the latter will then query the AN (possibly via the NAS), that in turn will perform unicast CAC for the access line and respond, indicating whether the unicast request is to be honored or denied. The above model could also be enhanced with the notion of "Delegation of Authorization". In such a model, the policy server delegates authority to the Access Node to perform multicast Admission Control on the access loop. In the case when the policy server queries the AN directly, the approach doesn't require the use of ANCP. It is therefore beyond the scope of this document. In the case when the policy server queries the AN indirectly via the NAS, the approach requires the use of ANCP and is therefore in the scope of this document.

3.4.2.1. Delegation of Authority - Bandwidth Delegation

The NAS uses ANCP to indicate to the AN whether or not Admission Control is required for a particular multicast flow on a given Access Port. In case Admission Control is required, the Access Node needs to know whether or not it is authorized to perform Admission Control itself and, if so, within which bounds it is authorized to do so (i.e., how much bandwidth is "delegated" by the NAS or the policy server). Depending on the type of multicast flow, Admission Control may or may not by done by the AN:

- Multicast flows that require a Conditional Access operation to be performed by the Access Node are put in the black or white list. In addition, the Access Node performs Admission Control for those flows in the white list for which it is authorized to do so.

- Multicast flows that require a Conditional Access operation to be performed by the NAS or the policy server, are put in the grey list. In addition, for those flows in the grey list for which the Access Node should perform Admission Control, the NAS or the policy server will delegate authority to the AN.

In some cases, the bandwidth that the NAS or the policy server initially delegated to the AN may not be enough to satisfy a multicast request for a new flow. In this scenario, the AN can use ANCP to query the NAS in order to request additional delegated multicast bandwidth. This is a form of extending the AN authorization to perform Admission Control. The NAS or the policy server decides if the request for more bandwidth can be satisfied and uses ANCP to send a response to the AN indicating the updated delegated multicast bandwidth. It is worth noting that in this case, the time taken to complete the procedure is an increment to the zapping delay. In order to minimize the zapping delay for future join requests, the AN can insert in the request message two values: the minimum amount of additional multicast bandwidth requested and the preferred additional amount. The first value is the amount that allows the present join request to be satisfied, the second value an amount that anticipates further join requests.

In some cases, the NAS or the policy server may not have enough unicast bandwidth to satisfy a new incoming video request: in these scenarios, the NAS can use ANCP to query (or instruct) the AN in order to decrease the amount of multicast bandwidth previously delegated on a given Access Port. This is a form of limiting/withdrawing AN authorization to perform Admission Control. The NAS can use ANCP to send a response to AN indicating the updated delegated multicast bandwidth. Based on considerations similar to those of the previous paragraph, it indicates the minimum amount of multicast bandwidth that it needs released and a preferred amount, which may be larger.

Note: in order to avoid impacting existing multicast traffic, the NAS must not decrease the amount of delegated multicast bandwidth to a value lower than the bandwidth that is currently in use. This requires the NAS to be aware of this information (e.g., by means of a separate query action).

In addition, in some cases, upon receiving a leave for a specific multicast flow, the AN may decide that it has an excess of delegated but uncommitted bandwidth. In such case, the AN can use ANCP to send a message to the NAS to release all of part of the unused multicast bandwidth that was previously delegated. In this process, the Access Node may decide to retain a minimum amount of bandwidth for multicast services.

3.4.2.2. When Not to Perform Admission Control for a Subset of Flows

In general, the Access Node and NAS may not be aware of all possible multicast groups that will be streamed in the access network. For instance, it is likely that there will be multicast streams offered across the Internet. For these unknown streams, performing bandwidth Admission Control may be challenging.

To solve this, these requests could be accepted without performing Admission Control. This solution works, provided that the network handles the streams as best effort, so that other streams (that are subject to Admission Control) are not impacted at times of congestion.

Disabling Admission Control for an unknown stream can be achieved by adding a "catch-all statement" in the Access Node white list or grey list. In case the Access Node queries the NAS, the NAS on his turn will have to accept the request. That way, the unknown streams are not blocked by default.

Next, in order to ensure that the streams are handled as best effort, the flow must be marked as such when entering the service provider network. This way, whenever congestion occurs somewhere in the access/aggregation network, this stream will be kicked out before the access provider's own premium content.

The above concept is applicable beyond the notion of "Internet streams" or other unknown streams; it can be applied to known multicast streams as well. In this case, the Access Node or NAS will accept the stream even when bandwidth may not be sufficient to support the stream. This again requires that the stream be marked as best-effort traffic before entering the access/aggregation network.

3.4.2.3. Multicast Admission Control and White Lists

As mentioned in Section 3.4.1, conditional access to popular IPTV channels can be achieved by means of a white and black list configured on the Access Node. This method allows the Access Node to autonomously decide whether or not access can be granted to a multicast flow.

