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Quality-of-Service Option for Proxy Mobile IPv6

Abstract

This specification defines a new mobility option, the Quality-of-Service (QoS) option, for Proxy Mobile IPv6. This option can be used by the local mobility anchor and the mobile access gateway for negotiating Quality-of-Service parameters for a mobile node's IP flows. The negotiated QoS parameters can be used for QoS policing and marking of packets to enforce QoS differentiation on the path between the local mobility anchor and the mobile access gateway. Furthermore, making QoS parameters available on the mobile access gateway enables mapping of these parameters to QoS rules that are specific to the access technology and allows those rules to be enforced on the access network using access-technology-specific approaches.

Status of This Memo

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1. Introduction

Mobile operators deploy Proxy Mobile IPv6 (PMIPv6) [RFC5213] to enable network-based mobility management for mobile nodes (MNs). Users can access IP-based services from their mobile device by using various radio access technologies. The currently supported mobile standards have adequate support for QoS-based service differentiation for subscriber traffic in cellular radio access networks. QoS policies are typically controlled by a policy control function, whereas the policies are enforced by one or more gateways in the infrastructure, such as the local mobility anchor (LMA) and the mobile access gateway (MAG), as well as by access network elements. Policy control and in-band QoS differentiation for access to the mobile operator network through alternative non-cellular access technologies are not supported in the currently specified standards. Although support for IP session handovers and IP flow mobility across access technologies already exists in cellular standards [TS23.402], QoS policy handovers across access technologies has not received much attention so far.

Based on the deployment trends, Wireless LAN (WLAN) can be considered as the dominant alternative access technology to complement cellular radio access. Since the 802.11e extension [IEEE802.11e-2005] provides QoS extensions to WLAN, it is beneficial to apply QoS policies to WLAN access, which enables QoS classification of downlink as well as uplink traffic between a mobile node and its local

mobility anchor. For realizing this capability, this specification identifies three functional operations:

- (a) Maintaining QoS classification during a handover between cellular radio access and WLAN access by means of establishing QoS policies in the handover target access network,
- (b) mapping of QoS classes and associated policies between different access systems, and
- (c) establishment of QoS policies for new data sessions/flows, which are initiated while using WLAN access.

This document specifies an extension to the PMIPv6 protocol [RFC5213] to establish QoS policies for a mobile node's data traffic on the local mobility anchor and the mobile access gateway. QoS policies are conveyed in-band with PMIPv6 signaling using the specified QoS option and are enforced on the local mobility anchor for downlink traffic and on the mobile access gateway and its access network for the uplink traffic. The specified option allows association between IP session classification characteristics, such as a Differentiated Services Code Point (DSCP) [RFC2474], and the expected QoS class for the IP session. This document specifies fundamental QoS attributes that apply on a per-mobile-node, per-mobility-session, or per-flow basis. The specified attributes are not specific to any access technology but are compatible with the Third Generation Partnership Project (3GPP) and IEEE 802.11 Wireless LAN QoS specifications [IEEE802.11-2012].

Additional QoS attributes can be specified and used with the QoS option, e.g., to represent more specific descriptions of latency constraints or jitter bounds. The specification of such additional QoS attributes as well as the handling of QoS policies between the mobile access gateway and the access network are out of the scope of this specification.

2. Conventions and Terminology

2.1. Conventions

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 RFC 2119 [RFC2119].

2.2. Terminology

All the mobility-related terms used in this document are to be interpreted as defined in the Proxy Mobile IPv6 specifications [RFC5213], [RFC5844], and [RFC7077]. Additionally, this document uses the following abbreviations:

Aggregate Maximum Bit Rate (AMBR)

AMBR defines the upper limit on the bit rate that can be provided by the network for a set of IP flows. IP packets within the flows exceeding the AMBR limit may be discarded by the rate-shaping function where the AMBR parameter is enforced. Variants of the "AMBR" term can be defined by restricting the target set of IP flows on which the AMBR is applied to a mobile node, mobility session, or flow direction. For example, Per-Mobile-Node Aggregate Maximum Downlink Bit Rate, Per-Mobile-Node Aggregate Maximum Uplink Bit Rate, Per-Mobility-Session Aggregate Maximum Downlink Bit Rate, and Per-Mobility-Session Aggregate Maximum Uplink Bit Rate are used in this document.

Allocation and Retention Priority (AARP)

AARP is used in congestion situations when there are insufficient resources for meeting all Service Requests. It is used primarily by the Admission Control function to determine whether a particular Service Request must be rejected due to lack of resources or honored by preempting an existing low-priority service.

Differentiated Services Code Point (DSCP)

In the Differentiated Services Architecture [RFC2474], packets are classified and marked to receive a particular per-hop forwarding behavior on nodes along their path based on the marking present on the packet. This marking on IPv4 and IPv6 packets that defines a specific per-hop behavior is known as DSCP. Refer to [RFC2474], [RFC2475], [RFC4594], and [RFC2983] for a complete explanation.

Downlink (DL) Traffic

The mobile node's IP packets that the mobile access gateway receives from the local mobility anchor are referred to as the Downlink traffic. The "Downlink" term used in the QoS attribute definition is always from the reference point of the mobile node, and it implies traffic heading towards the mobile node.

Guaranteed Bit Rate (GBR)

GBR denotes the assured bit rate that will be provided by the network for a set of IP flows. It is assumed that the network reserves the resources for supporting the GBR parameter. Variants of the "GBR" term can be defined by limiting the scope of the target IP flows on which the GBR is applied to a mobile node, mobility session, or flow direction. For example, Guaranteed Downlink Bit Rate and Guaranteed Uplink Bit Rate are used in this document.

Mobility Session

The term "mobility session" is defined in [RFC5213]. It refers to the creation or existence of state associated with the mobile node's mobility binding on the local mobility anchor and on the mobile access gateway.

QoS Service Request

A QoS Service Request is a set of QoS parameters that are defined to be enforced on one or more mobile node's IP flows. The parameters at the minimum include a DSCP marking and additionally may include Guaranteed Bit Rate or Aggregate Maximum Bit Rate. The Quality-of-Service option defined in this document represents a QoS Service Request.

Service Identifier

In some mobility architectures, multiple services within the same mobility service subscription are offered to a mobile node. Each of those services provide a specific service (for example, Internet Service and Voice Over IP Service) and has an identifier called "Service Identifier". 3GPP APN (Access Point Name) is an example of a Service Identifier. Refer to [RFC5149] for the definition of the Service Identifier and the mobility option used for carrying the Service Identifier.

Uplink (UL) Traffic

The mobile node's IP packets that the mobile access gateway forwards to the local mobility anchor are referred to as the Uplink traffic. The "Uplink" term used in the QoS attribute definitions is based on the reference point of the mobile node, and it implies traffic originating from the mobile node.

3. Overview of QoS Support in Proxy Mobile IPv6

The Quality-of-Service support in Proxy Mobile IPv6 specified in this document is based on the Differentiated Services Architecture ([RFC2474] and [RFC2475]). The access and the home network in the Proxy Mobile IPv6 domain are assumed to be DiffServ-enabled, with every network node in the forwarding path for the mobile node's IP traffic being DiffServ-compliant. The per-hop behavior for providing differential treatment based on the DiffServ marking in the packet is assumed to be supported in the Proxy Mobile IPv6 domain.

The local mobility anchor in the home network and the mobile access gateway in the access network define the network boundary between the access and the home network. As the tunnel entry and exit points for the mobile node's IP traffic, these entities are the logical choice for being chosen as the QoS enforcement points. The basic QoS functions such as marking, metering, policing, and rate-shaping on the mobile node's IP flows can be enforced at these nodes.

The local mobility anchor and the mobile access gateway can negotiate the Quality-of-Service parameters for a mobile node's IP flows based on the signaling extensions defined in this document. The QoS services that can be enabled for a mobile node are for meeting both the quantitative performance requirements (such as Guaranteed Bit Rate) as well as for realizing relative performance treatment by way of class-based differentiation. The subscriber's policy and the charging profile (for example, [TS22.115]) are key considerations for the mobility entities in the QoS service negotiation. The decision on the type of QoS services that are to be enabled for a mobile node is based on the subscriber profile and based on available network resources. The negotiated QoS parameters are used for providing QoS differentiation on the path between the local mobility anchor and the mobile access gateway. The signaling related to QoS services is strictly between the mobility entities and does not result in per-flow state or signaling to any other node in the network.

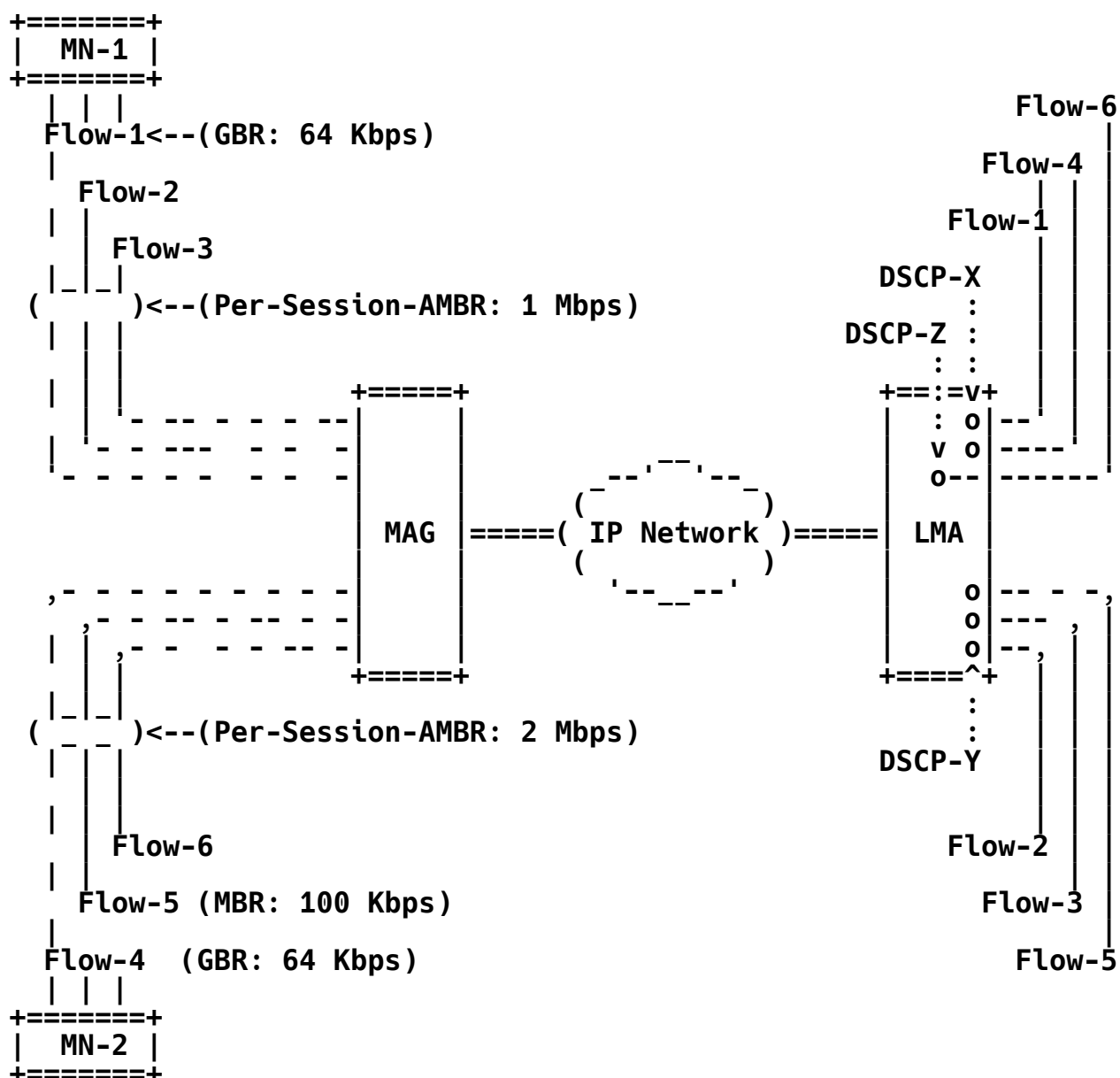


Figure 1: QoS Support

Figure 1 illustrates the support of QoS services in a Proxy Mobile IPv6 domain. The local mobility anchor and the mobile access gateway have negotiated QoS parameters for the mobility sessions belonging to MN-1 and MN-2. The negotiated QoS parameters include a Per-Session-AMBR of 1 Mbps and 2 Mbps for MN-1 and MN-2 respectively. Furthermore, different IP flows from MN-1 and MN-2 are given

different QoS service treatment, for example, a GBR of 64 Kbps for Flow-1 and Flow-4 is assured, a DSCP marking enforcement of "Z" on Flow-6, and an MBR of 100 Kbps on Flow-5.

