International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.2112

(06/2007)

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Next Generation Networks – Quality of Service and performance

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A QoS control architecture for Ethernet-based IP access networks

ITU-T Recommendation Y.2112

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ITU-T Recommendation Y.2112

A QoS control architecture for Ethernet-based IP access networks

Summary

ITU-T Recommendation Y.2112 specifies a QoS control architecture for Ethernet-based IP access networks. By applying the resource and admission control functions specified in ITU-T Recommendation Y.2111 and Ethernet-specific QoS mechanisms, it enables dynamic QoS control in the access network for a variety of services, such as voice over IP, video on demand and bandwidth on demand.

Source

ITU-T Recommendation Y.2112 was approved on 13 June 2007 by ITU-T Study Group 13 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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A QoS control architecture for Ethernet-based IP access networks

1 Scope

This Recommendation specifies a quality of service (QoS) control architecture and requirements covering aspects, such as resource reservation, admission control and gate control, for Ethernet-based IP access networks. Based on the resource and admission control functions (RACF) as defined in [ITU-T Y.2111], this Recommendation provides details specific to Ethernet-based IP access networks. An Ethernet-based IP access network is an IP access network which comprises the Ethernet aggregation network, access nodes, and edge nodes, and may also include the IP aggregation network.

In this Recommendation, the Ethernet aggregation network supports VLANs as defined in [b-IEEE 802.1Q] and [b-IEEE 802.1ad]. Note that the QoS mechanisms for the last mile user access segment are MAC technology-specific and as such are out of the scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.1231] ITU-T Recommendation Y.1231 (2000), *IP access network architecture*.

[ITU-T Y.2091] ITU-T Recommendation Y.2091 (2007), *Terms and definitions for Next Generation Networks*.

[ITU-T Y.2111] ITU-T Recommendation Y.2111 (2006), *Resource and admission control functions in Next Generation Networks*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 absolute QoS [ITU-T Y.2111]: This term refers to a traffic delivery service with numerical bounds on some or all of the QoS parameters. These bounds may be physical limits, or enforced limits such as those encountered through mechanisms like rate policing. The bounds may result from designating a class of network performance objectives for packet transfer.

3.1.2 gate control [ITU-T Y.2111]: The operation of opening or closing a gate. When a gate is open, the packets in the media flows are allowed to pass through; when a gate is closed, the packets in the media flows are not allowed to pass through.

3.1.3 IP access network [ITU-T Y.1231]: An implementation comprising network entities to provide the required access capabilities between an "IP user" and an "IP service provider" for the provision of IP services. "IP user" and "IP service provider" are logical entities which terminate the IP layer and/or IP related functions, and may also include lower layer functions.

3.1.4 IP core network [ITU-T Y.1231]: IP service provider's network, including one or more IP service providers.

3.1.5 media flow [ITU-T Y.2111]: A unidirectional media stream, which is specified by two endpoint identifiers and bandwidth, as well as class of service, if needed.

3.1.6 relative QoS [ITU-T Y.2111]: This term refers to a traffic delivery service without absolute bounds on the achieved bandwidth, packet delay or packet loss rates. It describes circumstances where certain classes of traffic are handled differently from other classes of traffic, and the classes achieve different levels of QoS.

3.1.7 session [ITU-T Y.2091]: A temporary telecommunication relationship among a group of objects in the service stratum that are assigned to collectively fulfil a task for a period of time. A session has a state that may change during its lifetime. Session-based telecommunications may, but need not be, assisted by intermediaries (see mediated services). Session-based telecommunications can be one-to-one, one-to-many, many-to-one, or many-to-many.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 edge router: An edge router is a router that operates at the edge of access network and aggregates IP datagrams from access network into the core network.

3.2.2 Ethernet-based IP access network: An IP access network that comprises the Ethernet aggregation network, access nodes (such as DSLAM), and edge nodes (such as BRAS) and may also include the IP aggregation network. Edge nodes are typically IP capable. Access nodes may be IP capable.

3.2.3 IP flow: A sequence of packets sent from a particular source to a particular destination, to which common routing is applied.

3.2.4 last mile user access: The portion of the access network between the CPE and the access node.

NOTE – If using IPv4, a flow is identified by the IPv4 5-tuple which includes source/destination IP addresses, protocol ID and source/destination port numbers. If using IPv6, a flow is identified by the IPv6 3-tuple which includes source/destination IP addresses and flow label.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAA Authentication, Authorization and Accounting

AN Access Node

APP Application Layer

BE Best Effort

BoD Bandwidth on Demand

BRAS Broadband Remote Access Server

CDN Content Delivery Network

CPE Customer Premises Equipment

CPN	Customer Premises Network
DHCP	Dynamic Host Configuration Protocol
DSCP	Differentiated Services Code Point
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
DST	Destination
EAP	Extensible Authentication Protocol
EN	Edge Node
ER	Edge Router
EXP	Experimental bits
GRE	Generic Routing Encapsulation
HTTP	HyperText Transfer Protocol
ID	Identifier
IMN	InterMediate Node
IP	Internet Protocol
L2TP	Layer 2 Tunnelling Protocol
LLDP	Link Layer Discovery Protocol
LSP	Label Switched Path
MAC	Media Access Control
MPLS	Multi-Protocol Label Switching
NACF	Network Attachment Control Function
PD-FE	Policy Decision Functional Entity
PE-FE	Policy Enforcement Functional Entity
PHB	Per Hop Behaviour
PHY	Physical Layer
PPP	Point-to-Point Protocol
QoS	Quality of Service
RACF	Resource and Admission Control Function
RSVP	Resource ReSerVation Protocol
SCF	Service Control Function
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SRC	Source
STP	Spanning Tree Protocol
S-VLAN	Service Virtual Local Area Network
TCP	Transmission Control Protocol
TRC-FE	Transport Resource Control Functional Entity

TRE-FE	Transport Resource Enforcement Functional Entity
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
VoD	Video on Demand
VoIP	Voice over IP
VPN	Virtual Private Network
WLAN	Wireless Local Area Network

5 Conventions

This clause is intentionally left blank.

6 Ethernet-based IP access network reference models

This Recommendation assumes that the Ethernet-based IP access network is comprised of: a last mile user access facility, an Ethernet aggregation network, an access node that may be IP capable (e.g., DSLAM), an edge node that is IP capable (e.g., BRAS) and may also include the IP aggregation network. See Figure 1 below. It also assumes that an Ethernet-based IP access network may support several different types of the last mile user access technologies. For example, an Ethernet-based IP DSLAM may support LAN/xDSL/WLAN user access, and different types of access nodes may be deployed and aggregated to the same BRAS. Additionally, it assumes that the BRAS may serve as an edge router; in that case there is no IP level aggregation performed. In this Recommendation, the edge node (EN) acts as the egress of upstream traffic that connects the IP access network to the core network. It may represent either a BRAS or ER.