IPTV is an example of a service that will not be offered as best effort, but requires some level of guaranteed quality of service. This requires the use of Multicast Admission Control. Hence, if the Access Node wants to autonomously perform the admission process, it must be aware of the bandwidth characteristics of multicast flows. Otherwise, the Access Node would have to query the NAS for Multicast Admission Control (per the grey list behavior); this would defeat the purpose of using a white and black list.

Some network deployments may combine the use of white list, black list, and grey list. The implications of such a model to the overall Multicast Admission Control model are not fully explored in this document.

3.4.3. Multicast Accounting and Reporting

It may be desirable to perform time- and/or volume-based accounting for certain multicast flows sent on particular Access Ports. In case the AN is performing the traffic replication process, it knows when replication of a multicast flow to a particular Access Port or user start and stops. Multicast accounting can be addressed in two ways:

- The AN keeps track of when replication for a given multicast flow starts or ends on a specified Access Port, and generates time- and/or volume-based accounting information per Access Port and per multicast flow, before sending it to a central accounting system for logging. Given that the AN communicates with the accounting system directly, the approach doesn't require the use of ANCP. It is therefore beyond the scope of this document;

- The AN keeps track of when replication for a given multicast flow starts or ends on a specified Access Port, and reports this information to the NAS for further processing. In this case, ANCP can be used to send the information from the AN to the NAS. This will be discussed in the remainder of this document.

The Access Node can send multicast accounting information to the NAS using the Information Report message. A distinction can be made between two cases:

- Basic accounting information: the Access Node informs the NAS whenever replication starts or ends for a given multicast flow on a particular Access Port;

- Detailed accounting information: the Access Node not only informs the NAS when replication starts or ends, but also informs the NAS about the multicast traffic volume replicated on the Access Port

for that multicast flow. This is done by adding a byte count in the Information Report message that is sent to the NAS when replication ends.

Upon receiving the Information Report messages, the NAS generates the appropriate time- and/or volume-based accounting records per access loop and per multicast flow to be sent to the accounting system.

The NAS should inform the Access Node about the type of accounting needed for a given multicast flow on a particular Access Port:

- No reporting messages need to be sent to the NAS.
- Basic accounting is required.
- Detailed accounting is required.

Note that in case of very fast channel changes, the amount of Information Report messages to be sent to the NAS could become high.

The ANCP requirements to support this use case are specified below in this document.

It may also be desirable for the NAS to have the capability to asynchronously query the AN to obtain an instantaneous status report related to multicast flows currently replicated by the AN. Such a reporting functionality could be useful for troubleshooting and monitoring purposes. The NAS can query the AN to know the following:

- Which flows are currently being sent on a specific Access Port (i.e., a report for one Access Port)
- On which Access Ports a specified multicast flow is currently being sent (i.e., a report for one multicast flow)
- Which multicast flows are currently being sent on each of the Access Ports (i.e., a global report for one Access Node)

3.4.4. Spontaneous Admission Response

The capability to dynamically stop the replication of a multicast flow can be useful in different scenarios: for example in case of prepaid service, when available credit expires, the Service Provider may want to be able to stop multicast replication on a specified Access Port for a particular user. Another example of applicability for this functionality is a scenario where a Service Provider would like to show a "Content Preview": in this case, a multicast content will be delivered just for a fixed amount of time.

In both cases, an external entity (for example, a policy server or an external application entity) can instruct the NAS to interrupt the multicast replication of a specified multicast flow to a specified Access Port or user. The NAS can then use ANCP to communicate this decision to the Access Node. This can be done with the Admission Response message.

In some deployment scenarios, the NAS may be made aware of end-users' requests to join/leave a multicast flow by other means than ANCP Admission Requests sent by the AN. One possible deployment scenario where this model applies is the case where the Access Node doesn't process the IGMP join/leave messages from the end-user (e.g., because they are tunneled), but forwards them to the NAS. In such environments, the NAS can control multicast replication on the AN via ANCP through the use of Spontaneous Admission Responses (i.e., sent by the NAS without prior receipt of a corresponding Admission Request).

4. Requirements

4.1. ANCP Functional Requirements

R-1 The ANCP MUST be easily extensible through the definition of new message types or TLVs to support use cases beyond those currently addressed in this document (this includes the use of Access Nodes different from a DSLAM, e.g., a PON Access Node).

R-2 The ANCP MUST be flexible enough to accommodate the various technologies that can be used in an access network and in the Access Node; this includes both ATM and Ethernet.

R-3 The Access Node Control interactions MUST be reliable (using either a reliable transport protocol (e.g., TCP) for the Access Node Control Protocol messages, or by designing ANCP to be reliable).

R-4 The ANCP MUST support "request/response" transaction-based interactions for the NAS to communicate control decisions to the Access Node, or for the NAS to request information from the Access Node. Transactions MUST be atomic, i.e., they are either fully completed, or rolled back to the previous state. This is required so that the network elements always remain in a known state, irrespective of whether or not the transaction is successful.