3.1. Quality-of-Service Option -- Usage Examples

Use Case 1: Figure 2 illustrates a scenario where a local mobility anchor initiates a QoS Service Request to a mobile access gateway.

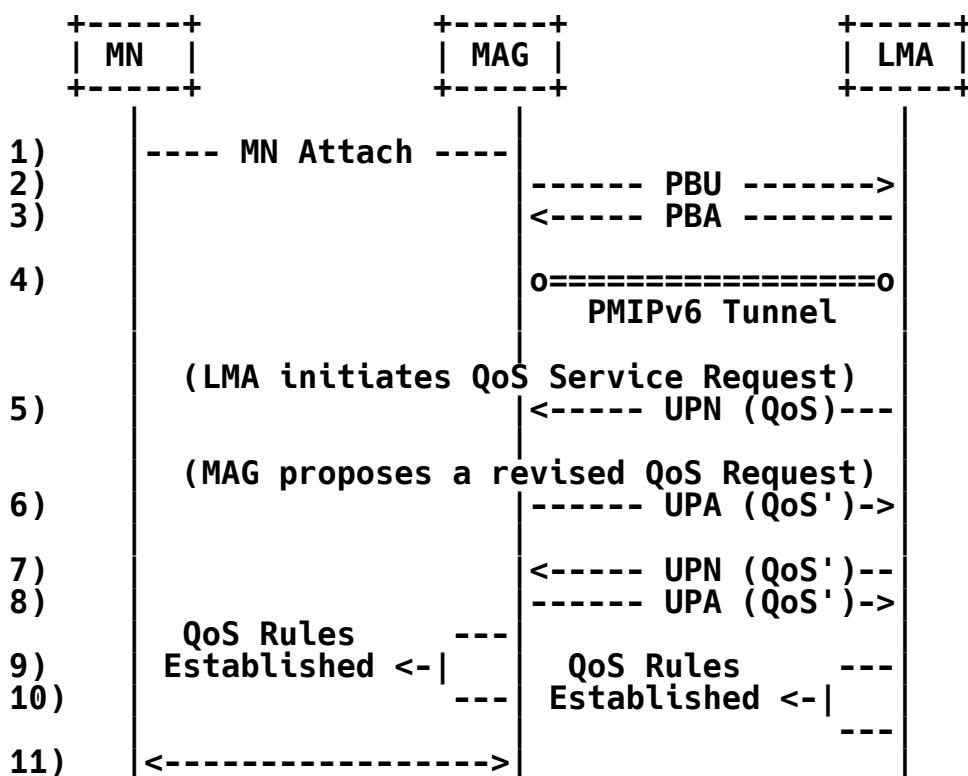


Figure 2: LMA-Initiated QoS Service Request

- o (1) to (4): MAG detects the mobile node's attachment to the access link and initiates the signaling with the local mobility anchor. Upon completing the signaling, the LMA and MAG establish the mobility session and the forwarding state.
- o (5) to (8): The LMA initiates a QoS Service Request to the mobile access gateway. The trigger for this service can be based on a trigger from a policy function, and the specific details of that trigger are outside the scope of this document. The LMA sends an Update Notification (UPN) message [RFC7077] to the MAG. The message includes the QoS option (Section 4.1), which includes a set of QoS parameters. On determining that it cannot support the

requested QoS Service Request for that mobile, the MAG sends an Update Notification Acknowledgement (UPA) message. The message contains a revised QoS option with an updated set of QoS attributes. The LMA accepts the revised QoS Service Request by sending a new Update Notification message including the updated QoS option.

- o (9) to (11): Upon successfully negotiating a QoS Service Request, the MAG and the LMA install the QoS rules for that Service Request. Furthermore, the MAG (using access-technology-specific mechanisms) installs the QoS rules on the access network.

Use Case 2: Figure 3 illustrates a scenario where a mobile access gateway initiates a QoS Service Request to a local mobility anchor.

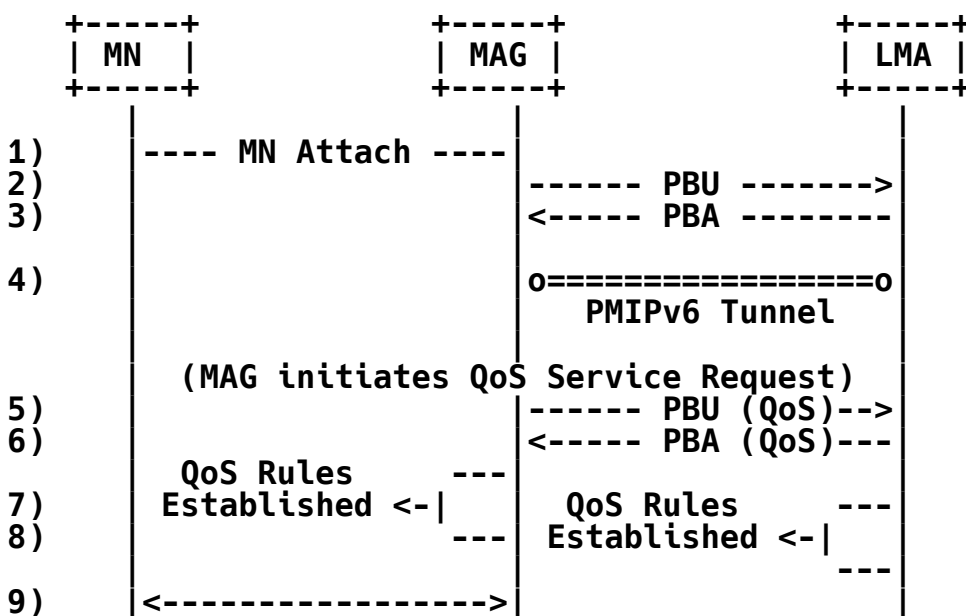


Figure 3: MAG-Initiated QoS Service Request

- o (1) to (4): MAG detects the mobile node's attachment to the access link and initiates the signaling with the local mobility anchor. Upon completing the signaling, the LMA and MAG establish the mobility session and the forwarding state.
- o (5) to (6): The MAG initiates a QoS Service Request to the local mobility anchor. The trigger for this service can be based on a trigger from the mobile node using access-technology-specific mechanisms. The specific details of that trigger are outside the scope of this document. The MAG sends a Proxy Binding Update (PBU) message [RFC5213] to the LMA. The message includes the QoS

option (Section 4.1), which includes a set of QoS parameters. The LMA agrees to the proposed QoS Service Request by sending a Proxy Binding Acknowledgement (PBA) message.

- o (7) to (9): Upon successfully negotiating a QoS Service Request, the MAG and the LMA install the QoS rules for that Service Request. Furthermore, the MAG using access-technology-specific mechanisms installs the QoS rules on the access network.

3.2. Quality-of-Service Attributes -- Usage Examples

This section identifies the use cases where the Quality-of-Service option (Section 4.1) and its attributes (Section 4.2) defined in this document are relevant.

- o The subscription policy offered to a mobile subscriber requires the service provider to enforce Aggregate Maximum Bit Rate (AMBR) limits on the subscriber's IP traffic. The local mobility anchor and the mobile access gateway negotiate the uplink and the downlink AMBR values for the mobility session and enforce them in the access and the home network. The QoS option (Section 4.1) with the QoS attributes Per-Session-Agg-Max-DL-Bit-Rate (Section 4.2.3) and Per-Session-Agg-Max-UL-Bit-Rate (Section 4.2.4) is used for this purpose.
- o In Community Wi-Fi deployments, the residential gateway participating in the Wi-Fi service is shared between the home user and the community Wi-Fi users. In order to ensure the home user's Wi-Fi service is not impacted because of the community Wi-Fi service, the service provider enables Guaranteed Bit Rate (GBR) for the home user's traffic. The QoS option (Section 4.1) with the QoS attributes Guaranteed-DL-Bit-Rate (Section 4.2.8) and Guaranteed-UL-Bit-Rate (Section 4.2.9) is used for this purpose.
- o A mobile user using the service provider's Voice over IP infrastructure establishes a VoIP call with some other user in the network. The negotiated call parameters for the VoIP call require a dedicated bandwidth of certain fixed value for the media flows associated with that VoIP session. The application function in the VoIP infrastructure notifies the local mobility anchor to enforce the GBR limits on that IP flow identified by the flow definition. The QoS option (Section 4.1) with the QoS attributes Guaranteed-DL-Bit-Rate (Section 4.2.8), Guaranteed-UL-Bit-Rate (Section 4.2.9), and QoS-Traffic-Selector (Section 4.2.10) is used for this purpose.

- o An emergency service may require network resources in conditions when the network resources have been fully allocated to other users and the network may be experiencing severe congestion. In such cases, the service provider may want to revoke resources that have been allocated and reassign them to emergency services. The local mobility anchor and the mobile access gateway negotiate Allocation and Retention Priority (AARP) values for the IP sessions associated with the emergency applications. The QoS option (Section 4.1) with the QoS attribute Allocation-Retention-Priority (Section 4.2.5) is used for this purpose.

4. Protocol Messaging Extensions

4.1. Quality-of-Service Option

The Quality-of-Service option is a mobility header option used by local mobility anchors and mobile access gateways for negotiating QoS parameters associated with a mobility session. This option can be carried in Proxy Binding Update (PBU) [RFC5213], Proxy Binding Acknowledgement (PBA) [RFC5213], Update Notification (UPN) [RFC7077] and Update Notification Acknowledgement (UPA) [RFC7077] messages. There can be more than one instance of the Quality-of-Service option in a single message. Each instance of the Quality-of-Service option represents a specific QoS Service Request.

The alignment requirement for this option is 4n.

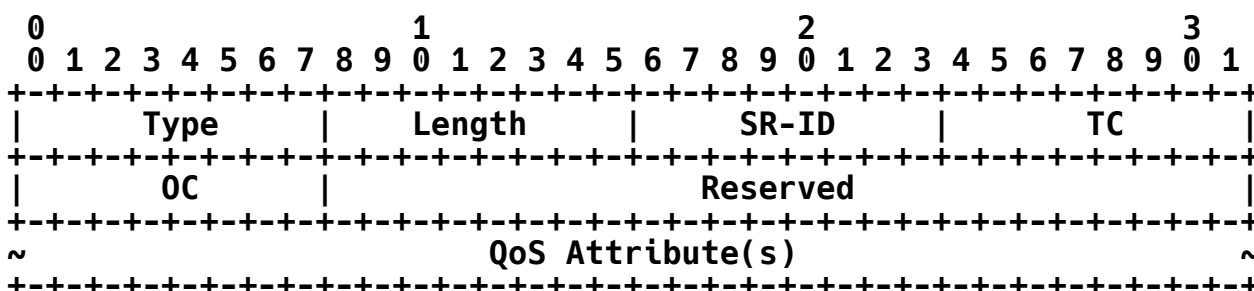


Figure 4: QoS Option

- o Type: 58
- o Length: 8-bit unsigned integer indicating the length of the option in octets, excluding the Type and Length fields.
- o Service Request Identifier (SR-ID): An 8-bit unsigned integer used for identifying the QoS Service Request. Its uniqueness is within the scope of a mobility session. The local mobility anchor always allocates the Service Request Identifier. When a new QoS Service

Request is initiated by a mobile access gateway, the Service Request Identifier in the initial request message is set to a value of (0), and the local mobility anchor allocates a Service Request Identifier and includes it in the response. For any new QoS Service Requests initiated by a local mobility anchor, the Service Request Identifier is set to the allocated value.

- o Traffic Class (TC): Traffic Class consists of a 6-bit DSCP field followed by a 2-bit reserved field.

Differentiated Services Code Point (DSCP)

A 6-bit unsigned integer indicating the code point value, as defined in [RFC2475] to be used for the mobile node's IP flows. When this DSCP marking needs to be applied only for a subset of a mobile node's IP flows, there will be a Traffic Selector attribute (Section 4.2.10) in the option, which provides the flow selectors. In the absence of any such Traffic Selector attribute, the DSCP marking applies to all the IP flows associated with the mobility session.

Reserved

The last two bits in the Traffic Class field are currently unused. These bits MUST be initialized by the sender to (0) and MUST be ignored by the receiver.

- o Operational Code (OC): 1-octet Operational code indicates the type of QoS request.