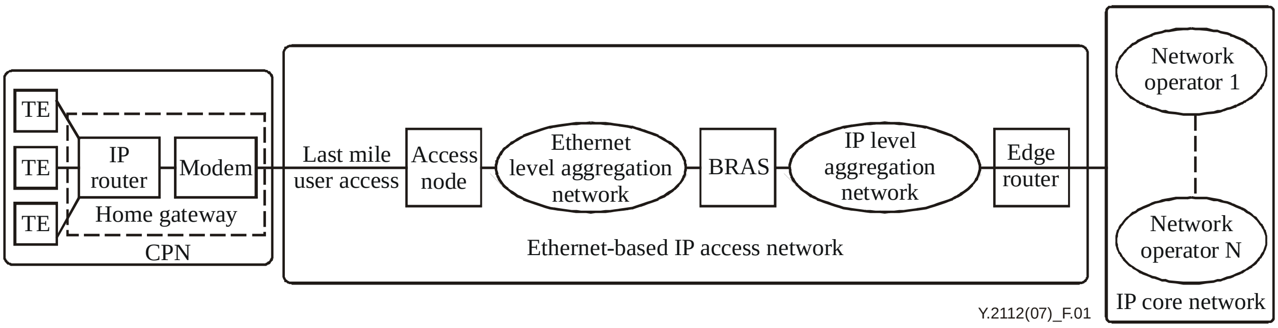

Figure 1 – Generic architectural and topological model of Ethernet-based IP access network

Generally, L2 or L3 switches are used for Ethernet level traffic aggregation per subscriber, and L3 switches or IP routers are used for IP level aggregation per QoS class or service type.

Home gateways may consist of modems and an IP router; however, either element can be optional depending on the type of last mile user access technology.

The access node terminates the last mile access facility on the network side, and physically may be a single device or a chain of subtended devices. It may be located at a central office or a remote site or both. It must have one or more Ethernet uplink interfaces when residing in an Ethernet-based IP access network.

The broadband remote access server (BRAS) terminates the user access link (e.g., PPP, EAP [b-IETF RFC 2284], VLAN), performs network access control, and aggregates the user traffic into a VLAN, VPN, or tunnel as with native IP traffic. It must have one or more Ethernet downlink interfaces and be able to terminate its Ethernet layer when residing in an Ethernet-based IP access network. The BRAS also provides: policy management, AAA and DHCP interfaces; user access control, and assigns user IP addresses.

The edge router (ER) is an egress IP router which connects an IP access network to one or multiple IP service providers in an IP core network. An edge router may aggregate IP traffic from one or multiple BRAS. It may also contain NAT and/or firewall elements.

Figure 2 uses PPP as an example to illustrate the protocol layered model of an Ethernet-based IP access network.

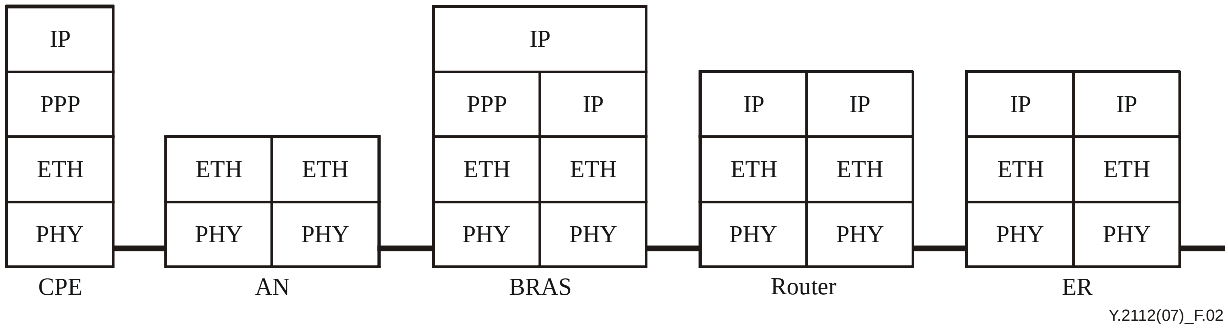

Figure 2 – An example of protocol layered model of an Ethernet-based IP access network

7 Requirements for support of dynamic QoS control

Ethernet-based IP access networks conforming to this Recommendation are required to be able to:

1) Support dynamic QoS control for a variety of services, such as voice over IP, video on demand and bandwidth on demand. The QoS control procedure may be triggered by application layer protocols such as SIP, H.323, HTTP, etc.

2) Support QoS differentiation based on service types and users.

3) Support absolute QoS and relative QoS.

4) Support admission control on a per flow basis. The service layer informs the transport layer of the flow description (IPv4 5-tuple or IPv6 3-tuple). The service layers determine the QoS requirements for a media flow based on the service type, service level agreement (SLA) or user explicit QoS request and inform the requirements to the transport layer.

It is desirable for Ethernet-based IP access networks conforming to this Recommendation to also be able to:

5) Support admission control for media flows with QoS requirements based on user profiles, SLA, operator policy rules and network resource availability. The traditional policy control framework [b-IETF RFC 2475] only makes allowance for admission control at per-user or per-network level based on SLA and policy rules.

6) Collect the network topology and resource information by static or dynamic means.

8 Functional architecture for support of dynamic QoS control

Figure 3 illustrates a reference architecture for support of dynamic QoS control over Ethernet-based IP access networks.

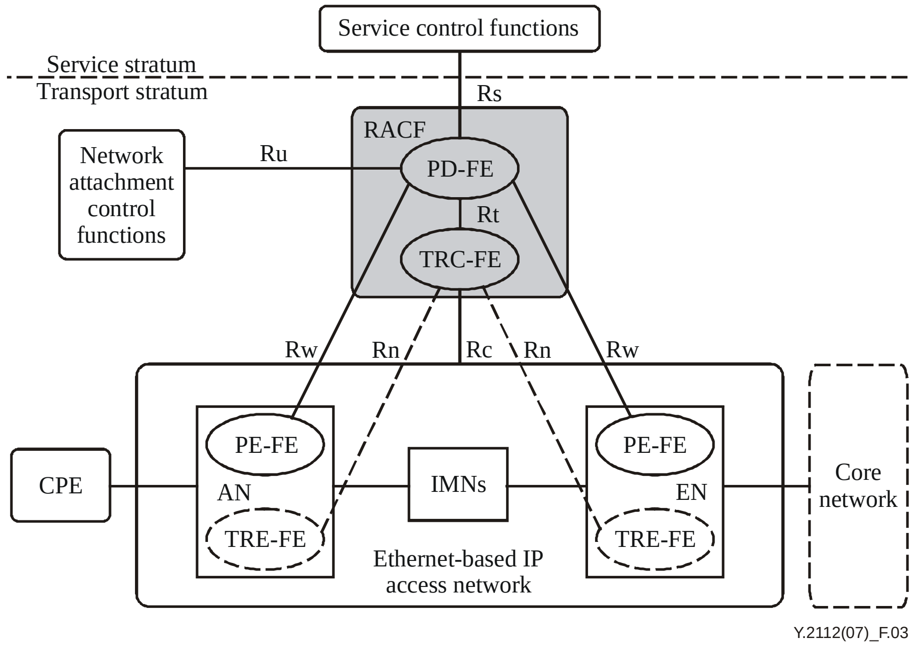

Figure 3 – Functional architecture for support of dynamic QoS control

8.1 Overview

The reference architecture allows different applications over various types of access networks which may use different transport technologies.