In case the NAS wants to communicate a bulk of independent control decisions to the Access Node, the transaction (and notion of atomicity) applies to the individual control decisions. This avoids

having to roll back all control decisions. Similarly, if the NAS wants to request a bulk of independent information elements from the Access Node, the notion of transaction applies to the individual information elements.

R-5 The ANCP MUST be scalable enough to allow a given NAS to control at least 5000 Access Nodes.

R-6 The operation of the ANCP in the NAS and Access Nodes MUST be controllable via a management station (e.g., via SNMP). This MUST allow a management station to retrieve statistics and alarms related to the operation of the ANCP, as well as to allow it to initiate OAM operations and retrieve corresponding results.

4.2. ANCP Multicast Requirements

R-7 The ANCP MUST support providing multicast conditional access information to Access Ports on an Access Node, using black, grey, and white lists.

R-8 The ANCP MUST support binding a particular black, grey, and white List to a given Access Port.

R-9 Upon receiving a join to a multicast flow that matches the grey list, the ANCP MUST allow the AN to query the NAS to request an admission decision for replicating that multicast flow to a particular Access Port.

R-10 The ANCP MUST allow the NAS to send an admission decision to the AN indicating whether or not a multicast flow may be replicated to a particular Access Port.

R-11 The ANCP MUST allow the NAS to indicate to the AN whether or not Admission Control is needed for some multicast flows on a given Access Port, and (where needed) whether or not the Access Node is authorized to perform Admission Control itself (i.e., whether or not AN Bandwidth Delegation applies).

R-12 In case of Admission Control without AN Bandwidth Delegation, the ANCP MUST allow the NAS to reply to a query from the AN indicating whether or not a multicast flow is allowed to be replicated to a particular Access Port.

R-13 In case of Admission Control with AN Bandwidth Delegation, the ANCP MUST allow the NAS to delegate a certain amount of bandwidth to the AN for a given Access Port for multicast services only.

R-14 In case of Admission Control with AN Bandwidth Delegation, the ANCP MUST allow the AN to query the NAS to request additional multicast bandwidth on a given Access Port.

R-15 In case of Admission Control with AN Bandwidth Delegation, the ANCP MUST allow the NAS to query (or to instruct) the AN to reduce the amount of bandwidth previously delegated on a given Access Port.

R-16 In case of Admission Control with AN Bandwidth Delegation, the ANCP MUST allow the AN to inform the NAS if it autonomously releases redundant multicast bandwidth on a given Access Port.

R-17 The ANCP MUST allow the AN to send an Information Report message to the NAS whenever replication of a multicast flow on a particular Access Port starts or ends.

R-18 The ANCP MUST allow the AN to send an Information Report message to the NAS indicating the multicast traffic volume that has been replicated on that port.

R-19 The ANCP MUST allow the NAS to indicate to the AN whether or not multicast accounting is needed for a multicast flow on a particular Access Port.

R-20 In case multicast accounting is needed for a multicast flow on a particular Access Port, the ANCP MUST allow the NAS to indicate to the AN whether or not additional volume accounting information is required.

R-21 The ANCP MUST allow the NAS to revoke a decision to replicate a multicast flow to a particular Access Port, which had been conveyed earlier to an AN.

R-22 The ANCP MUST support partial updates of the white, grey, and black lists.

R-23 The ANCP MUST allow the NAS to query the AN to obtain information on what multicast flows are currently being replicated on a given Access Port, what Access Ports are currently receiving a given multicast flow, or what multicast flows are currently replicated on each Access Port.

4.3. Protocol Design Requirements

R-24 The ANCP SHOULD provide a "shutdown" sequence allowing the protocol to inform the peer that the system is gracefully shutting down.

R-25 The ANCP SHOULD include a "report" model for the Access Node to spontaneously communicate to the NAS changes of states.

R-26 The ANCP SHOULD support a graceful restart mechanism to enable it to be resilient to network failures between the AN and NAS.

R-27 The ANCP MUST provide a means for the AN and the NAS to inform each peer about the supported use cases (either use cases defined in this document or future use cases yet to be defined), and to negotiate a common subset.

4.4. Access Node Control Adjacency Requirements

The notion of an Access Node Control Adjacency is defined in Section 1.2.

R-28 The ANCP MUST support an adjacency protocol in order to automatically synchronize its operational state between its peers, to agree on which version of the protocol to use, to discover the identity of its peers, and to detect when they change.

R-29 The ANCP MUST include a mechanism to automatically detect adjacency loss.

R-30 A loss of the Access Node Control Adjacency MUST NOT affect subscriber connectivity.

R-31 If the Access Node Control Adjacency is lost, it MUST leave the network elements in a known state, irrespective of whether or not the ongoing transaction was successful.