RESPONSE: (0)
Response to a QoS request

ALLOCATE: (1)
Request to allocate QoS resources

DE-ALLOCATE: (2)
Request to de-Allocate QoS resources

MODIFY: (3)
Request to modify QoS parameters for a previously negotiated QoS Service Request

QUERY: (4)
Query to list the previously negotiated QoS Service Requests that are still active

- (4) - Per-Session-Agg-Max-UL-Bit-Rate
This QoS attribute, Per-Mobility-Session Aggregate Maximum Uplink Bit Rate, is defined in Section 4.2.4.
 - (5) - Allocation-Retention-Priority
This QoS attribute, Allocation and Retention Priority, is defined in Section 4.2.5.
 - (6) - Aggregate-Max-DL-Bit-Rate
This QoS attribute, Aggregate Maximum Downlink Bit Rate, is defined in Section 4.2.6.
 - (7) - Aggregate-Max-UL-Bit-Rate
This QoS attribute, Aggregate Maximum Uplink Bit Rate, is defined in Section 4.2.7.
 - (8) - Guaranteed-DL-Bit-Rate
This QoS attribute, Guaranteed Downlink Bit Rate, is defined in Section 4.2.8.
 - (9) - Guaranteed-UL-Bit-Rate
This QoS attribute, Guaranteed Uplink Bit Rate, is defined in Section 4.2.9.
 - (10) - QoS-Traffic-Selector
This QoS attribute, QoS Traffic Selector, is defined in Section 4.2.10.
 - (11) - QoS-Vendor-Specific-Attribute
This QoS attribute, QoS Vendor-Specific Attribute, is defined in Section 4.2.11.
 - (12) to (254) - Reserved
These values are reserved for future allocation.
 - (255) - Reserved
This value is reserved and cannot be used.
- o Length: 8-bit unsigned integer indicating the number of octets needed to encode the Value, excluding the Type and Length fields.
 - o Value: The format of this field is based on the Type value.

4.2.1. Per-Mobile-Node Aggregate Maximum Downlink Bit Rate

This attribute, **Per-MN-Agg-Max-DL-Bit-Rate**, represents the maximum downlink bit rate for a mobile node. It is a variant of the "AMBR" term defined in Section 2.2. This value is an aggregate across all mobility sessions associated with that mobile node.

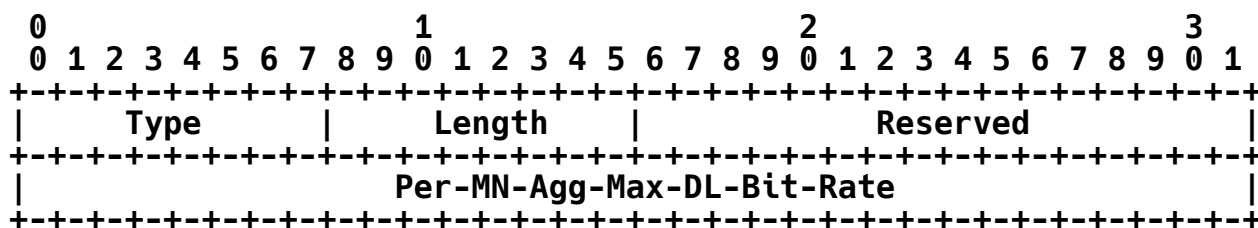
This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message sent by a local mobility anchor, it indicates the maximum aggregate downlink bit rate that is being requested for the mobile node at the peer.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement message, it indicates the maximum aggregate downlink bit rate that the peer agrees to offer.

If multiple mobility sessions are established for a mobile node, through multiple mobile access gateways with sessions anchored either on a single local mobility anchor or spread out across multiple local mobility anchors, then it depends on the operator's policy and the specific deployment as to how the total bandwidth for the mobile node on each MAG-LMA pair is computed.

When a QoS option includes both the **Per-MN-Agg-Max-DL-Bit-Rate** attribute and the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **QoS-Traffic-Selector** attribute does not apply to this attribute.



- o Type: 1
- o Length: The length in octets of the attribute, excluding the Type and Length fields. This value is set to (6).

- o **Reserved:** This field is unused for now. The value **MUST** be initialized by the sender to 0 and **MUST** be ignored by the receiver.
- o **Per-MN-Agg-Max-DL-Bit-Rate:** This is a 32-bit unsigned integer that indicates the aggregate maximum downlink bit rate that is requested/allocated for all the mobile node's IP flows. The measurement units for Per-MN-Agg-Max-DL-Bit-Rate are bits per second.

4.2.2. Per-Mobile-Node Aggregate Maximum Uplink Bit Rate

This attribute, Per-MN-Agg-Max-UL-Bit-Rate, represents the maximum uplink bit rate for the mobile node. It is a variant of the "AMBR" term defined in Section 2.2. This value is an aggregate across all mobility sessions associated with that mobile node.

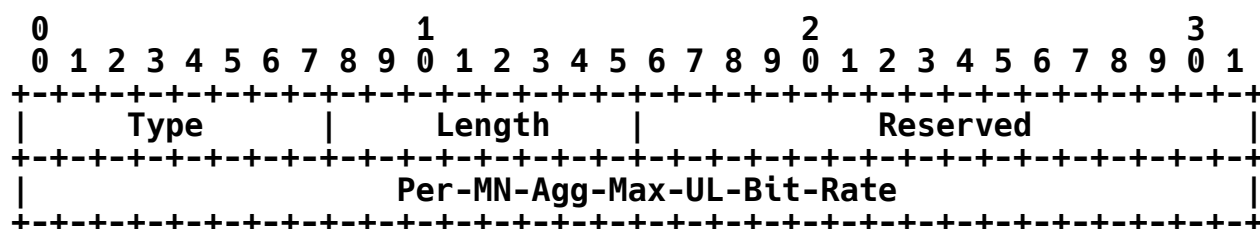
This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message sent by the local mobility anchor, it indicates the maximum aggregate uplink bit rate that is being requested for the mobile node at the peer.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement message, it indicates the maximum aggregate uplink bit rate that the peer agrees to offer for that mobile node.

If multiple mobility sessions are established for a mobile node, through multiple mobile access gateways with sessions anchored either on a single local mobility anchor or spread out across multiple local mobility anchors, then it depends on the operator's policy and the specific deployment as to how the total bandwidth for the mobile node on each MAG-LMA pair is computed.

When a QoS option includes both the Per-MN-Agg-Max-UL-Bit-Rate attribute and the QoS-Traffic-Selector attribute (Section 4.2.10), then the QoS-Traffic-Selector attribute does not apply to this attribute.



- o Type: 2
- o Length: The length in octets of the attribute, excluding the Type and Length fields. This value is set to (6).
- o Reserved: This field is unused for now. The value MUST be initialized by the sender to 0 and MUST be ignored by the receiver.
- o Per-MN-Agg-Max-UL-Bit-Rate: This is a 32-bit unsigned integer that indicates the aggregate maximum uplink bit rate that is requested/allocated for the mobile node's IP flows. The measurement units for Per-MN-Agg-Max-UL-Bit-Rate are bits per second.

4.2.3. Per-Mobility-Session Aggregate Maximum Downlink Bit Rate

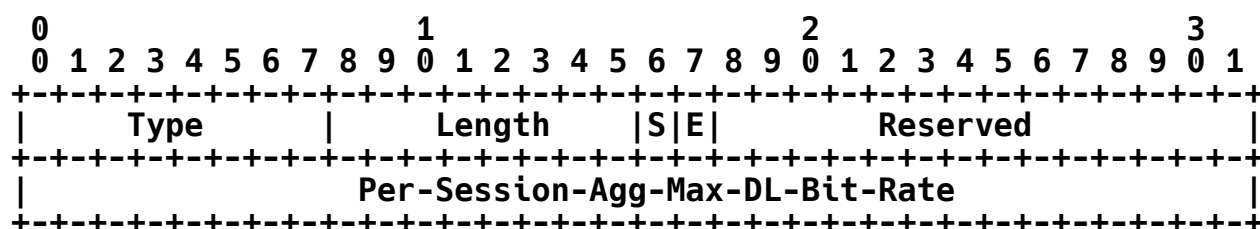
This attribute, Per-Session-Agg-Max-DL-Bit-Rate, represents the maximum downlink bit rate for the mobility session. It is a variant of the "AMBR" term defined in Section 2.2.

This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message sent by the local mobility anchor, it indicates the maximum aggregate downlink bit rate that is being requested for that mobility session.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement message, it indicates the maximum aggregate downlink bit rate that the peer agrees to offer for that mobility session.

When a QoS option includes both the Per-Session-Agg-Max-DL-Bit-Rate attribute and the QoS-Traffic-Selector attribute (Section 4.2.10), then the QoS-Traffic-Selector attribute does not apply to this attribute.



- o Type: 3
- o Length: The length of the attribute in octets, excluding the Type and Length fields. This value is set to (6).
- o Service (S) flag: This flag is used for extending the scope of the target flows for Per-Session-Agg-Max-DL-Bit-Rate to the mobile node's other mobility sessions sharing the same Service Identifier. 3GPP Access Point Name (APN) is an example of a Service Identifier, and that identifier is carried using the Service Selection mobility option [RFC5149].
 - * When the (S) flag is set to a value of (1), then the Per-Session-Agg-Max-DL-Bit-Rate is measured as an aggregate across all the mobile node's other mobility sessions sharing the same Service Identifier associated with this mobility session.
 - * When the (S) flag is set to a value of (0), then the target flows are limited to the current mobility session.
 - * The (S) flag MUST NOT be set to a value of (1) when there is no Service Identifier associated with the mobility session.
- o Exclude (E) flag: This flag is used to request that the downlink flows for which the network is providing Guaranteed-Bit-Rate service be excluded from the target IP flows for which Per-Session-Agg-Max-DL-Bit-Rate is measured.
 - * When the (E) flag is set to a value of (1), then the request is to exclude the IP flows for which Guaranteed-DL-Bit-Rate (Section 4.2.8) is negotiated from the flows for which Per-Session-Agg-Max-DL-Bit-Rate is measured.
 - * When the (E) flag is set to a value of (0), then the request is not to exclude any IP flows from the target IP flows for which Per-Session-Agg-Max-DL-Bit-Rate is measured.

- * When the (S) flag and (E) flag are both set to a value of (1), then the request is to exclude all the IP flows sharing the Service Identifier associated with this mobility session from the target flows for which Per-Session-Agg-Max-DL-Bit-Rate is measured.
- o **Reserved:** This field is unused for now. The value **MUST** be initialized by the sender to 0 and **MUST** be ignored by the receiver.
- o **Per-Session-Agg-Max-DL-Bit-Rate:** This is a 32-bit unsigned integer that indicates the aggregate maximum downlink bit rate that is requested/allocated for all the IP flows associated with that mobility session. The measurement units for Per-Session-Agg-Max-DL-Bit-Rate are bits per second.

4.2.4. Per-Mobility-Session Aggregate Maximum Uplink Bit Rate

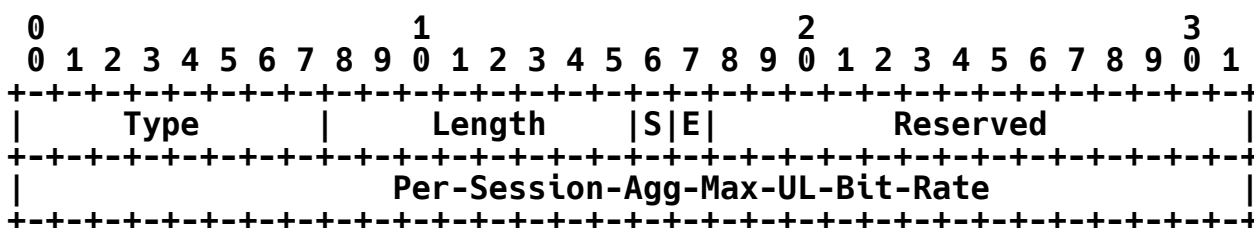
This attribute, Per-Session-Agg-Max-UL-Bit-Rate, represents the maximum uplink bit rate for the mobility session. It is a variant of the "AMBR" term defined in Section 2.2.

This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message [RFC7077] sent by the local mobility anchor, it indicates the maximum aggregate uplink bit rate that is being requested for that mobility session.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement [RFC7077] message, it indicates the maximum aggregate uplink bit rate that the peer agrees to offer for that mobility session.

When a QoS option includes both the Per-Session-Agg-Max-UL-Bit-Rate attribute and the QoS-Traffic-Selector attribute (Section 4.2.10), then the QoS-Traffic-Selector attribute does not apply to this attribute.