The service control functions (SCF) deals with service requests. SCF determines the QoS requirements (including bandwidth and QoS classes) of each media flow by inspecting the type of service or user explicit QoS request in application layer signalling (e.g., in SDP). It then sends the resource request to the resource and admission control functions (RACF) via the Rs reference point. SCF is service specific and may be realized in any service subsystems offering services that require the control of transport resources, e.g., IP multimedia subsystem. SCF may be implemented as a stand-alone box or as a function module embedded in other equipment.

RACF deals with resource requests containing specific QoS requirements for IP flows. RACF receives the QoS request from SCF and maps the service QoS parameters and priority to transport QoS parameters and priority. RACF makes admission control, path selection and resource allocation for the resource request of a media flow based on user profile, SLA, operator policy rules and network resource availability. Note that path selection in RACF means the selection of ingress and egress points within a single domain to satisfy QoS resource requirements rather than network routing. If the QoS request from SCF is admitted, RACF installs the QoS admission decision to AN/EN. RACF will maintain the network topology and resource status information when the resource status or topology changes. Generally, interface or network failure will cause topology and resource status change. RACF may be implemented as stand-alone equipment or as a function module embedded in other equipment.

Transport functions of the Ethernet-based IP access network include three types of network nodes: access node (AN), edge node (EN) and intermediate node (IMN). Note that IMNs represent the network elements located in Ethernet aggregation network in the IP access network (see Figure 1).

Customer premises equipment (CPE) refers to all the devices in a CPN. It generally is a customer terminal, e.g., SIP terminal. It is assumed that CPN should be able to forward customer packets without congestion, and ensure the QoS of the customer flows within the CPN.

8.2 QoS mechanisms

8.2.1 Support of relative QoS

For support of relative QoS, RACF enforces its admission control decision at the aggregate or flow level via the Rn or Rw reference point. AN and EN are required to classify, mark, police, shape, queue and schedule the traffic entering and leaving the access network according to the QoS configuration. IMN forwards the packets according to the priority marked by AN/EN. It is desirable that the requirements of the Rn, Rw and Rc reference points conform to the policy control framework [b-IETF RFC 2475].

8.2.2 Support of absolute QoS

For support of absolute QoS, it is required to avoid bandwidth contention and traffic congestion within the network in addition to perform bandwidth policing and traffic shaping at the edge of the network. There is one way to achieve this:

Give RACF the full awareness of a logical tree-based network topology and the link resource attributes of the whole access network. RACF makes admission control based on this awareness to ensure that sufficient resources are available within the network for the current media flows with absolute QoS requirements. The logical tree-based network topology can be achieved by enabling spanning tree protocol (STP) or static configuration (e.g., configuring VLANs) or retrieving the topology and resource status information from a network management system.

If the AN is a Layer 2 device without IP capability, RACF is required to perform gate control only at EN via the Rw reference point. If the AN is IP capable, RACF is required to perform gate control at both AN and EN via the Rw reference point.

8.3 Resource and admission control function (RACF)

As defined in [ITU-T Y.2111], RACF consists of two functional entities: policy decision functional entity (PD-FE) and transport resource control functional entity (TRC-FE).

8.4 Policy decision functional entity (PD-FE)

The PD-FE handles the QoS resource requests received from the SCF via the Rs reference point or from PE-FE via the Rw reference point.

8.5 Transport resource control functional entity (TRC-FE)

The TRC-FE is responsible for transport technology dependent resource control. The basic functions of TRC-FE are described in [ITU-T Y.2111]. A TRC-FE over an Ethernet-based IP access network contains the following functions:

– Network topology maintenance: In an IEEE 802.1Q/802.1ad enabled Ethernet, most nodes handle packets using MAC bridging or virtual bridging based on MAC addresses and VLAN IDs. Generally, the active network topology is loop-free and is fully connected by means of spanning tree protocol [b-IEEE 802.1Q]. TRC-FE may collect the topology using SNMP or by static configuration.
– Network resource maintenance: This function collects and maintains the transport resource status information via the Rc reference point.

- QoS mapping-technology dependent: This function maps the network QoS parameters and classes received from the PD-FE via the Rt reference point to transport (technology dependent) QoS parameters and classes based on specific transport policy rules, and accommodating the diversity of transport technologies. In the case of Ethernet-based IP access networks, TRC-FE maps the network QoS parameters and classes into IEEE 802.1Q/802.1ad VLAN priorities and traffic classes (e.g., the mapping of [b-ITU-T Y.1541] QoS classes and VLAN priority/traffic classes). Note that, according to [b-IEEE 802.1Q], a given port has one or more queues and each queue corresponds to a distinct traffic class. Each frame is mapped to a traffic class using the traffic class table for the port and the frame's priority. Up to eight traffic classes may be supported, allowing separate queues for each priority.
- Technology dependent decision point: This function receives and responds to the QoS resource request from PD-FE via the Rt reference point.
- Control of transport resource enforcement: This function controls TRE-FE to enforce the transport resource policy rules at the technology-dependent aggregate level via Rn reference point. The transport policy rules may include bandwidth allocation/rate limiting, marking/remarking, shaping/policing, etc. It should be noted that all these policy rules should be based on IEEE 802.1Q/802.1ad VLAN.

8.6 Transport functions

Transport functions of the Ethernet-based IP access network include three types of network nodes: access node (AN), edge node (EN) and intermediate node (IMN). PE-FE or TRE-FE or both may be located in AN and EN. PE-FE and TRE-FE are defined in [ITU-T Y.2111].

8.6.1 Access node (AN)

The AN directly connects to the CPN and terminates the first/last mile link signals such as Ethernet, xDSL, cable, GPON/EPON, etc. Generally, it is a Layer 2 device which may have IP awareness. PE-FE located in AN enforces the network policy rules at per flow level and TRE-FE located in AN enforces the transport resource policy rules at per aggregate level. QoS mechanisms of AN include buffer management, queuing and scheduling, packet filtering, traffic classification, marking, policing, and shaping. The PE-FE/TRE-FE located in AN performs QoS control functions at the flow level or aggregate level under the control of the RACF via the Rn or Rw reference points.

8.6.1.1 PE-FE located in AN

If PE-FE is located in AN, it enforces the transport resource policy rules at flow level in the upstream direction. The functions of PE-FE include:

- Opening and closing gate.
- Rate limiting and bandwidth allocation.
- Traffic classification and marking.
- Traffic policing and shaping.
- Mapping of IP-layer QoS information (e.g., DiffServ code point) onto IEEE 802.1Q/802.1ad VLAN priority/traffic class.
- Collecting and reporting resource usage information (e.g., start-time, end-time, octets of sent data).