R-32 The ANCP MUST support a mechanism to synchronize access port configuration and status information between ANCP peers as part of establishing or recovering the Access Node Control Adjacency.

4.5. ANCP Transport Requirements

R-33 The Access Node Control Mechanism MUST be defined in a way that is independent of the underlying layer 2 transport technology. Specifically, the Access Node Control Mechanism MUST support transmission over an ATM as well as over an Ethernet aggregation network.

R-34 The ANCP MUST use the IP protocol stack.

R-35 If the layer 2 transport technology is based on ATM, then the ANCP peers must use the encapsulation according to [RFC2684] (IPoA).

R-36 If the layer 2 transport technology is based on Ethernet, then the ANCP peers must use the encapsulation according to [RFC894] (IPoE).

4.6. Access Node Requirements

This section lists the requirements for an AN that supports the use cases defined in this document. Note that this document does not intend to impose absolute requirements on network elements. Therefore, the words "must" and "should" used in this section are not capitalized.

4.6.1. General Architecture

The Access Node Control Mechanism is defined to operate between an Access Node (AN) and a NAS. In some cases, one AN can be connected to more than one physical NAS device (e.g., in case different wholesale service providers have different NAS devices). In such a model, the physical AN needs to be split in virtual ANs, each having its own Access Node Control reporting and/or enforcement function.

R-37 An Access Node as physical device can be split in logical partitions. Each partition may have its independent NAS. Therefore, the Access Node must support at least 2 partitions. The Access Node should support 8 partitions.

R-38 One partition is grouped of several Access Ports. Each Access Port on an Access Node must be assigned uniquely to one partition.

It is assumed that all circuits (i.e., ATM PVCs or Ethernet VLANs) on top of the same physical Access Port are associated with the same partition. In other words, partitioning is performed at the level of the physical Access Port only.

R-39 Each AN partition must have a separate Access Node Control Adjacency to a NAS.

R-40 Each AN partition must be able to enforce access of the controllers to their designated partitions.

R-41 The Access Node should be able to establish and maintain ANCP Adjacencies to redundant controllers.

4.6.2. Control Channel Attributes

The Control Channel is a bidirectional IP communication interface between the controller function (in the NAS) and the reporting/enforcement function (in the AN). It is assumed that this interface is configured (rather than discovered) on the AN and the NAS.

Depending on the network topology, the Access Node can be located in a street cabinet or in a central office. If an Access Node in a street cabinet is connected to a NAS, all user traffic and Access Node Control data can use the same physical link.

R-42 The Control Channel should use the same facilities as the ones used for the data traffic. Note that this is actually a deployment consideration, which has no impact on the actual protocol design.

R-43 The Access Node must process control transactions in real-time (i.e., with a specific response latency).

R-44 The Access Node should mark Access Node Control Protocol messages with a high priority (e.g., Variable Bit Rate - Real Time (VBR-RT) for ATM cells, p-bit 6 or 7 for Ethernet packets) in order to avoid or reduce the likelihood of dropping packets in case of network congestion.

R-45 If ATM interfaces are used, then any Virtual Path Identifier (VPI) and Virtual Circuit Identifier (VCI) value must be able to be used for the purpose of supporting the Access Node Control Channel.

R-46 If Ethernet interfaces are used then any C-VID and S-VID must be able to be used for the purpose of supporting the Access Node Control Channel.

4.6.3. Capability Negotiation Failure

R-47 In case the Access Node and NAS cannot agree on a common set of capabilities, as part of the ANCP capability negotiation procedure, the Access Node must report this to network management.

4.6.4. Adjacency Status Reporting

R-48 The Access Node should support generating an alarm to a management station upon loss or malfunctioning of the Access Node Control Adjacency with the NAS.

4.6.5. Identification

R-49 To identify the Access Node and Access Port within a control domain, a unique identifier is required. This identifier must be in line with the addressing scheme principles specified in Section 3.9.3 of TR-101.

R-50 In a Broadband Forum TR-101 network architecture, an Access Circuit Identifier (ACI) identifying an AN and Access Port is added to DHCP and PPPoE messages. The NAS must use the same ACI format in ANCP messages in order to allow the NAS to correlate this information with the information present in DHCP and PPPoE messages.

4.6.6. Multicast

R-51 The AN must deny any join to a multicast flow matching the black list for the relevant Access Port.

R-52 The AN must accept any join to a multicast flow matching the white list and for which no Bandwidth Delegation is used.

R-53 Upon receiving a join to a multicast flow that matches the white list and for which Bandwidth Delegation is used, the AN must perform the necessary bandwidth admission control check for the new flow before starting the multicast flow replication. This may involve a decision made locally, or querying the NAS or external system such as a policy server, to request additional delegated multicast bandwidth on a given Access Port.