- o **Type: 4**
- o **Length:** The length of the attribute in octets, excluding the Type and Length fields. This value is set to (6).
- o **Service (S) flag:** This flag is used for extending the scope of the target flows for Per-Session-Agg-Max-UL-Bit-Rate to the mobile node's other mobility sessions sharing the same Service Identifier. 3GPP Access Point Name (APN) is an example of a Service Identifier, and that identifier is carried using the Service Selection mobility option [RFC5149].
 - * When the (S) flag is set to a value of (1), then the Per-Session-Agg-Max-UL-Bit-Rate is measured as an aggregate across all the mobile node's other mobility sessions sharing the same Service Identifier associated with this mobility session.
 - * When the (S) flag is set to a value of (0), then the target flows are limited to the current mobility session.
 - * The (S) flag **MUST NOT** be set to a value of (1) when there is no Service Identifier associated with the mobility session.
- o **Exclude (E) flag:** This flag is used to request that the uplink flows for which the network is providing Guaranteed-Bit-Rate service be excluded from the target IP flows for which Per-Session-Agg-Max-UL-Bit-Rate is measured.
 - * When the (E) flag is set to a value of (1), then the request is to exclude the IP flows for which Guaranteed-UL-Bit-Rate (Section 4.2.9) is negotiated from the flows for which Per-Session-Agg-Max-UL-Bit-Rate is measured.
 - * When the (E) flag is set to a value of (0), then the request is not to exclude any IP flows from the target IP flows for which Per-Session-Agg-Max-UL-Bit-Rate is measured.
 - * When the (S) flag and (E) flag are both set to a value of (1), then the request is to exclude all the IP flows sharing the Service Identifier associated with this mobility session from the target flows for which Per-Session-Agg-Max-UL-Bit-Rate is measured.
- o **Reserved:** This field is unused for now. The value **MUST** be initialized by the sender to 0 and **MUST** be ignored by the receiver.

- o **Per-Session-Agg-Max-UL-Bit-Rate:** This is a 32-bit unsigned integer that indicates the aggregate maximum uplink bit rate that is requested/allocated for all the IP flows associated with that mobility session. The measurement units for Per-Session-Agg-Max-UL-Bit-Rate are bits per second.

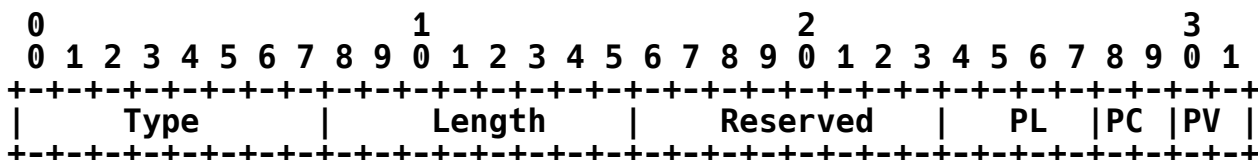
4.2.5. Allocation and Retention Priority

This attribute, **Allocation-Retention-Priority**, represents allocation and retention priority for the mobility session or a set of IP flows. It is defined in Section 2.2.

This attribute can be included in the **Quality-of-Service** option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When the QoS option includes both the **Allocation-Retention-Priority** attribute and the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Allocation-Retention-Priority** attribute is to be applied at a flow level. The traffic selector in the **QoS-Traffic-Selector** attribute identifies the target flows.

When the QoS option including the **Allocation-Retention-Priority** attribute does not include the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Allocation-Retention-Priority** attribute is to be applied to all the IP flows associated with that mobility session.



- o **Type:** 5
- o **Length:** The length of the attribute in octets, excluding the Type and Length fields. This value is set to (2).
- o **Reserved:** This field is unused for now. The value **MUST** be initialized by the sender to 0 and **MUST** be ignored by the receiver.
- o **Priority-Level (PL):** This is a 4-bit unsigned integer value. It is used to decide whether a mobility session establishment or modification request can be accepted; this is typically used for admission control of Guaranteed Bit Rate traffic in case of resource limitations. The priority level can also be used to

decide which existing mobility session to preempt during resource limitations. The priority level defines the relative timeliness of a resource request.

Values 1 to 15 are defined, with value 1 as the highest level of priority.

Values 1 to 8 should only be assigned for services that are authorized to receive prioritized treatment within an operator domain. Values 9 to 15 may be assigned to resources that are authorized by the home network and thus applicable when a mobile node is roaming.

- o **Preemption-Capability (PC):** This is a 2-bit unsigned integer value. It defines whether a service data flow can get resources that were already assigned to another service data flow with a lower priority level. The following values are defined:

Enabled (0): This value indicates that the service data flow is allowed to get resources that were already assigned to another IP data flow with a lower priority level.

Disabled (1): This value indicates that the service data flow is not allowed to get resources that were already assigned to another IP data flow with a lower priority level. The values (2) and (3) are reserved.

- o **Preemption-Vulnerability (PV):** This is a 2-bit unsigned integer value. It defines whether a service data flow can lose the resources assigned to it in order to admit a service data flow with a higher priority level. The following values are defined:

Enabled (0): This value indicates that the resources assigned to the IP data flow can be preempted and allocated to a service data flow with a higher priority level.

Disabled (1): This value indicates that the resources assigned to the IP data flow shall not be preempted and allocated to a service data flow with a higher priority level. The values (2) and (3) are reserved.

4.2.6. Aggregate Maximum Downlink Bit Rate

This attribute, **Aggregate-Max-DL-Bit-Rate**, represents the maximum downlink bit rate for the mobility session. It is a variant of the "AMBR" term defined in Section 2.2.

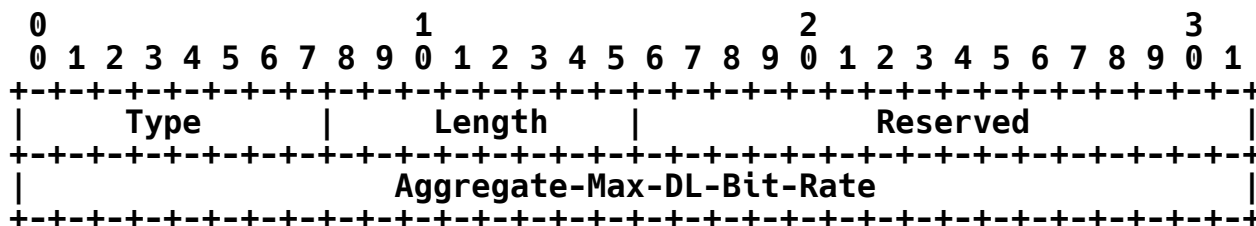
This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message sent by the local mobility anchor, it indicates the maximum aggregate bit rate for downlink IP flows that is being requested.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement message, it indicates the maximum aggregate downlink bit rate that the peer agrees to offer.

When a QoS option includes both the Aggregate-Max-DL-Bit-Rate attribute and the QoS-Traffic-Selector attribute (Section 4.2.10), then the Aggregate-Max-DL-Bit-Rate attribute is to be enforced at a flow level, and the traffic selectors present in the QoS-Traffic-Selector attribute identify those target flows.

When the QoS option that includes the Aggregate-Max-DL-Bit-Rate attribute does not include the QoS-Traffic-Selector attribute (Section 4.2.10), then the Aggregate-Max-DL-Bit-Rate attribute is to be applied to all the IP flows associated with the mobility session.



- o Type: 6
- o Length: The length of the attribute in octets, excluding the Type and Length fields. This value is set to (6).
- o Reserved: This field is unused for now. The value MUST be initialized by the sender to 0 and MUST be ignored by the receiver.
- o Aggregate-Max-DL-Bit-Rate: This is a 32-bit unsigned integer that indicates the aggregate maximum downlink bit rate that is requested/allocated for downlink IP flows. The measurement units for Aggregate-Max-DL-Bit-Rate are bits per second.

4.2.7. Aggregate Maximum Uplink Bit Rate

This attribute, **Aggregate-Max-UL-Bit-Rate**, represents the maximum uplink bit rate for the mobility session. It is a variant of the "AMBR" term defined in Section 2.2.

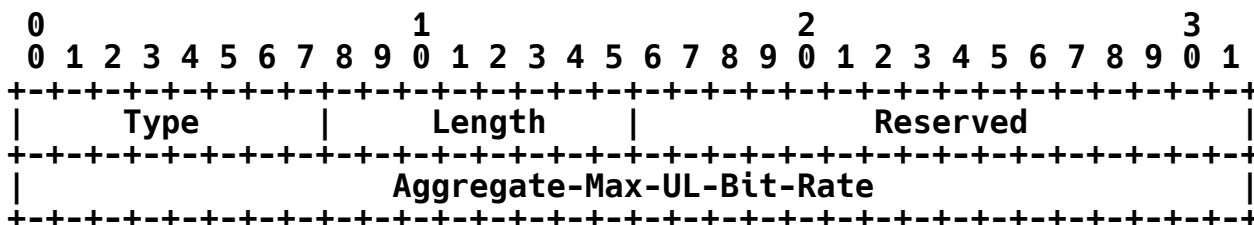
This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message sent by the local mobility anchor, it indicates the maximum aggregate uplink bit rate that is being requested.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement message, it indicates the maximum aggregate uplink bit rate that the peer agrees to offer.

When a QoS option includes both the **Aggregate-Max-UL-Bit-Rate** attribute and the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Aggregate-Max-UL-Bit-Rate** attribute is to be enforced at a flow level, and the traffic selectors present in the **QoS-Traffic-Selector** attribute identify those target flows.

When the QoS option that includes the **Aggregate-Max-UL-Bit-Rate** attribute does not include the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Aggregate-Max-UL-Bit-Rate** attribute is to be applied to all the IP flows associated with the mobility session.



- o **Type:** 7
- o **Length:** The length of the attribute in octets, excluding the Type and Length fields. This value is set to (6).
- o **Reserved:** This field is unused for now. The value **MUST** be initialized by the sender to 0 and **MUST** be ignored by the receiver.

- o **Aggregate-Max-UL-Bit-Rate:** This is a 32-bit unsigned integer that indicates the aggregate maximum uplink bit rate that is requested/allocated for all the IP flows associated with that mobility session. The measurement units for Aggregate-Max-UL-Bit-Rate are bits per second.

4.2.8. Guaranteed Downlink Bit Rate

This attribute, **Guaranteed-DL-Bit-Rate**, represents the assured bit rate on the downlink path that will be provided for a set of IP flows associated with a mobility session. It is a variant of the "GBR" term defined in Section 2.2.

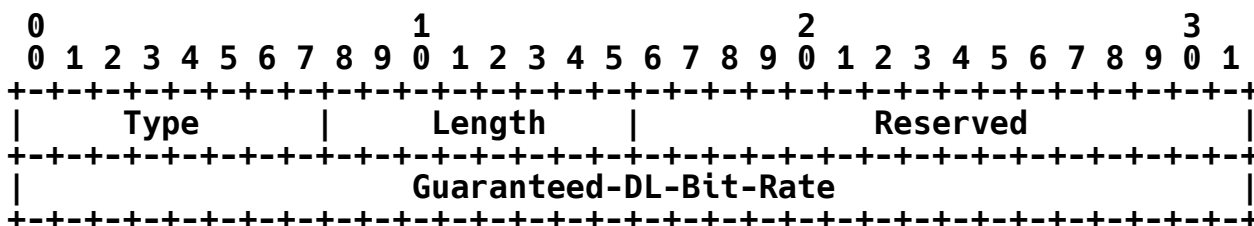
This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message sent by the local mobility anchor, it indicates the guaranteed downlink bit rate that is being requested.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement message, it indicates the guaranteed downlink bit rate that the peer agrees to offer.

When a QoS option includes both the **Guaranteed-DL-Bit-Rate** attribute and the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Guaranteed-DL-Bit-Rate** attribute is to be enforced at a flow level, and the traffic selectors present in the **QoS-Traffic-Selector** attribute identify those target flows.

When the QoS option that includes the **Guaranteed-DL-Bit-Rate** attribute does not include the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Guaranteed-DL-Bit-Rate** attribute is to be applied to all the IP flows associated with the mobility session.



- o **Type:** 8

- o **Length:** The length of the attribute in octets, excluding the Type and Length fields. This value is set to (6).
- o **Reserved:** This field is unused for now. The value **MUST** be initialized by the sender to 0 and **MUST** be ignored by the receiver.
- o **Guaranteed-DL-Bit-Rate:** This is a 32-bit unsigned integer that indicates the guaranteed bandwidth in bits per second for downlink IP flows. The measurement units for Guaranteed-DL-Bit-Rate are bits per second.

4.2.9. Guaranteed Uplink Bit Rate

This attribute, **Guaranteed-UL-Bit-Rate**, represents the assured bit rate on the uplink path that will be provided for a set of IP flows associated with a mobility session. It is a variant of the "GBR" term defined in Section 2.2.