Note that PE-FE located in AN has only part of the PE-FE functions defined in [ITU-T Y.2111].

8.6.1.2 TRE-FE located in AN

If TRE-FE is located in AN, it enforces the transport resource policy rules at aggregate level in upstream direction. The functions of TRE-FE include:

– Rate limiting and bandwidth allocation.

– Traffic classification and marking.

– Traffic policing and shaping.

– Collecting and reporting resource usage information (e.g., start-time, end-time, octets of sent data).

TRE-FE should be able to perform the above functions on a per aggregate level basis including user port (physical port or logical port), Ethertype, VLAN ID, and VLAN priority.

8.6.2 Intermediate node (IMN)

IMN refers to all the network nodes between EN and AN in an Ethernet-based IP access network. Generally, IMNs consist of Ethernet switches.

The nodes within the Ethernet aggregation network are required to be S-VLAN bridges according to [b-IEEE 802.1ad] and are required to be configurable on a per S-VLAN basis. An IMN contains the following functions:

– Queuing and scheduling: The IMN must support at least 4 traffic classes for Ethernet frames, and configurable mapping to these traffic classes from 8 possible VLAN priorities. It must support strict priority scheduling, and should be able to support weighted priority scheduling which provides support of mapping DiffServ PHBs to VLAN priorities.

– Collecting and reporting resource status information: The IMN must collect and report the resources status information including:

    1) the physical ports resource status;

    2) the S-VLAN ports resource status.

8.6.3 Edge node (EN)

EN acts as the egress of upstream traffic that connects the IP access network to the core network. It is a Layer 3 device with routing capabilities. A PE-FE is located in EN and performs QoS mechanisms dealing with the user traffic directly, including buffer management, queuing and scheduling, packet filtering, traffic classification, marking, policing, and shaping. As a key injection node for support of dynamic QoS control, the EN with PE-FE performs QoS control functions at flow level under the control of the RACF via the Rw reference point. A TRE-FE may be located in EN and enforces the transport resource policy rules at a per aggregate level.

8.6.3.1 PE-FE located in EN

PE-FE located in EN performs the same functions as defined in clause 8.6.1.1. Note that it enforces the transport resource policy rules in upstream and downstream directions if there is no PE-FE located in AN.

8.6.3.2 TRE-FE located in EN

TRE-FE located in EN performs the same functions as defined in clause 8.6.1.2. Note that it enforces the transport resource policy rules at aggregate level in downstream direction.

9 Reference point requirements

This clause defines the reference point requirements for support of the dynamic QoS control.

9.1 Rs between SCF and PD-FE

The Rs reference point is the same as defined in [ITU-T Y.2111].

9.2 Rt between PD-FE and TRC-FE

The Rt reference point is the same as defined in [ITU-T Y.2111].

9.3 Ru between PD-FE and NACF

The Ru reference point is the same as defined in [ITU-T Y.2111].

9.4 Rw between PD-FE and PE-FE

The Rw reference point is the same as defined in [ITU-T Y.2111].

9.5 Rc between TRC-FE and access network nodes

The TRC-FE interacts with the access network nodes through the Rc reference point. The main function of this reference point is to gather information on resource attributes (e.g., bandwidth) and network topology.

Network topology and resource attributes collection is the basis for making flow route determination, admission control and resource allocation for support of dynamic QoS control.

TRC-FEs conforming to this Recommendation are required to be able to:

– Timely and accurately gather the link layer topology and resource attributes from transport elements via the Rc reference point. Note that the topology and resource information may be provisioned in the TRC-FE.

– Timely and accurately track the changes of the link layer topology and resource attributes via the Rc reference point.

– Timely and accurately track the changes of the topology and resource attributes of the logical network connections via the Rc reference point.

– Request notification of events (e.g., link or port failure) from a transport element to update the resource status information.

It is desirable for TRC-FEs conforming to this Recommendation to also be able to:

– Timely and accurately gather the topology and resource attributes of the logical network connections (e.g., S-VLAN) from transport elements via the Rc reference point. Note that the topology and resource information for the logical network connections may be provisioned in the TRC-FE.

– Timely and accurately gather the topology and resource attributes at the Ethernet traffic class level (e.g., 802.1p).

– Timely and accurately track the changes of the topology and resource attributes at the Ethernet traffic class level (e.g., 802.1p).

The details of the Rc reference point are for further study.

9.6 Rn between TRC-FE and TRE-FE

The Rn reference point is for further study.

10 Procedures for support of dynamic QoS control

This clause defines the procedures that can be applied in the reference architecture for support of dynamic QoS control.

10.1 Network topology and resource attributes collection

Topology and resource attributes of the Ethernet-based IP access network can be obtained by means of static configuration or dynamic collection. In the case of dynamic collection, the information can be acquired from the MIBs of the network nodes via a defined protocol and then sorted together. The logical connection state is available in the VLAN MIB. The spanning tree state is available in the Bridge MIB. The link speed is available in the Interface MIB. The adjacent device connectivity is available in the LLDP MIB (link layer discovery protocol [b-IEEE 802.1AB]). The acquired network topology and resource attributes and the resource allocation status are stored in the network topology and resource status information, which is generally maintained on TRC-FE. Flow admission control, route determination and resource allocation are done on the basis of user profiles, SLAs, operator policy rules and network topology and resource status information.

10.2 Resource allocation

The procedure of resource allocation as illustrated in Figure 4 is the same as that defined in [ITU-T Y.2111].