R-54 Upon receiving a join to a multicast flow which matches the grey list and for which no Bandwidth Delegation is used, the AN must support using ANCP to query the NAS to receive a response indicating whether that join is to be honored or denied. In this case, the NAS will perform both the necessary conditional access and the admission control checks for the new flow.

R-55 Upon receiving a join to a multicast flow that matches the grey list and for which Bandwidth Delegation is used, the AN must first perform the necessary bandwidth admission control check for the new flow. If successful, the AN must support using ANCP to query the NAS to receive a response indicating whether that join is to be honored or denied.

R-56 In case of Admission Control with AN Bandwidth Delegation, the AN must support using ANCP to notify the NAS when the user leaves the multicast flow.

R-57 In case of Admission Control with AN Bandwidth Delegation, the AN must support using ANCP to query the NAS to request additional delegated multicast bandwidth on a given Access Port; the AN should be able to specify both the minimum and the preferred amount of additional multicast bandwidth requested.

R-58 In case of Admission Control with AN Bandwidth Delegation, upon receiving a Bandwidth Delegation Request from the NAS querying the AN for the delegated multicast bandwidth on a given Access Port, the AN must support using ANCP to send a Bandwidth Delegation Response, indicating the currently delegated multicast bandwidth.

R-59 In case of Admission Control with AN Bandwidth Delegation, it may happen that the NAS wants to "revoke" all or part of the delegated bandwidth. Part of the previously delegated bandwidth may however be in use by multicast services. Therefore, upon receiving a Bandwidth Delegation Request from the NAS instructing to decrease the delegated multicast bandwidth on a given Access Port, the AN must support using ANCP to send a Bandwidth Delegation Response, indicating the delegated multicast bandwidth after the decrease (indicating how much of the delegated bandwidth can be returned to the NAS without impacting multicast services that are currently running).

R-60 In case of Admission Control with AN Bandwidth Delegation, the AN must support using ANCP to send a Bandwidth Release message to the NAS in order to release unused delegated multicast bandwidth on a given Access Port.

R-61 If the requested multicast flow is not part of any list associated with the Access Port, the AN must discard the message.

R-62 If the requested multicast flow is part of multiple lists associated with the Access Port, the AN must use the most specific match.

R-63 If the requested multicast flow has the same most specific match in multiple lists, the AN must give precedence to the black list, followed by the grey list, and then the white list.

R-64 The AN must support configuring a "catch-all" statement in the black, white, or grey list in order to enforce a default behavior for a join to a multicast flow which doesn't match any other entry in a list for the relevant Access Port.

R-65 Upon querying the NAS, the AN must not propagate the join message before the successful authorization from the NAS is received.

R-66 Upon receiving a leave for a multicast flow that matches the grey list, the AN should be able to autonomously stop replication and advertise this event to the NAS.

R-67 The AN must support using ANCP to send an Information Report message to the NAS whenever replication starts or ends.

R-68 The AN should support using ANCP to send an Information Report message to the NAS indicating the multicast traffic volume that has been replicated on that port.

R-69 Upon request by the NAS, the AN must support using ANCP to send an Information Report message to the NAS, indicating what multicast flows are currently being replicated on a given Access Port.

R-70 Upon request by the NAS, the AN must support using ANCP to send an Information Report message to the NAS, indicating what Access Ports are currently receiving a given multicast flow.

R-71 Upon request by the NAS, the AN must support using ANCP to send an Information Report message to the NAS, indicating what multicast flows are currently being replicated on each Access Port.

R-72 Upon receiving an Admission Response from the NAS, indicating that replication of a multicast flow is to start or stop on a given access port of the AN, the AN must enforce this decision. This decision must be taken irrespective of whether or not a corresponding Admission Request was issued by the AN earlier.

4.6.7. Message Handling

R-73 The Access Node must be designed to allow fast completion of ANCP operations, in the order of magnitude of tens of milliseconds.

R-74 The Access Node should avoid sending bursts of ANCP messages related to notification of line attributes or line state, by spreading message transmission over time.

4.6.8. Parameter Control

Naturally, the Access Node Control Mechanism is not designed to replace an Element Manager managing the Access Node. There are parameters in the Access Node, such as the DSL noise margin and DSL Power Spectral Density (PSD), which are not allowed to be changed via ANCP or any other control session, but only via the Element Manager. This has to be ensured and protected by the Access Node.

When using ANCP for access-loop configuration, the EMS needs to configure on the Access Node which parameters may or may not be modified using the Access Node Control Mechanism. Furthermore, for those parameters that may be modified using ANCP, the EMS needs to specify the default values to be used when an Access Node comes up after recovery.

R-75 When access-loop configuration via ANCP is required, the EMS must configure on the Access Node which parameter set(s) may be changed/controlled using ANCP.

R-76 Upon receiving an Access Node Control Request message, the Access Node must not apply changes to the parameter set(s) that have not been enabled by the EMS.