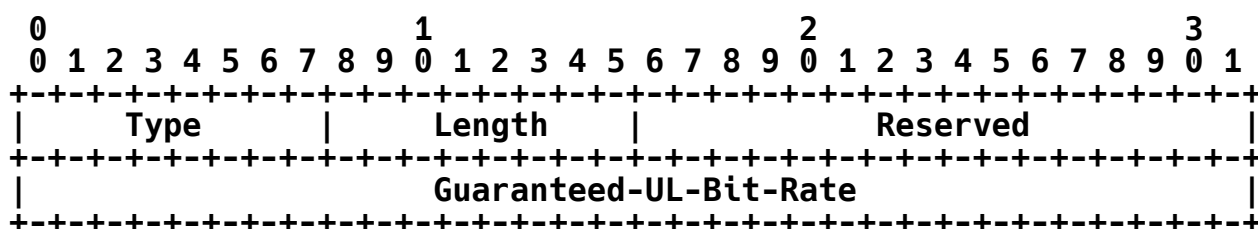
This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can only be a single instance of this attribute present in a QoS option.

When this attribute is present in a Proxy Binding Update sent by a mobile access gateway or in an Update Notification message sent by the local mobility anchor, it indicates the guaranteed uplink bit rate that is being requested.

When this attribute is present in a Proxy Binding Acknowledgement message or in an Update Notification Acknowledgement message, it indicates the guaranteed uplink bit rate that the peer agrees to offer.

When a QoS option includes both the **Guaranteed-UL-Bit-Rate** attribute and the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Guaranteed-UL-Bit-Rate** attribute is to be enforced at a flow level, and the traffic selectors present in the **QoS-Traffic-Selector** attribute identify those target flows.

When the QoS option that includes the **Guaranteed-UL-Bit-Rate** attribute does not include the **QoS-Traffic-Selector** attribute (Section 4.2.10), then the **Guaranteed-UL-Bit-Rate** attribute is to be applied to all the IP flows associated with the mobility session.



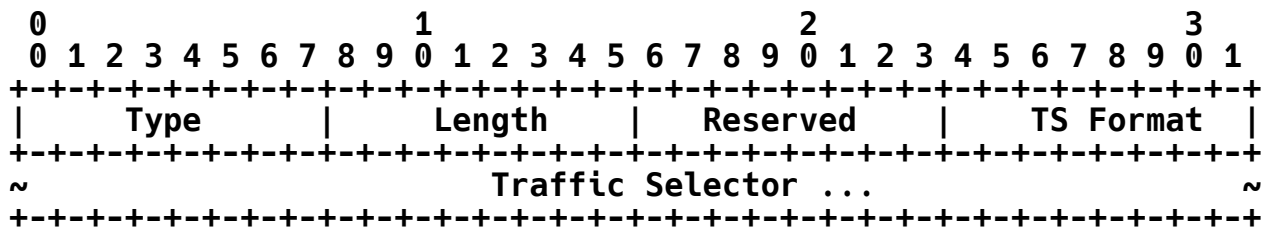
- o Type: 9
- o Length: The length of the attribute in octets, excluding the Type and Length fields. This value is set to (6).
- o Reserved: This field is unused for now. The value MUST be initialized by the sender to 0 and MUST be ignored by the receiver.
- o Guaranteed-UL-Bit-Rate: This is a 32-bit unsigned integer that indicates the guaranteed bandwidth in bits per second for uplink IP flows. The measurement units for Guaranteed-UL-Bit-Rate are bits per second.

4.2.10. QoS Traffic Selector

This attribute, QoS-Traffic-Selector, includes the parameters used to match packets for a set of IP flows.

This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute.

When a QoS option that includes the QoS-Traffic-Selector also includes any one or more of the attributes Allocation-Retention-Priority (Section 4.2.5), Aggregate-Max-DL-Bit-Rate (Section 4.2.6), Aggregate-Max-UL-Bit-Rate (Section 4.2.7), Guaranteed-DL-Bit-Rate (Section 4.2.8), and Guaranteed-UL-Bit-Rate (Section 4.2.9), then those included attributes are to be enforced at a flow level, and the traffic selectors present in the QoS-Traffic-Selector attribute identify those target flows. Furthermore, the DSCP marking in the QoS option is to be applied only to a partial set of the mobile node's IP flows, and the traffic selectors present in the QoS-Traffic-Selector attribute identify those target flows.

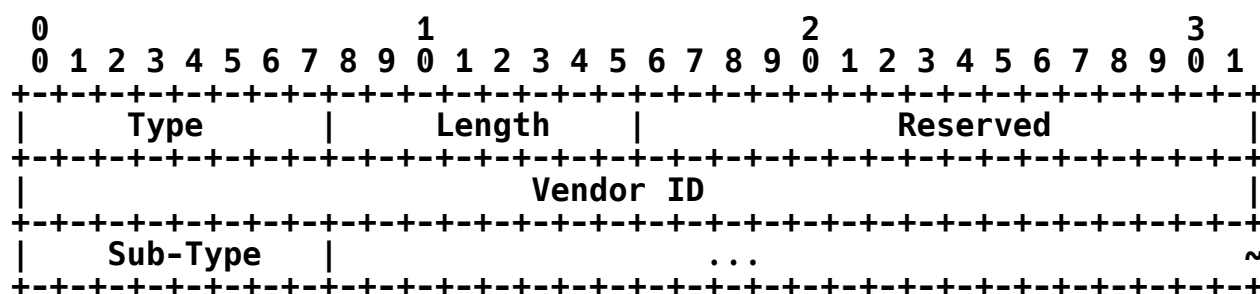


- o Type: 10
- o Length: The length of the attribute in octets, excluding the Type and Length fields.
- o Reserved: This field is unused for now. The value MUST be initialized by the sender to 0 and MUST be ignored by the receiver.
- o TS Format: An 8-bit unsigned integer indicating the Traffic Selector Format. The values are allocated from the "Traffic Selector Format" namespace for the traffic selector sub-option defined in [RFC6089]; those defined in [RFC6089] are repeated here for clarity. Value (0) is reserved and MUST NOT be used. When the value of the TS Format field is set to (1), the format that follows is the IPv4 Binary Traffic Selector specified in Section 3.1 of [RFC6088], and when the value of TS Format field is set to (2), the format that follows is the IPv6 Binary Traffic Selector specified in Section 3.2 of [RFC6088].
- o Traffic Selector: variable-length field for including the traffic specification identified by the TS format field.

4.2.11. QoS Vendor-Specific Attribute

This attribute is used for carrying vendor-specific QoS attributes. The interpretation and the handling of this option are specific to the vendor implementation.

This attribute can be included in the Quality-of-Service option defined in Section 4.1, and it is an optional attribute. There can be multiple instances of this attribute with different sub-type values present in a single QoS option.



- o Type: 11
- o Length: The length of the attribute in octets, excluding the Type and Length fields.
- o Reserved: This field is unused for now. The value MUST be initialized by the sender to 0 and MUST be ignored by the receiver.
- o Vendor ID: The Vendor ID is the SMI (Structure of Management Information) Network Management Private Enterprise Code of the IANA-maintained "Private Enterprise Numbers" registry [SMI].
- o Sub-Type: An 8-bit field indicating the type of vendor-specific information carried in the option. The namespace for this sub-type is managed by the vendor identified by the Vendor ID field.

4.3. New Status Code for Proxy Binding Acknowledgement

This document defines the following new status code value for use in Proxy Binding Acknowledgement message.

CANNOT_MEET_QOS_SERVICE_REQUEST (Cannot meet QoS Service Request): 179

4.4. New Notification Reason for Update Notification Message

This document defines the following new Notification Reason value for use in Update Notification message.

QOS_SERVICE_REQUEST (QoS Service Requested): 5

4.5. New Status Code for Update Notification Acknowledgement Message

This document defines the following new status code value for use in Update Notification Acknowledgement message.

CANNOT_MEET_QOS_SERVICE_REQUEST (Cannot meet QoS Service Request):
130

5. Protocol Considerations

5.1. Local Mobility Anchor Considerations

- o The conceptual Binding Cache entry data structure maintained by the local mobility anchor, described in Section 5.1 of [RFC5213], can be extended to store a list of negotiated Quality-of-Service requests to be enforced. There can be multiple such entries, and each entry must include the Service Request Identifier, DSCP value, and the attributes defined in Section 4.2.

LMA Receiving a QoS Service Request:

- o On receiving a Proxy Binding Update message with an instance of the Quality-of-Service option included in the message and the Operational Code field of the Quality-of-Service option set to QUERY, then the local mobility anchor includes all the Quality-of-Service option(s) reflecting the currently negotiated QoS Service Requests for that mobility session in the response message. The Operational Code field in each of the Quality-of-Service option(s), which is included in the response message, is set to RESPONSE.
- o On receiving a Proxy Binding Update message with one or more instances of the Quality-of-Service option included in the message and the Operational Code field set to ALLOCATE, the local mobility anchor processes the option(s) and determines if the QoS Service Request for the proposed QoS Service Request(s) can be met. Each instance of the Quality-of-Service option represents a specific QoS Service Request. This determination to accept the request(s) can be based on policy configured on the local mobility anchor, available network resources, or other considerations.
- o If the local mobility anchor can support the proposed QoS Service Requests in entirety, then it sends a Proxy Binding Acknowledgement message with a status code value of (0).
 - * The message includes all the Quality-of-Service option instances copied (including all the option content) from the received Proxy Binding Update message. The local mobility

anchor assigns a Service Request Identifier to each Service Request and sets the SR-ID field of each included Quality-of-Service option accordingly.

- * The Operational Code field in each of the Quality-of-Service option(s) is set to RESPONSE.
- * The local mobility anchor should enforce the Quality-of-Service rules for all the negotiated QoS Service Requests on the mobile node's uplink and downlink traffic.
- o If the local mobility anchor cannot support any of the requested QoS Service Requests in entirety, it rejects the request and sends a Proxy Binding Acknowledgement message with the status code value set to CANNOT_MEET_QOS_SERVICE_REQUEST (Cannot meet QoS Service Request).
 - * Since the local mobility anchor cannot support the requested QoS services for that mobile node, the Proxy Binding Acknowledgement message will not include any Quality-of-Service options. This serves as an indication to the mobile access gateway that QoS services are not supported for that mobile node.
 - * The denial of a QoS Service Request MUST NOT result in removal of the mobility session for that mobile node.
- o If the local mobility anchor can support QoS services for the mobile node, but only with lower quality values than indicated in the QoS attributes of a received QoS option or only for some of the received QoS Service Requests, the local mobility anchor includes the QoS option for the supported QoS Service Requests in the Proxy Binding Acknowledgement message with an updated set of QoS attributes.
 - * If the local mobility anchor cannot support some of the received QoS Service Requests for that mobile node, then the Quality-of-Service option for these QoS Service Requests is not included in the Proxy Binding Acknowledgement message. This serves as an indication to the mobile access gateway that a particular QoS Service Request is not supported for that mobile node. This includes the case where the attributes in a QoS option have conflicting requirements, for example, Per-Session-Agg-Max-UL-Bit-Rate is lower than Guaranteed-UL-Bit-Rate.
 - * The local mobility anchor includes only QoS options in the Proxy Binding Acknowledgement message for supported QoS attributes. The contents of each option (including the QoS

attributes) reflect the QoS service parameters that the local mobility anchor can support for that mobile node. The local mobility anchor sets the values of each supported QoS attribute according to the level of QoS it can support for the mobile node. The Service Request Identifier in each of the included QoS options is set to a value of (0). The Operational Code field in each of the included Quality-of-Service option(s) is set to NEGOTIATE. This serves as an indication for the mobile access gateway to resend the Proxy Binding Update message with the revised QoS parameters.

LMA Sending a QoS Service Request:

- o The local mobility anchor, at any time, can initiate a QoS Service Request for a mobile node by sending an Update Notification message [RFC7077]. The Notification Reason in the Update Notification message is set to a value of QOS_SERVICE_REQUEST, and the Acknowledgement Requested (A) flag is set to a value of (1).

* New QoS Service Request:

- + The message includes one or more instances of the Quality-of-Service option. Each instance of the option will include one or more QoS attributes.
- + The Operational Code field in the Quality-of-Service option is set to ALLOCATE.
- + The Service Request Identifier is set to the allocated value.
- + The DSCP field in the Traffic Class (TC) field is set to the requested DSCP value.

* Modification of an existing QoS Service Request:

- + The message includes one or more instances of the Quality-of-Service option with the QoS attributes reflecting the updated values in the attributes and the updated list of attributes.
- + The Operational Code field in the Quality-of-Service option is set to MODIFY.
- + The Service Request Identifier is set to a value that was allocated for that QoS Service Request.