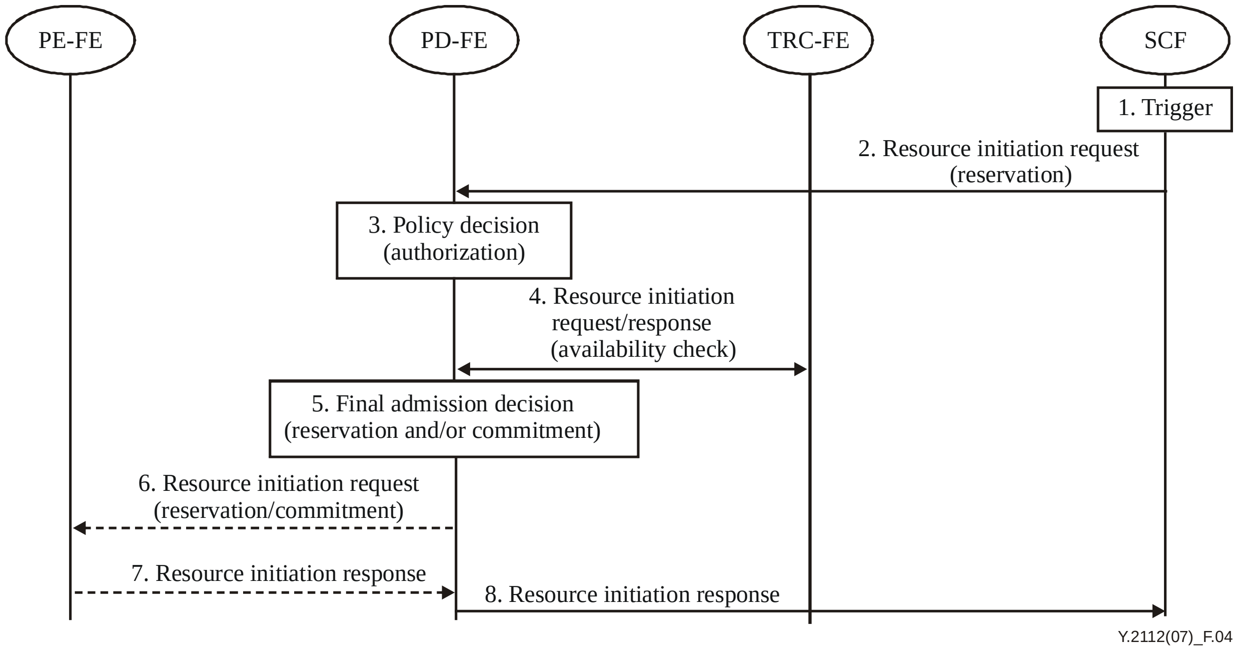

Figure 4 – Resource allocation procedure

10.3 Resource modification

The procedure of resource modification as illustrated in Figure 5 is the same as that defined in [ITU-T Y.2111].

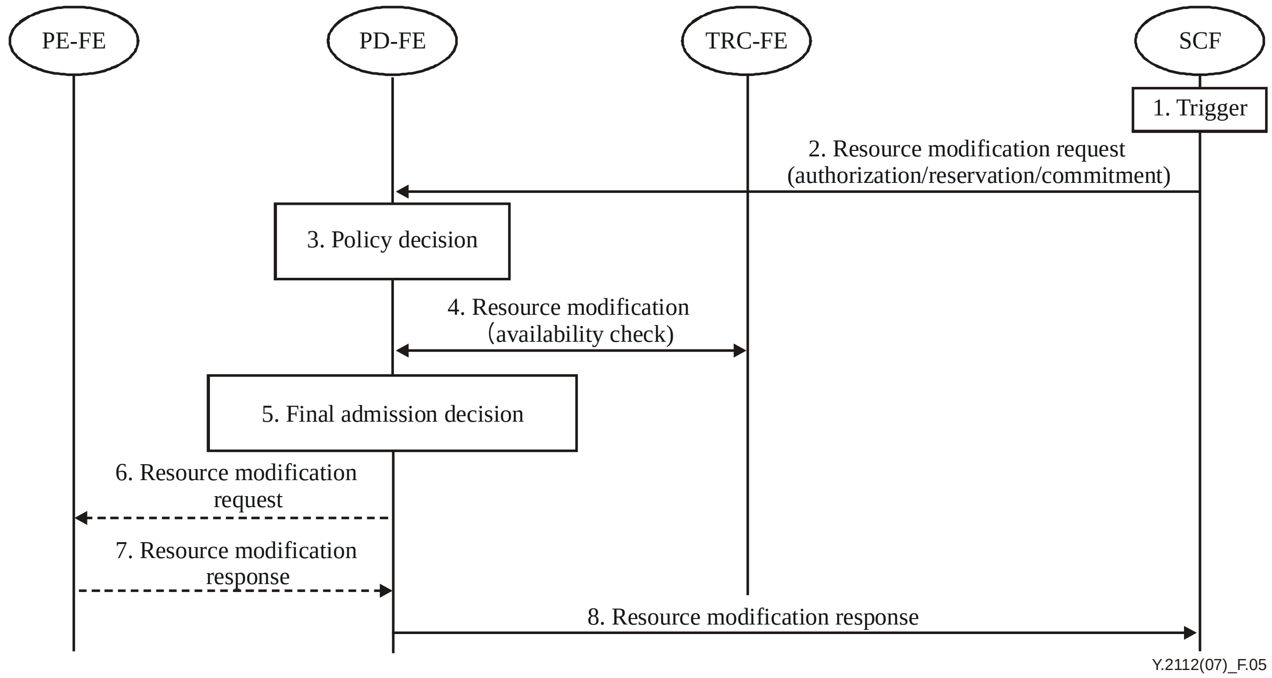

Figure 5 – Resource modification procedure

10.4 Resource release

The procedure of resource release as illustrated in Figure 6 is the same as that defined in [ITU-T Y.2111].

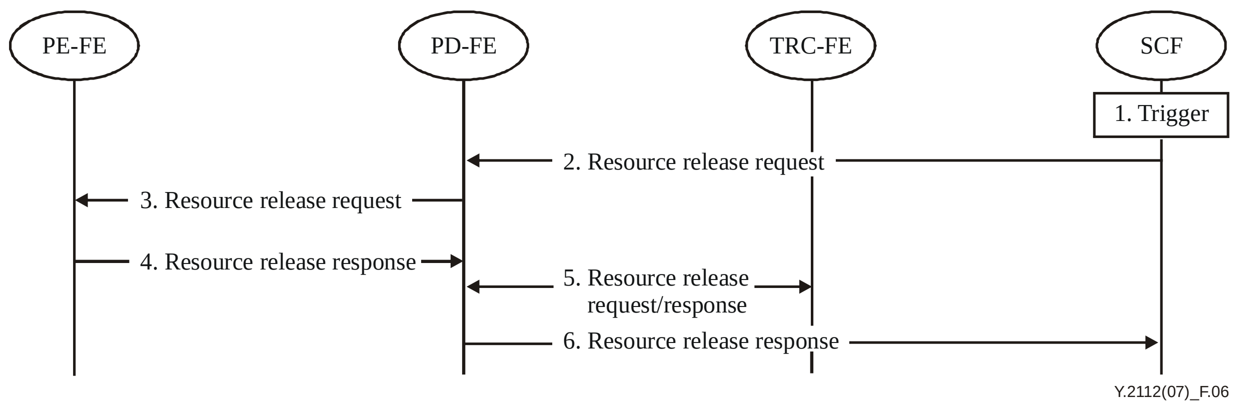

Figure 6 – Resource release procedure

10.5 Failure handling

This clause introduces the procedure of resource release due to interface failure or network failure. AN/EN will trigger the resource release procedure if AN/EN is not able to provide the reserved QoS resource any longer for the media flow due to its interface failure; TRC-FE will trigger resource release procedure if TRC-FE perceives the network is not able to provide the reserved QoS resource any longer for the media flow due to network failure.

10.5.1 TRE-FE-indicated resource release procedure

As shown in Figure 7, TRE-FE should release all resources related to the failed interface and send "Resource Unavailable Indication" to TRC-FE. The resources related to the failed interface are marked as unavailable in network topology and resource information. TRC-FE sends a Resource Notification to the PD-FE on its own initiative. PD-FE forwards "Resource Notification" to SCF if the reserved QoS resource is relevant with an SCF session. A message containing flows description is sent from TRC-FE to PE-FE, and then the PE-FE removes the identifications and classifications of the flows including the identifications and classifications of the opposite direction flows for the bidirectional flows.