4.7. Network Access Server Requirements

This section lists the requirements for a NAS that supports the use cases defined in this document. Note that this document does not intend to impose absolute requirements on network elements. Therefore, the words "must" and "should" used in this section are not capitalized.

4.7.1. General Architecture

R-77 The NAS must establish ANCP Adjacencies only with authorized ANCP peers.

R-78 The NAS must support the capability to simultaneously run ANCP with multiple ANs in a network.

R-79 The NAS must be able to establish an Access Node Control Adjacency to a particular partition on an AN and control the access loops belonging to such a partition.

R-80 The NAS must support obtaining access-loop information (e.g., net data rate), from its peer Access Node partitions via the Access Node Control Mechanism.

R-81 The NAS must support shaping traffic directed towards a particular access loop to not exceed the net data rate learned from the AN via the Access Node Control Mechanism.

R-82 The NAS should support reducing or disabling the shaping limit used in the Hierarchical Scheduling process, according to per-subscriber authorization data retrieved from a AAA or policy server.

R-83 The NAS must support reporting of access-loop attributes learned via the Access Node Control Mechanism to a Policy or AAA Server using RADIUS Vendor-Specific Attributes (VSAs).

R-84 In a TR-059/TR-101 network architecture, the NAS shapes traffic sent to a particular Access Port according to the bitrate available on that port. The NAS should take into account the layer 1 and layer 2 encapsulation overhead on the Access Port, retrieved from the AN via the Access Node Control Mechanism.

R-85 The NAS should support dynamically configuring and reconfiguring discrete service parameters for access loops that are controlled by the NAS. The configurable service parameters for access loops could be driven by local configuration on the NAS or by a policy server.

R-86 The NAS should support triggering an AN via the Access Node Control Mechanism to execute local OAM procedures on an access loop that is controlled by the NAS. If the NAS supports this capability, then the following applies:

* The NAS must identify the access loop on which OAM procedures need to be executed by specifying an Access Circuit Identifier (ACI) in the request message to the AN.

* The NAS should support processing and reporting of the remote OAM results learned via the Access Node Control Mechanism.

* As part of the parameters conveyed within the OAM message to the AN, the NAS should send the list of test parameters pertinent to the OAM procedure. The AN will then execute the OAM procedure on the specified access loop according to the specified parameters. In case no test parameters are conveyed, the AN and NAS must use default and/or appropriately computed values.

* After issuing an OAM request, the NAS will consider the request to have failed if no response is received after a certain period of time. The timeout value should be either the one sent within the OAM message to the AN, or the computed timeout value when no parameter was sent.

The exact set of test parameters mentioned above depends on the particular OAM procedure executed on the access loop. An example of a set of test parameters is the number of loopbacks to be performed on the access loop and the timeout value for the overall test. In this case, and assuming an ATM-based access loop, the default value for the timeout parameter would be equal to the number of F5 loopbacks to be performed, multiplied by the F5 loopback timeout (i.e., 5 seconds per the ITU-T I.610 standard).

R-87 The NAS must treat PPP or DHCP session state independently from any Access Node Control Adjacency state. The NAS must not bring down the PPP or DHCP sessions just because the Access Node Control Adjacency goes down.

R-88 The NAS should internally treat Access Node Control traffic in a timely and scalable fashion.

R-89 The NAS should support protection of Access Node Control communication to an Access Node in case of line card failure.

4.7.2. Control Channel Attributes

R-90 The NAS must mark Access Node Control Protocol messages as high priority (e.g., appropriately set Diffserv Code Point (DSCP), Ethernet priority bits, or ATM Cell Loss Priority (CLP) bit) such that the aggregation network between the NAS and the AN can prioritize the Access Node Control Protocol messages over user traffic in case of congestion.

4.7.3. Capability Negotiation Failure

R-91 In case the NAS and Access Node cannot agree on a common set of capabilities, as part of the ANCP capability negotiation procedure, the NAS must report this to network management.

R-92 The NAS must only commence Access Node Control information exchange and state synchronization with the AN when there is a non-empty common set of capabilities with that AN.

4.7.4. Adjacency Status Reporting

R-93 The NAS must support generating an alarm to a management station upon loss or malfunctioning of the Access Node Control Adjacency with the Access Node.

4.7.5. Identification

R-94 The NAS must support correlating Access Node Control Protocol messages pertaining to a given access loop with subscriber session(s) over that access loop. This correlation must be achieved by either:

* Matching an Access Circuit Identifier (ACI) inserted by the AN in Access Node Control Protocol messages with the corresponding ACI value received in subscriber signaling (e.g., PPPoE and DHCP) messages as inserted by the AN. The format of ACI is defined in [TR-101]; or

* Matching an ACI inserted by the AN in Access Node Control Protocol messages with an ACI value locally configured for a static subscriber on the NAS.

4.7.6. Multicast

R-95 The NAS must support using ANCP to configure multicast conditional access information to Access Ports on an Access Node, using black lists, grey lists, and white lists.