- + The DSCP field in the Traffic Class (TC) field is set to the requested DSCP value.
- * Deletion of an existing QoS Service Request:
 - + The message includes the Quality-of-Service option(s) with the relevant QoS attributes.
 - + The Operational Code field in the Quality-of-Service option is set to DE-ALLOCATE.
 - + The Service Request Identifier is set to a value that was allocated for that QoS Service Request.
 - + The DSCP field in the Traffic Class (TC) field is set to the DSCP value associated with that request.
- * Query for the previously negotiated QoS Service Requests:
 - + The message includes a single instance of the Quality-of-Service option without including any QoS attributes.
 - + The Operational Code field in the Quality-of-Service option is set to QUERY.
 - + The Service Request Identifier is set to a value of (0).
 - + The DSCP field in the Traffic Class (TC) field is set to a value of (0).
- o Handling a Response to the QoS Service Request:
 - * If the received Update Notification Acknowledgement [RFC7077] message has the Status Code field set to a value (0), the local mobility anchor should enforce the Quality-of-Service rules for the negotiated QoS parameters on the mobile node's uplink and downlink traffic.
 - * If the received Update Notification Acknowledgement message has the Status Code field set to a value CANNOT_MEET_QOS_SERVICE_REQUEST, the local mobility anchor applies the following considerations:
 - + The denial of a QoS Service Request results in removal of any QoS state associated with that request.

- + If the message did not include any Quality-of-Service option(s), then it is an indication from the mobile access gateway that QoS services are not enabled for the mobile node.
- + If the Operational Code field in the Quality-of-Service option is set to a value of NEGOTIATE and the message includes one or more instances of the Quality-of-Service option, but the option contents reflect a downgraded/revised set of QoS parameters, then the local mobility anchor MAY choose to agree to proposed QoS Service Request by resending a new Update Notification message with the updated Quality-of-Service option(s).

General Considerations:

- o Any time the local mobility anchor removes a mobile node's mobility session by removing a Binding Cache entry [RFC5213] for which QoS resources have been previously allocated, those allocated resources are released.
- o Any time the local mobility anchor receives a Proxy Binding Update with HI hint = 3 (inter-MAG handover), the local mobility anchor when sending a Proxy Binding Acknowledgement message includes the QoS option(s) for each of the QoS Service Requests that are active for that mobile node. This allows the mobile access gateway to allocate QoS resources on the current path. This is relevant for the scenario where a mobile node performs a handover to a new mobile access gateway that is unaware of the previously negotiated QoS services.

5.2. Mobile Access Gateway Considerations

- o The conceptual Binding Update List entry data structure maintained by the mobile access gateway, described in Section 6.1 of [RFC5213], can be extended to store a list of negotiated Quality-of-Service requests to be enforced. There can be multiple such entries, and each entry must include the Service Request Identifier, DSCP value and the attributes defined in Section 4.2.

MAG Receiving a QoS Service Request:

- o On receiving an Update Notification message with one or more instances of the Quality-of-Service option included in the message, the mobile access gateway processes the option(s) and determines if the QoS Service Request for the proposed QoS Service Request(s) can be met. Each instance of the Quality-of-Service option represents a specific QoS Service Request. This

determination to accept the request(s) can be based on policy configured on the mobile access gateway, available network resources, or other considerations.

- o If the mobile access gateway can support the proposed QoS Service Requests in entirety, then it sends an Update Notification Acknowledgement message with a status code value of (0).
 - * The message includes all the Quality-of-Service option instances copied (including all the option content) from the received Update Notification message. However, if the Operational Code field in the request is a QUERY, then the message includes all the Quality-of-Service option(s) reflecting the currently negotiated QoS Service Requests for that mobility session.
 - * The Operational Code field in each of the Quality-of-Service option(s) is set to RESPONSE.
 - * The mobile access gateway should enforce the Quality-of-Service rules for all the negotiated QoS Service Requests on the mobile node's uplink and downlink traffic.
- o If the mobile access gateway cannot support any of the requested QoS Service Requests in entirety, then it rejects the request and sends an Update Notification Acknowledgement message with the status code set to CANNOT_MEET_QOS_SERVICE_REQUEST (Cannot meet QoS Service Request).
 - * The denial for QoS Service Request MUST NOT result in removal of the mobility session for that mobile node.
 - * The Update Notification Acknowledgement message may include the Quality-of-Service option(s) based on the following considerations.
 - + If the mobile access gateway cannot support QoS services for that mobile node, then the Quality-of-Service option is not included in the Update Notification Acknowledgement message. This serves as an indication to the local mobility anchor that QoS services are not supported for that mobile node.
 - + If the mobile access gateway can support QoS services for the mobile node, but only with lower quality values than indicated in the QoS attributes of a received QoS option, the mobile access gateway includes the QoS option in the Update Notification Acknowledgement message with an updated set of QoS attributes. The mobile access gateway sets the

values of each QoS attribute according to the level of QoS it can support for the mobile node. The mobile access gateway includes only QoS options in the Update Notification Acknowledgement message for supported QoS attributes. If the mobile access gateway receives one or multiple QoS options, whose QoS attributes are not supported, it omits these QoS options in the Update Notification Acknowledgement message. This includes the case where the attributes in a QoS option have conflicting requirements, for example, Per-Session-Agg-Max-UL-Bit-Rate is lower than Guaranteed-UL-Bit-Rate. The contents of each option (including the QoS attributes) reflect the QoS service parameters that the mobile access gateway can support for that mobile node. The Operational Code field in each of the Quality-of-Service option(s) is set to NEGOTIATE. This serves as an indication to the local mobility anchor to resend the Update Notification message with the revised QoS parameters.

MAG Sending a QoS Service Request:

- o The mobile access gateway, at any time, can initiate a QoS Service Request for a mobile node by sending a Proxy Binding Update message. The QoS Service Request can be initiated as part of the initial Binding registration or during Binding re-registrations.

*** New QoS Service Request:**

- + The message includes one or more instances of the Quality-of-Service option. Each instance of the option will include one or more QoS attributes.
- + The Operational Code field in each of the Quality-of-Service option is set to ALLOCATE.
- + The Service Request Identifier is set to a value of (0).
- + The DSCP value in the Traffic Class field reflects the requested DSCP value.

*** Modification of an existing QoS Service Request:**

- + The message includes one or more instances of the Quality-of-Service option with the QoS attributes reflecting the updated values in the attributes and the updated list of attributes.
- + The Operational Code field in the Quality-of-Service option is set to MODIFY.

- + The Service Request Identifier is set to a value that was allocated for that QoS Service Request.
- + The DSCP field in the Traffic Class (TC) field is set to the requested DSCP value.
- * Deletion of an existing QoS Service Request:
 - + The message includes the Quality-of-Service option(s) with the relevant QoS attributes.
 - + The Operational Code field in the Quality-of-Service option is set to DE-ALLOCATE.
 - + The Service Request Identifier is set to a value that was allocated for that QoS Service Request.
 - + The DSCP field in the Traffic Class (TC) field is set to the DSCP value associated with that request.
- * Query for the previously negotiated QoS Service Requests:
 - + The message includes a single instance of the Quality-of-Service option without including any QoS attributes.
 - + The Operational Code field in the Quality-of-Service option is set to QUERY.
 - + The Service Request Identifier is set to a value of (0).
 - + The DSCP field in the Traffic Class (TC) field is set to a value of (0).
- o Handling a Response to the QoS Service Request:
 - * If the received Proxy Binding Acknowledgement message has the Status Code field set to a value of (0), the mobile access gateway should enforce the Quality-of-Service rules for the negotiated QoS parameters on the mobile node's uplink and downlink traffic.
 - * If the received Proxy Binding Acknowledgement message has the Status Code field set to a value of CANNOT_MEET_QOS_SERVICE_REQUEST, the mobile access gateway applies the following considerations.
 - + The denial of a QoS Service Request results in removal of any QoS state associated with that request.

- + If the message did not include any Quality-of-Service option(s), then it is an indication from the local mobility anchor that QoS services are not enabled for the mobile node.
- + If the Operational Code field in the Quality-of-Service option is set to a value of NEGOTIATE and the message includes one or more instances of the Quality-of-Service option, but the option contents reflect a downgraded/revised set of QoS parameters, then the mobile access gateway MAY choose to agree to proposed QoS Service Request by resending a new Proxy Binding Update message with the updated Quality-of-Service option.

* General Considerations:

- + There can be more than one QoS Service Request in a single message. If so, the message includes an instance of a Quality-of-Service option for each of those Service Requests. Furthermore, the DSCP value is different in each of those requests.
- + Any time the mobile access gateway removes a mobile node's mobility session by removing a Binding Update List entry [RFC5213] for which QoS resources have been previously allocated, those allocated resources are released.

6. QoS Services in Integrated WLAN-3GPP Networks

6.1. Technical Scope and Procedure

The QoS option specified in this document can provide the equivalent level of QoS information defined in 3GPP, which is used to enforce QoS policies for IP flows that have been established while the mobile node is attached to WLAN access or moved from 3GPP to WLAN access. The QoS classification defined by the 3GPP specification [TS23.207] [TS29.212] is provided by Differentiated Services techniques in the IP transport network. The QoS classification used in the IP transport network is further translated to WLAN QoS-specific techniques in the WLAN access using appropriate WLAN QoS specifications [IEEE802.11aa-2012] [WMM1.2.0]. The details are described in Appendix A and Appendix B.

Figure 6 illustrates a generalized architecture where the QoS option can be used. The QoS policies could be retrieved from a Policy Control Function (PCF), such as defined in current cellular mobile communication standards, which aims to assign an appropriate QoS

class to a mobile node's individual flows. Alternatively, more static and default QoS rules could be made locally available, e.g., on a local mobility anchor, through administration.

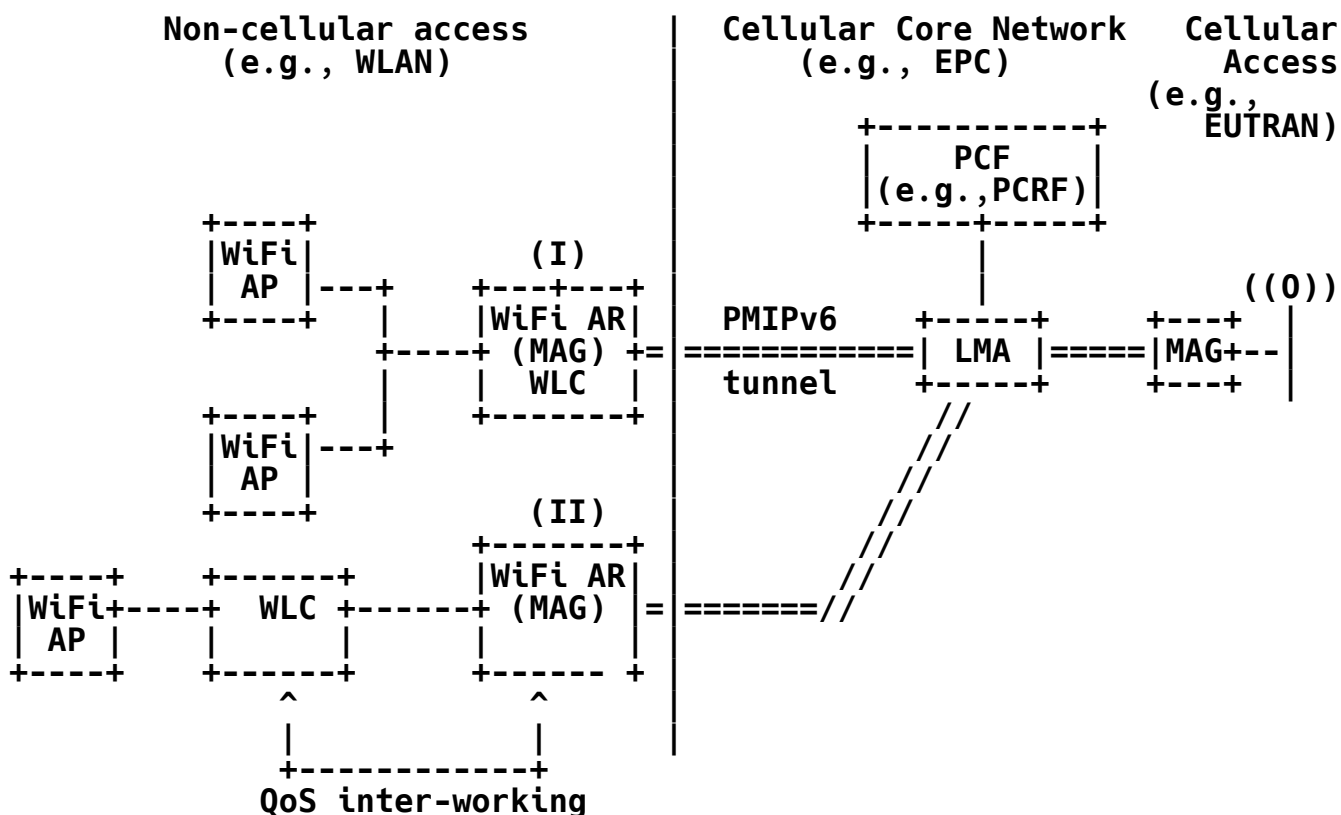


Figure 6: Architecture for QoS Inter-Working between Cellular Access and Non-Cellular Access

During a mobile node's handover from cellular access to non-cellular access, e.g., a wireless LAN (WLAN) radio access network, the mobile node's QoS policy rules, as previously established on the local mobility anchor for the mobile node's communication through the cellular access network, are moved to the handover target mobile access gateway serving the non-cellular access network. Such a non-cellular mobile access gateway can have an access-technology-specific controller or function co-located, e.g., a Wireless LAN Controller (WLC), as depicted in option (I) of Figure 6. Alternatively, the access-specific architecture can be distributed, and the access-technology-specific control function is located external to the mobile access gateway, as depicted in option (II). In this case, the mobile access gateway and the access-technology-specific control

function (e.g., the WLC) must provide some protocol for QoS inter-working. Details of such inter-working are out of the scope of this specification.