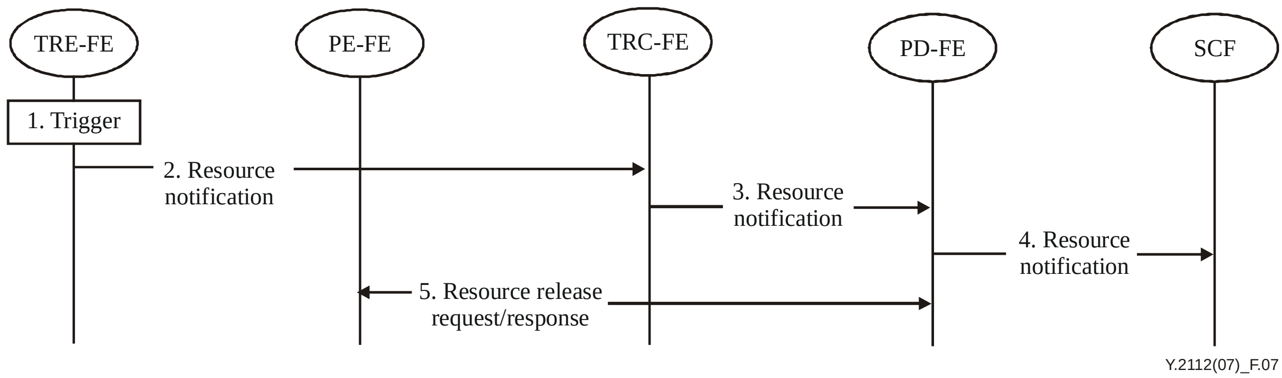

Figure 7 – TRE-FE-indicated resource release procedure

10.5.2 PE-FE-indicated resource release procedure

The PE-FE-indicated resource release procedure shown in Figure 8 is the same as that defined in [ITU-T Y.2111].

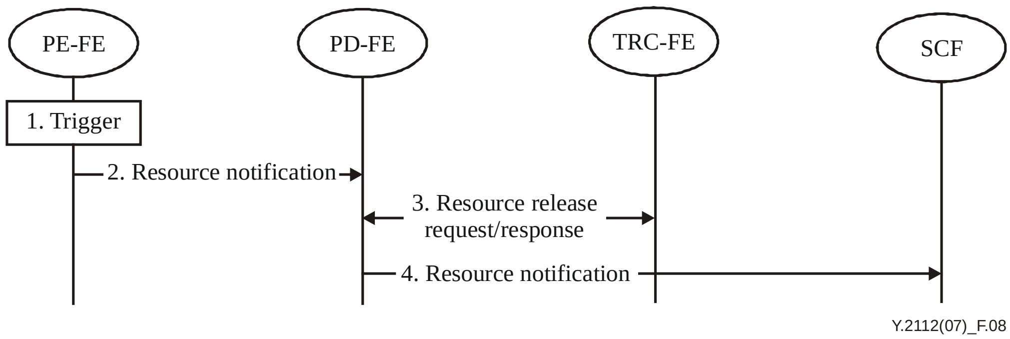

Figure 8 – PE-FE-indicated resource release procedure

10.5.3 TRC-FE-indicated resource release procedure

The TRC-FE-indicated resource release procedure shown in Figure 9 is the same as that defined in [ITU-T Y.2111].

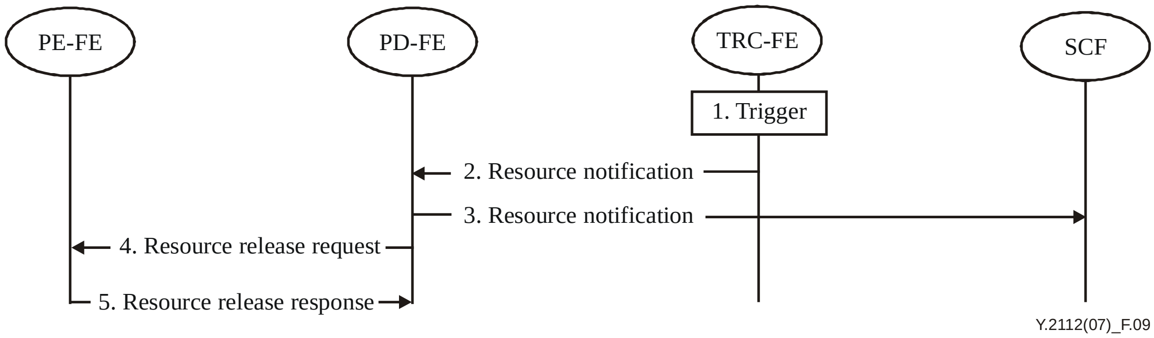

Figure 9 – TRC-FE-indicated resource release procedure

11 Deployment scenarios

Depending on the specific environments, there are various RACF deployment scenarios.

Assume that the access network has a star topology consisting of pipes between the EN and each AN. As such, all IP flows are forwarded through one edge node.

Scenario 1: If it is assumed that the bandwidth per pipe is reserved and guaranteed, the topology of the access network is not of concern and admission control can be simplified. For example, RACF can perform admission control based on the reserved bandwidth for the user (i.e., the pipe), the total bandwidth of the existing connections over the pipe, and the bandwidth of the newly requested connection.

Scenario 2: If it is assumed that the bottleneck of the bandwidth is limited, such as the link between the edge router and the first L2 switch, the resources of other links in the access network are not of concern and again admission control can be simplified. For example, RACF can perform admission control based on the provisioned bandwidth for such bottleneck link, the total bandwidth of the existing connection over the link, and the bandwidth of the newly requested connection.

12 Security considerations

This clause addresses security considerations specific to the Ethernet. Refer to [ITU-T Y.2111] for the general security considerations and requirements for the RACF.

– To protect the communication between RACF entities in an Ethernet-based IP access network, a dedicated signalling network through the use of a separate VLAN or physical link can be used.
– MAC address filtering can be used to protect RACF functional entities from being accessed by illegitimate entities.
– To prevent the network topology and port state information from being modified by the CPE, the CPE is required to not be part of the spanning tree computation. As such, the spanning tree protocol (STP) is required to be enabled only on network-facing ports at a minimum.

Appendix I

Ethernet-based IP access networks and QoS

(This appendix does not form an integral part of this Recommendation)

In general, the bearer QoS (i.e., bearer network performance) control issues are network resource control issues. By implementing resource controls, the network performance can be optimized, including the upper bound on packet performance, i.e., delay, delay variation, and loss can be met.

Depending on the resource attributes, an Ethernet-based IP access network could be partitioned into three segments, namely the last mile user access segment, the Ethernet level aggregation segment, and the IP level aggregation segment, if present. For each segment, there are typical QoS mechanisms available in the data plane.