R-96 The NAS must support using ANCP to indicate to the AN whether or not Admission Control is needed for some multicast flows on a given Access Port and where needed whether or not the Access Node is authorized to perform Admission Control itself (i.e., whether or not AN Bandwidth Delegation applies).

R-97 Upon receiving a query from the AN for a request to replicate a multicast flow to a particular Access Port, and no AN Bandwidth Delegation is used for that flow, the NAS must be able to perform the necessary checks (conditional access and/or admission control) for the new flow. The NAS must support using ANCP to reply to the AN indicating whether the request is to be honored or denied. This may involve a decision made locally or querying an external system such as a policy server.

R-98 Upon receiving a query from the AN for a request to replicate a multicast flow to a particular Access Port, and Admission Control with AN Bandwidth Delegation is used for that flow, the NAS must be able to perform the conditional access checks (if needed), and must support using ANCP to delegate a certain amount of bandwidth to the AN for a given Access Port.

R-99 In case of Admission Control with AN Bandwidth Delegation, upon receiving a Bandwidth Delegation Request from the AN requesting to increase the delegated multicast bandwidth on a given Access Port, the NAS must support using ANCP to send a Bandwidth Delegation Response indicating the new delegating multicast bandwidth.

R-100 In case of Admission Control with AN Bandwidth Delegation, the NAS must support using ANCP to send a request to the AN to decrease the amount of multicast bandwidth previously delegated on a given Access Port; the NAS should be able to specify both the minimum and the preferred amount of decrement of multicast bandwidth requested.

R-101 In case of Admission Control with AN Bandwidth Delegation, upon receiving an ANCP Bandwidth Release message, the NAS must be able to update accordingly its view of the multicast bandwidth delegated to the AN.

R-102 The NAS must support using ANCP to configure the Access Node with the "maximum number of multicast streams" allowed to be received concurrently per Access Port.

R-103 The NAS must support using ANCP to incrementally add, remove, and modify individual entries in white, black, and grey lists.

R-104 The NAS must support using ANCP to indicate to the AN whether or not multicast accounting is needed for a multicast flow on a particular Access Port.

R-105 In case multicast accounting is needed for a multicast flow on a particular Access Port, the NAS should support using ANCP to indicate to the AN whether or not additional volume accounting information is required.

R-106 The NAS must support using ANCP to query the AN to obtain information on what multicast flows are currently replicated on a given Access Port.

R-107 The NAS must support using ANCP to query the AN to obtain information on what Access Ports are currently receiving a given multicast flow.

R-108 The NAS must support using ANCP to query the AN to obtain information on what multicast flows are currently replicated on each Access Port.

R-109 When Multicast replication occurs on the AN, the NAS must support using ANCP to revoke the authorization to replicate a multicast flow to a particular Access Port.

R-110 The NAS should support using ANCP to indicate to the AN that replication of a multicast flow is to start or stop on a given access port of the AN, without having received a corresponding Admission Request from the AN earlier on.

4.7.7. Message Handling

R-111 The NAS must be designed to allow fast completion of ANCP operations, in the order of magnitude of tens of milliseconds.

R-112 The NAS should protect its resources from misbehaving Access Node Control peers by providing a mechanism to dampen information related to an Access Node partition.

4.7.8. Wholesale Model

Broadband Forum TR-058 [TR-058], Broadband Forum TR-059 [TR-059], and Broadband Forum TR-101 [TR-101] describe a DSL broadband access architecture and how it enables wholesaling. In such a model, the broadband access provider has a wholesale agreement with one or more service providers. The access provider owns the broadband access network and manages connectivity to the service providers. This allows service providers to provide broadband services to retail customers without having to own the access network infrastructure itself.

When applying the Access Node Control Mechanism to a wholesale network architecture, a number of additional requirements apply.

R-113 In case of wholesale access, the network provider's NAS should support reporting of access-loop attributes learned from the AN via the Access Node Control Mechanism (or values derived from such attributes), to a retail provider's network gateway owning the corresponding subscriber(s).

R-114 In case of Layer 2 Tunneling Protocol (L2TP) wholesale, the NAS must support a proxy architecture that gives different providers conditional access to dedicated Access Node Control resources on an Access Node.

R-115 The NAS when acting as an L2TP Access Concentrator (LAC) must communicate generic access-line-related information to the L2TP Network Server (LNS) in a timely fashion.

R-116 The NAS when acting as a LAC may asynchronously notify the LNS of updates to generic access-line-related information.

5. Management-Related Requirements

This section lists the management-related requirements for the AN and NAS. Note that this document does not intend to impose absolute requirements on network elements. Therefore, the words "must" and "should" used in this section are not capitalized.