6.2. Relevant QoS Attributes

The QoS Option shall at least contain a DSCP value being associated with IP flows of a mobility session. The DSCP value should correspond to the 3GPP QoS Class Index (QCI), which identifies the type of service in terms of QoS characteristics (e.g., conversational voice, streaming video, signaling, and best effort); more details on DSCP and QCI mapping are given in Appendix A. Optional QoS information could also be added. For instance, in order to comply with the bearer model defined in 3GPP [TS23.203], the following QoS parameters are conveyed for each PMIPv6 mobility session:

- o Default, non-GBR bearer (QCI=5-9)
 - * DSCP=(BE, AF11, AF21, AF31, AF32)
 - * Per-MN AMBR-UL/DL
 - * Per-Session AMBR-UL/DL {S=1,E=1}
 - * AARP

APN (Access Point Name) is provided via the Service Selection ID defined in [RFC5149]. If APN is not interpreted by Wi-Fi AP, the latter will police only based on Per-MN AMBR-UL/DL (without Per-Session AMBR-UL/DL) on the Wi-Fi link.

- o Dedicated, GBR bearer (QCI=1-4)
 - * DSCP=(EF, AF41)
 - * GBR-UL/DL
 - * MBR-UL/DL
 - * AARP
 - * TS

Wi-Fi AP will perform the policy enforcement with the minimum bit rate=GBR and the maximum bit rate=MBR.

- o Dedicated, non-GBR bearer (QCI=5-9)
 - * DSCP=(BE, AF11, AF21, AF31, AF32)
 - * Per-MN AMBR-UL/DL
 - * Per-Session AMBR-UL/DL {S=1,E=1}
 - * AARP
 - * TS

If APN is not interpreted by Wi-Fi AP, it will police based only on Per-MN AMBR-UL/DL (without Per-Session AMBR-UL/DL) on the Wi-Fi link.

If DSCP values follow the 3GPP specification and deployment, the code point can carry intrinsically additional attributes according to Figure 7 in Appendix A.

For some optional QoS attributes, the signaling can differentiate enforcement per mobility session and per IP flow. For the latter, as long as the AMBR constraints are met, the rule associated with the identified flow(s) overrules the aggregated rules that apply per mobile node or per mobility session. Additional attributes can be appended to the QoS option, but their definition and specification is out of scope of this document and are left as considerations for actual deployment.

7. IANA Considerations

IANA has completed the following actions:

- o Action-1: This specification defines a new mobility option, the Quality-of-Service (QoS) option. The format of this option is described in Section 4.1. The type value 58 for this mobility option has been allocated from the "Mobility Options" registry at <<http://www.iana.org/assignments/mobility-parameters>>.
- o Action-2: This specification defines a new mobility attribute format, the Quality-of-Service attribute. The format of this attribute is described in Section 4.2. This attribute can be carried in the Quality-of-Service mobility option. The type values for this attribute are managed by IANA in a new registry, the "Quality-of-Service Attribute Registry". This registry is maintained under the "Mobile IPv6 parameters" registry at <<http://www.iana.org/assignments/mobility-parameters>>. This specification reserves the type values listed below. All other

values (12 - 254) are unassigned and may be assigned by IANA using the Specification Required policy [RFC5226]. The Designated Expert reviewing the value assignment is expected to verify that the protocol extension follows the Proxy Mobile IPv6 architecture and does not raise backward-compatibility issues with existing deployments.

Value	Description	Reference
0	Reserved	RFC 7222
1	Per-MN-Agg-Max-DL-Bit-Rate	RFC 7222
2	Per-MN-Agg-Max-UL-Bit-Rate	RFC 7222
3	Per-Session-Agg-Max-DL-Bit-Rate	RFC 7222
4	Per-Session-Agg-Max-UL-Bit-Rate	RFC 7222
5	Allocation-Retention-Priority	RFC 7222
6	Aggregate-Max-DL-Bit-Rate	RFC 7222
7	Aggregate-Max-UL-Bit-Rate	RFC 7222
8	Guaranteed-DL-Bit-Rate	RFC 7222
9	Guaranteed-UL-Bit-Rate	RFC 7222
10	QoS-Traffic-Selector	RFC 7222
11	QoS-Vendor-Specific-Attribute	RFC 7222
255	Reserved	RFC 7222

- o Action-3: This document defines a new status code, CANNOT_MEET_QOS_SERVICE_REQUEST (179), for use in Proxy Binding Acknowledgement messages, as described in Section 4.3. This value has been assigned from the "Status Codes" registry at <http://www.iana.org/assignments/mobility-parameters>.
- o Action-4: This document defines a new Notification Reason, QOS_SERVICE_REQUEST (5), for use in Update Notification messages [RFC7077] as described in Section 4.4. This value has been assigned from the "Update Notification Reasons Registry" at <http://www.iana.org/assignments/mobility-parameters>.

- o Action-5: This document defines a new status code, CANNOT_MEET_QOS_SERVICE_REQUEST (130), for use in Update Notification Acknowledgement messages [RFC7077] as described in Section 4.5. This value has been assigned from the "Update Notification Acknowledgement Status Registry" at <http://www.iana.org/assignments/mobility-parameters>.

8. Security Considerations

The Quality-of-Service option defined in this specification is for use in Proxy Binding Update, Proxy Binding Acknowledgement, Update Notification, and Update Notification Acknowledgement messages. This option is carried in these messages like any other mobility header option. [RFC5213] and [RFC7077] identify the security considerations for these signaling messages. When included in these signaling messages, the Quality-of-Service option does not require additional security considerations.

9. Acknowledgements

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Appendix A. Information When Implementing 3GPP QoS in IP Transport Network

A.1. Mapping Tables

Mapping between 3GPP QCI values and DSCP is defined in [GSMA.IR.34] as follows.

QCI	Traffic Class	DiffServ Per-Hop-Behavior	DSCP
1	Conversational	EF	101110
2	Conversational	EF	101110
3	Conversational	EF	101110
4	Streaming	AF41	100010
5	Interactive	AF31	011010
6	Interactive	AF32	011100
7	Interactive	AF21	010010
8	Interactive	AF11	001010
9	Background	BE	000000

Figure 7: QCI/DSCP Mapping Table

Mapping between QoS attributes defined in this document and 3GPP QoS parameters is as follows.

Section	PMIPv6 QoS Attribute	3GPP QoS Parameter
4.2.1	Per-MN-Agg-Max-DL-Bit-Rate	UE AMBR-DL
4.2.2	Per-MN-Agg-Max-UL-Bit-Rate	UE AMBR-UL
4.2.3	Per-Session-Agg-Max-DL-Bit-Rate Flags: (S=1, E=1)	APN AMBR-DL
4.2.4	Per-Session-Agg-Max-UL-Bit-Rate Flags: (S=1, E=1)	APN AMBR-UL
4.2.5	Allocation-Retention-Priority	ARP
4.2.6	Aggregate-Max-DL-Bit-Rate	MBR-DL
4.2.7	Aggregate-Max-UL-Bit-Rate	MBR-UL
4.2.8	Guaranteed-DL-Bit-Rate	GBR-DL
4.2.9	Guaranteed-UL-Bit-Rate	GBR-UL
4.2.10	QoS-Traffic-Selector	TFT

Figure 8: QoS Attributes and 3GPP QoS Parameters Mapping Table

A.2. Use Cases and Protocol Operations

The following subsections provide example message flow charts for scenarios where the QoS option extensions will apply as described in Section 6.1 to the protocol operation for QoS rules establishment (Appendices A.2.1 and A.2.2) and to modification (Appendix A.2.3).

A.2.1. Handover of Existing QoS Rules

In Figure 9, the MN is first connected to the LTE network with a multimedia session, such as a video call, with appropriate QoS parameters set by the Policy Control Function. Then, the MN discovers a Wi-Fi AP (e.g., at home or in a cafe) and switches to it, provided that Wi-Fi access has a higher priority when available. Not only is the session continued, but the QoS is also maintained after moving to the Wi-Fi access. In order for that to happen, the LMA delivers the QoS parameters according to the bearer type on the 3GPP access to the MAG via the PMIPv6 signaling with the QoS option

(OC=ALLOCATE, SR-ID, QoS attributes, etc.). The equivalent QoS treatment is provided by the Wi-Fi AP toward the MN on the Wi-Fi link.

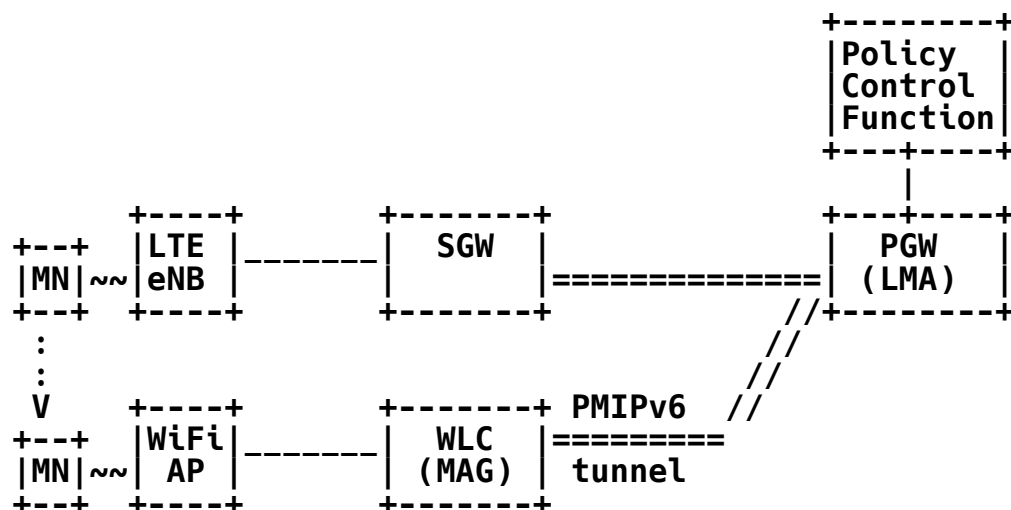
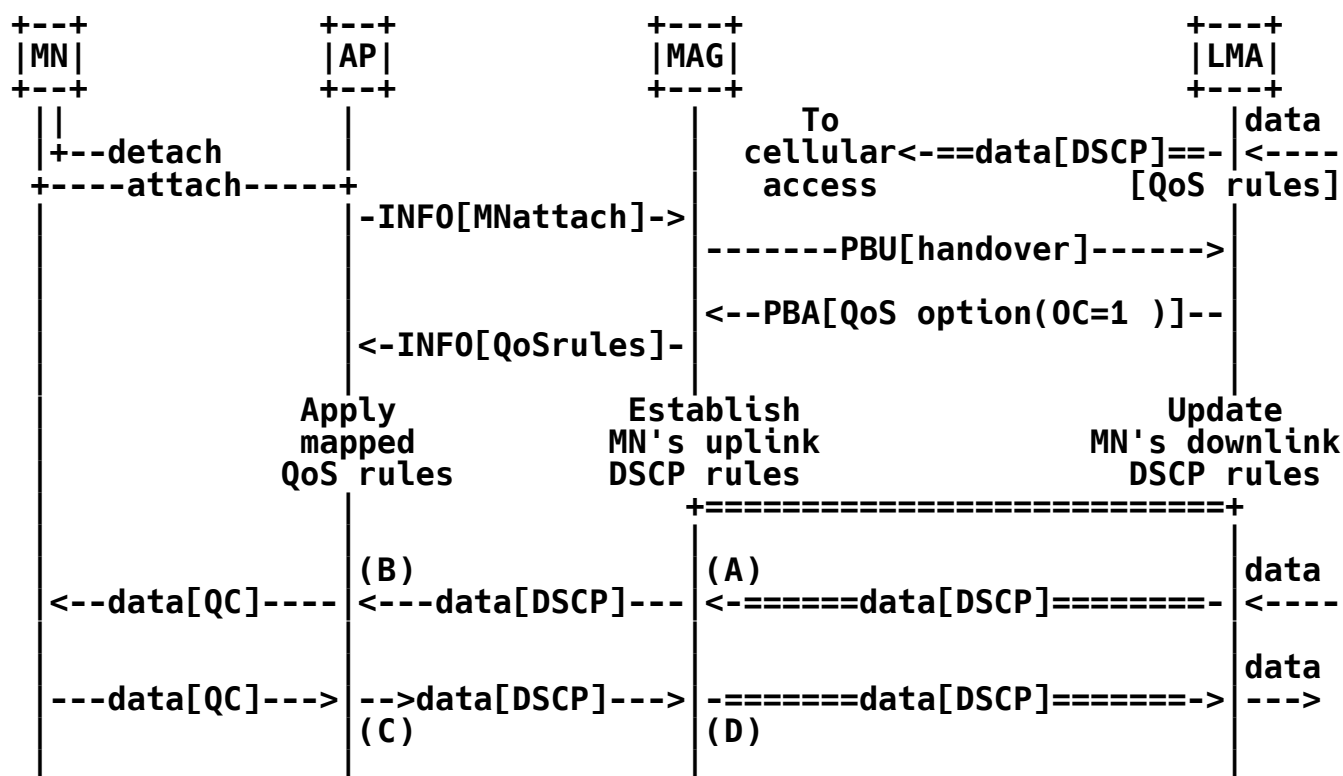