At the joint nodes such as access node, BRAS and edge router, the mapping between the different QoS mechanisms shall be done for end-to-end QoS delivery.

These joint nodes enforce policy control and gate control. The related QoS mechanisms for different network segments are discussed below.

QoS mechanisms in the last mile user access segment

The QoS mechanisms for the last mile segment are highly MAC technology-dependent and are out of the scope of this Recommendation.

QoS mechanisms in the Ethernet level aggregation segment

[b-IEEE 802.1Q] defines eight priority levels and the traffic class expediting mechanisms utilizing these priorities for support of different classes of service. [b-IEEE 802.1Q] defines the tag format for adding VLAN ID, priority level and canonical format indicator fields into an Ethernet MAC frame header. They enable QoS information to be tagged onto any MAC frame, and thus enable Ethernet switches to handle the tagged frames with differentiation at the Ethernet layer. Queuing, scheduling, policing, shaping and filtering mechanisms can be applied based on classification and marking the 802.1Q tag.

The inner VLAN could be configured per user from the access node to BRAS for user traffic separation, traceability and security, usually called the 'customer VLAN'. Q-in-Q (i.e., VLAN stacking defined by [b-IEEE 802.1ad]) mechanism could be used for Ethernet level traffic aggregation in case 4096 VLAN IDs are not enough. The granularity of the user VLAN could be smaller so that BRAS could easily distinguish service types and aggregate service traffic according to the VLAN ID without IP level inspection, e.g., a user may have multiple VLANs, each respectively for voice, video and data services.

The access node is the first point where the traffic from multiple user access lines are aggregated into a single network, and thus should shape and police the traffic on a user access line to the subscribed access rate. BRAS should shape and police the traffic on user VLANs to the subscribed access rate and do the mapping between IP DSCPs and VLAN priorities.

QoS mechanisms in the IP level aggregation segment

[b-IETF RFC 2474] defines the DSCPs (maximum 64) in the DiffServ field of the IP headers for support of different classes of service. [b-IETF RFC 2475] defines the DiffServ architecture utilizing these IP DSCPs. Queuing, scheduling, policing, shaping and filtering mechanisms can be applied based on classification and marking the IP DSCPs. At each DiffServ router, the packets that belong to the same class of service are subjected to the same per hop behaviour (PHB) (i.e., a group of forwarding behaviours). A number of PHBs and their related DSCPs have been standardized within IETF, including the expedited forwarding (EF) PHB, the assured forwarding (AF1~4) PHB group, and the default best effort (BE) PHB.

The tunnels (e.g., L2TP, GRE), VLANs, MPLS LSPs and VPNs could be configured per service type or QoS class for IP level traffic aggregation as additions to native IP and for traffic separation among different services. MPLS LSPs can be established for resource reservation and explicit routing. BRAS and edge router should do the mapping between VLAN priorities, IP DSCPs, and MPLS EXP bits.

Appendix II

Last-mile user access technology

(This appendix does not form an integral part of this Recommendation)

The last mile user access technologies are diverse, e.g., LAN, xDSL, WLAN, EPON, PLC, etc. Different types of last mile user access systems have different types of modems and access nodes. Examples are given in Table II.1. This list is not exhaustive.

Table II.1 – Example mapping between last mile user access technologies and AN and modem types

Last mile user access technology	Access node	Modem/Adapter
LAN	L2 Switch	LAN adapter
xDSL	DSLAM	xDSL modem
WLAN	WLAN AP	WLAN adapter
Cable	CMTS	Cable Modem
PLC	EPLC-SHE	EPLC-SCPE
EPON	OLT	ONU
UMTS	RNC+Node B	USIM card

Appendix III

Use cases

(This appendix does not form an integral part of this Recommendation)

III.1 Overview

This clause provides example use cases, which show how this Recommendation is applied and how it supports dynamic QoS control for Ethernet-based IP access networks. The functional entities defined are mapped into physical devices together with a high-level description of call procedure.

III.2 Voice over IP

A VoIP use case (session establishment procedure from the caller's point of view) is shown in Figure III.1 and described below.

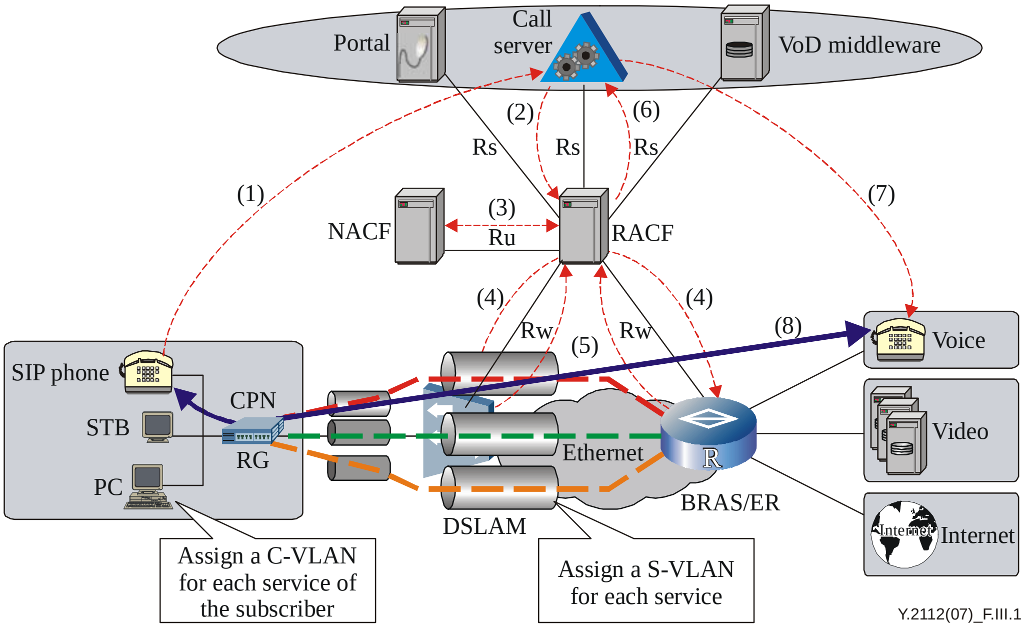

Figure III.1 – Use case of VoIP (session establishment procedure from caller's point of view)

(1) The SIP Endpoint (i.e., CPE) initiates the SIP call. The SIP Endpoint sends a SIP INVITE to the destination SIP Endpoint.

(2) The call server (i.e., SCF) sends the QoS request to RACF.

(3) The RACF requests the subscription information of the requested service from NACF via Ru reference point. (See Note)

(4) The RACF makes the final decision based on policy rules, resource availability and subscription information. If the QoS request is admitted, the RACF pushes the gate control, packet marking and bandwidth allocation decisions to the DSLAM and BRAS via Rw reference point.

(5) The DSLAM and BRAS acknowledge the QoS installation.

(6) The RACF sends positive response to the call server.

(7) The call server initiates the SIP INVITE to the callee's call server. The callee's call server will initiate the similar procedure as the caller's call server.