R-117 It must be possible to configure the following parameters on the Access Node and the NAS:

* Parameters related to the Control Channel transport method: these include the VPI/VCI and transport characteristics (e.g., VBR-RT or Constant Bitrate (CBR)) for ATM networks, or the C-VLAN ID, S-VLAN ID, and p-bit marking for Ethernet networks;

* Parameters related to the Control Channel itself: these include the IP address of the IP interface on the Access Node and the NAS.

R-118 When the operational status of the Control Channel is changed (up>down, down>up) a linkdown/linkup trap should be sent towards the EMS. This requirement applies to both the AN and the NAS.

R-119 The Access Node must provide the possibility using SNMP to associate individual DSL lines with specific Access Node Control Adjacencies.

R-120 The Access Node must notify the EMS of configuration changes made by the NAS on the AN using ANCP, in a timely manner.

R-121 The Access Node must provide a mechanism that allows the concurrent access on the same resource from several managers (EMS via SNMP, NAS via ANCP). Only one manager may perform a change at a certain time.

R-122 The ANCP may provide a notification mechanism to inform the NAS about configuration changes done by an EMS, in a timely manner. This applies only to changes of parameters that are part of the use case "Access-Loop Configuration" (Section 3.2).

6. Security Considerations

[RFC5713] lists the ANCP-related security threats that could be encountered on the Access Node and the NAS. It develops a threat model and identifies requirements for ANCP security, aiming to decide which security functions are required at the ANCP level.

With multicast handling as described in this document, ANCP protocol activity between the AN and the NAS is triggered by join/leave requests coming from the end-user equipment. This could potentially be used for denial-of-service attacks against the AN and/or the NAS.

This is not a new class of risk over already possible IGMP messages sent from subscribers to the NAS when the AN uses no IGMP snooping, and thus is transparent as long as processing of ANCP messages on the NAS/AN is comparably efficient and protected against congestion.

To mitigate this risk, the AN MAY implement control-plane protection mechanisms such as limiting the number of multicast flows a given user can simultaneously join, or limiting the maximum rate of join/leave from a given user.

We also observe that an operator can easily deploy some protection against attacks using invalid multicast flows by taking advantage of the mask-based match in the black list. This way, joins for invalid multicast flows can be denied at the AN level without any ANCP protocol interactions and without NAS involvement.

R-123 The ANCP MUST comply with the security requirements spelled out in RFC 5713.

R-124 The Access Node MUST NOT allow the sending of Access Node Control Messages towards the customer premises.

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8. References

8.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2684] Grossman, D. and J. Heinanen, "Multiprotocol Encapsulation over ATM Adaptation Layer 5", RFC 2684, September 1999.

[RFC5713] Moustafa, H., Tschofenig, H., and S. De Cnodder, "Security Threats and Security Requirements for the Access Node Control Protocol (ANCP)", RFC 5713, January 2010.

[RFC894] Hornig, C., "A Standard for the Transmission of IP Datagrams over Ethernet Networks", STD 41, RFC 894, April 1984.

[TR-101] Cohen, A. and E. Shrum, "Migration to Ethernet-Based DSL Aggregation", Broadband Forum TR-101, May 2006.

8.2. Informative References

[G.993.2] ITU-T, "Very high speed digital subscriber line transceivers 2 (VDSL2)", ITU-T Rec. G.993.2, Feb 2006.

[G.997.1] ITU-T, "Physical layer management for digital subscriber line (DSL) transceivers", ITU-T Rec. G.997.1, Sep 2005.

[RFC2225] Laubach, M. and J. Halpern, "Classical IP and ARP over ATM", RFC 2225, April 1998.

[RFC2364] Gross, G., Kaycee, M., Lin, A., Malis, A., and J. Stephens, "PPP Over AAL5", RFC 2364, July 1998.

[RFC2516] Mamakos, L., Lidl, K., Evarts, J., Carrel, D., Simone, D., and R. Wheeler, "A Method for Transmitting PPP Over Ethernet (PPPoE)", RFC 2516, February 1999.

[RFC2881] Mitton, D. and M. Beadles, "Network Access Server Requirements Next Generation (NASREQNG) NAS Model", RFC 2881, July 2000.

[RFC3376] Cain, B., Deering, S., Kouvelas, I., Fenner, B., and A. Thyagarajan, "Internet Group Management Protocol, Version 3", RFC 3376, October 2002.

[RFC4607] Holbrook, H. and B. Cain, "Source-Specific Multicast for IP", RFC 4607, August 2006.

[TR-058] Elias, M. and S. Ooghe, "Multi-Service Architecture & Framework Requirements", Broadband Forum TR-058, September 2003.

[TR-059] Anschutz, T., "DSL Evolution - Architecture Requirements for the Support of QoS-Enabled IP Services", Broadband Forum TR-059, September 2003.

[TR-147] Voigt, N., Ooghe, S., and M. Platnic, "Layer 2 Control Mechanism For Broadband Multi-Service Architectures", Broadband Forum TR-147, November 2008.

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