(8) The call server receives the "200 OK" response and the session is established.

NOTE – This step is only needed if the RACF does not already have the subscription information from the NACF upon the attachment of the endpoint device to the access network.

III.3 Video on demand

A video on demand use case (session establishment procedure) is shown in Figure III.2 and described below.

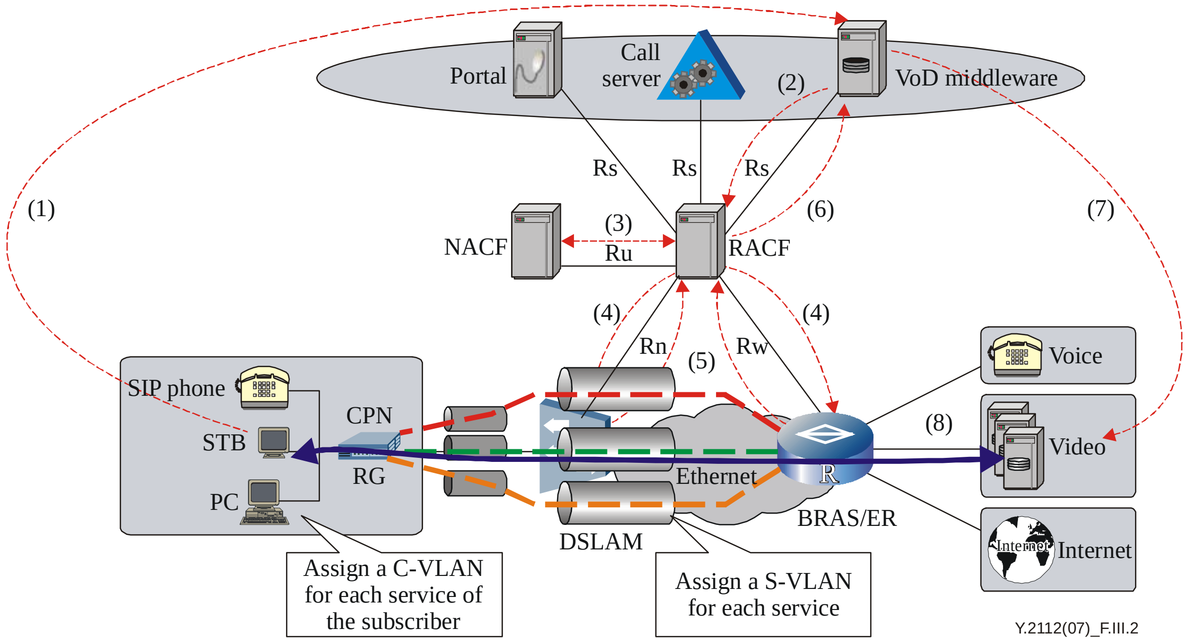

Figure III.2 – Use case of video on demand (session establishment procedure)

(1) The STB requests the list of program from EPG when it starts up. The STB sends the video request to the VoD middleware (SCF) with user name and password.

(2) The VoD middleware authorizes the user and locates the video content. The VoD middleware sends the QoS request to RACF.

(3) The RACF requests the subscription information of the requested service from NACF via Ru reference point. (See Note in clause III.4.)

(4) The RACF makes the final decision based on policy rules, resource availability and subscription information. If the QoS request is admitted, the RACF pushes the gate control, packet marking and bandwidth allocation decisions to the DSLAM and BRAS via Rw reference point.

(5) The DSLAM and BRAS acknowledge the QoS installation.

(6) The RACF sends acknowledgement to the VoD middleware.

(7) The VoD middleware informs the video server (e.g., CDN node) to deliver the requested video program.

(8) The user receives the request video service with QoS guarantees.

III.4 Bandwidth on demand

A bandwidth on demand use case (session establishment procedure) is shown in Figure III.3 and described below.

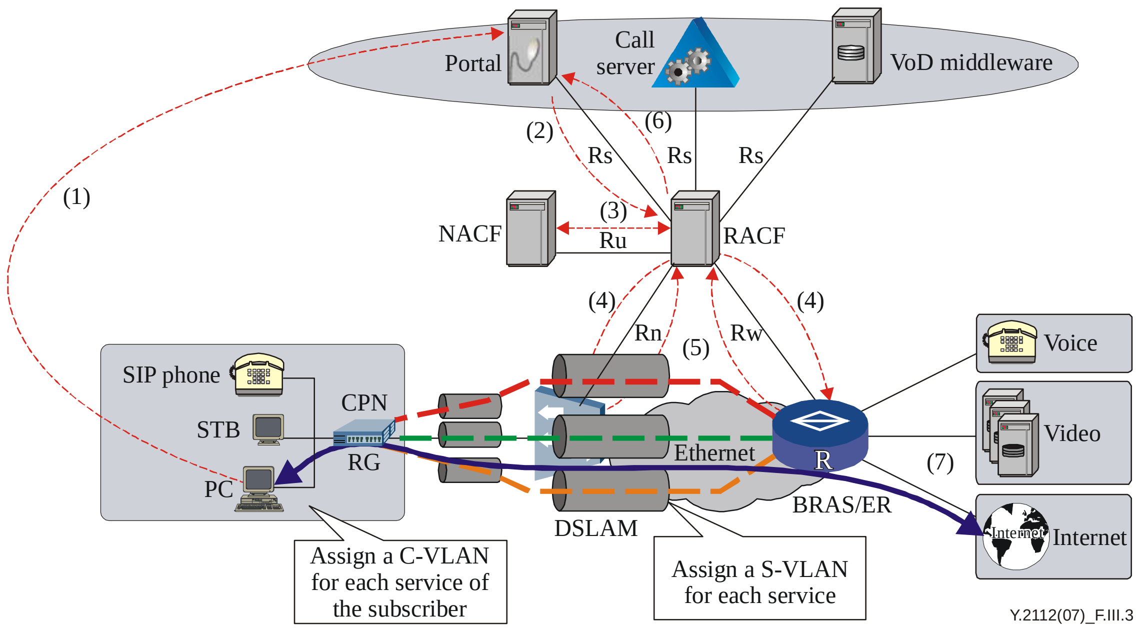

Figure III.3 – Use case of bandwidth on demand (session establishment procedure)

(1) The user sends the BoD service request to the web portal.

(2) The web portal interacts with the AAA system to validate the user and then sends a QoS request (i.e., bandwidth request) to RACF.

(3) The RACF requests the subscription information of the requested service from NACF via the Ru reference point. (See Note.)

(4) The RACF makes the final decision based on policy rules, resource availability and subscription information. If the QoS request is admitted, the RACF pushes the gate control, packet marking and bandwidth allocation decisions to the DSLAM and BRAS via Rw reference point.

(5) The DSLAM and BRAS acknowledge the QoS installation.

(6) The RACF sends acknowledgement to the web portal.

(7) The user accesses the Internet service with the requested bandwidth.

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Printed in Switzerland
Geneva, 2008