Figure 9: Handover Scenario (from LTE to WLAN)

Figure 10 shows an example of how the QoS rules can be conveyed and enforced between the LMA and MN in the case of a handover from 3GPP access to WLAN access.



- (A): Apply DSCP at link to AP
 (B): Enforce mapped QoS rules to access technology
 (C): Map MN-indicated QoS Class (QC) to DSCP on the AP-MAG link, or validate MN-indicated QC and apply DSCP on the AP-MAG link according to QoS rules
 (D): Validate received DSCP and apply DSCP according to QoS rules

Figure 10: Handover of QoS Rules

A.2.2. Establishment of QoS Rules

A single operator has deployed both a fixed access network and a mobile access network. In this scenario, the operator may wish a harmonized QoS management on both accesses, but the fixed access network does not implement a QoS control framework. So, the operator chooses to rely on the 3GPP policy control function, which is a standard framework to provide a QoS control, and to enforce the 3GPP QoS policy on the Wi-Fi access network. The PMIP interface is used to realize this QoS policy provisioning.

The use case is depicted on Figure 11. The MN first attaches to the Wi-Fi network. During the attachment process, the LMA, which may communicate with Policy Control Function (using procedures outside

the scope of this document), provides the QoS parameters to the MAG via the QoS option (OC=ALLOCATE) in the PMIP signaling (i.e., PBA). Subsequently, an application on the MN may trigger the request for alternative QoS resources, e.g., by use of the WMM-API (Wi-Fi Multimedia - API). The MN may request that traffic resources be reserved using L2 signaling, e.g., sending an Add Traffic System (ADDTS) message [IEEE802.11-2012]. The request is relayed to the MAG, which includes the QoS parameters in the QoS option (OC=ALLOCATE) on the PMIP signaling (i.e., the PBU initiated upon flow creation). The LMA, in coordination with the PCF, can then authorize the enforcement of such QoS policy. Then, the QoS parameters are provided to the MAG via the QoS option (OC=ALLOCATE, SR-ID, QoS attributes, etc.) in the PMIP signaling, and the equivalent QoS treatment is provided towards the MN on the Wi-Fi link.

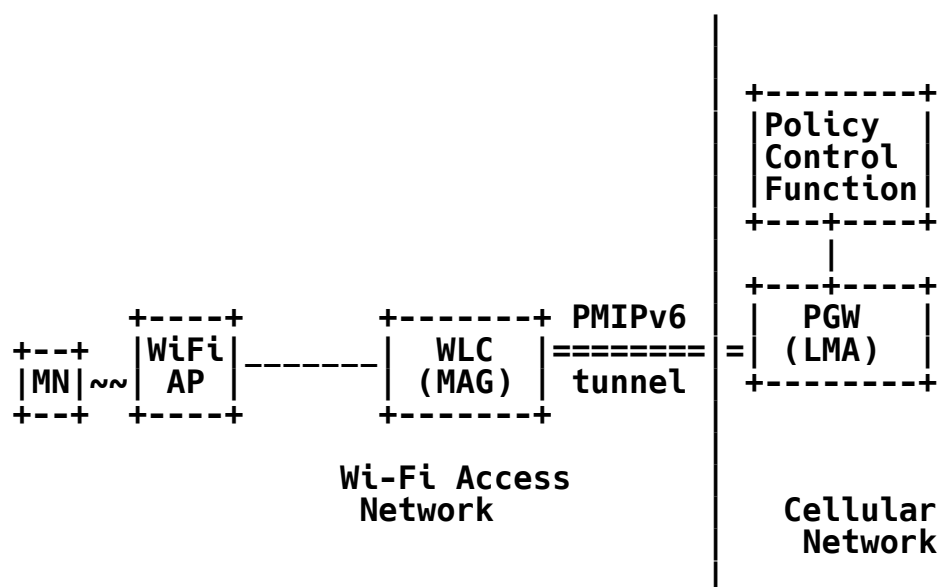
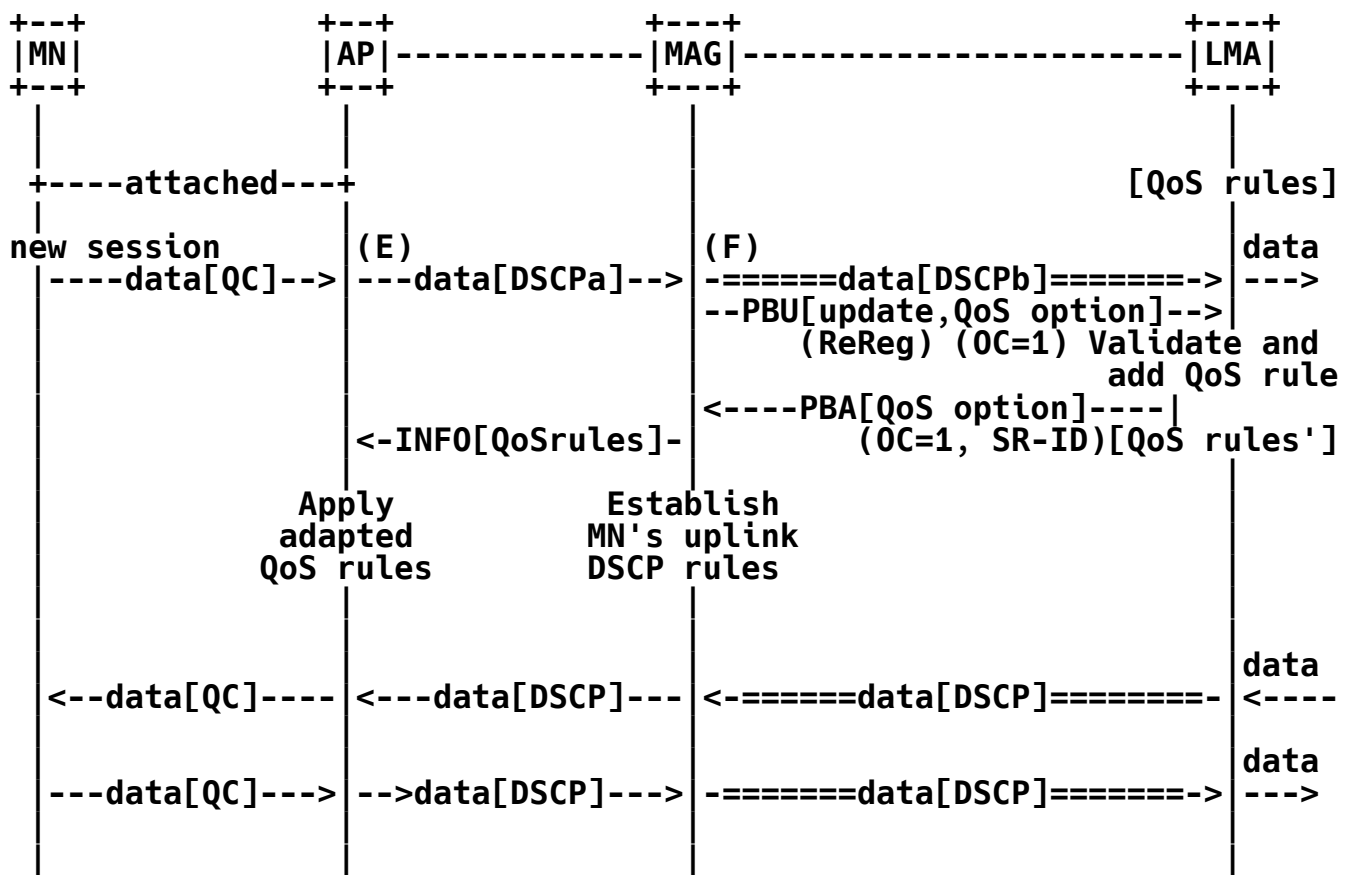


Figure 11: QoS Policy Provisioning

Figure 12 shows an example of how the QoS rules can be conveyed and enforced between the LMA and MN in the case of initial attachment to WLAN access.



(E): AP may enforce uplink QoS rules according to priority class set by the MN

(F): MAG can enforce a default QoS class until the local mobility anchor classifies the new flow (notified with PBA) or the mobile access gateway classifies new flow and proposes the associated QoS class to the local mobility anchor for validation (proposed with PBU, notification of validation result with PBA)

Figure 12: Adding New QoS Service Request for MN-Initiated Flow

A.2.3. Dynamic Update to QoS Policy

A mobile node is attached to the WLAN access and has obtained QoS parameters from the LMA for that mobility session. Having obtained the QoS parameters, a new application, e.g., IP Multimedia Subsystems (IMS) application, gets launched on the mobile node that requires certain QoS support.

The application on the mobile node initiates the communications via a dedicated network function (e.g., IMS Call Session Control Function). Once the communication is established, the application network function notifies the PCF about the new IP flow. The PCF function in turn notifies the LMA about the needed QoS parameters identifying the IP flow and QoS parameters. LMA sends an Update Notification message [RFC7077] to the MAG with the Notification Reason value set to QOS_SERVICE_REQUEST. On receiving the Update Notification message, the MAG completes the PBU/PBA signaling for obtaining the new QoS parameters via the QoS options (OC=MODIFY, SR-ID, QoS attributes, etc.). The MAG provisions the newly obtained QoS parameters on the access network to ensure the newly established IP flow gets its requested network resources.

Upon termination of the established IP flow, the application function again notifies the PCF function to remove the established QoS parameters. The PCF notifies the LMA to withdraw the QoS resources established for that voice flow. The LMA sends an Update Notification message to the MAG with the "Notification Reason" value set to "FORCE-REREGISTRATION". On receiving this Update Notification Acknowledgement message, the MAG completes the PBU/PBA signaling for removing the existing QoS rules (OC=DE-ALLOCATE, SR-ID). The MAG then removes the QoS parameters from the corresponding IP flow and releases the dedicated network resources on the access network.

Appendix B. Information When Implementing PMIP-Based QoS Support with IEEE 802.11e

This section shows, as an example, the end-to-end QoS management with a 802.11e-capable WLAN access link and a PMIP-based QoS support.

The 802.11e, or Wi-Fi Multimedia (WMM), specification provides prioritization of packets for four types of traffic, or access categories (ACs):

Voice (AC_VO): Very high-priority queue with minimum delay. Time-sensitive data such as VoIP and streaming mode are automatically sent to this queue.

Video (AC_VI): High-priority queue with low delay. Time-sensitive video data is automatically sent to this queue.

Best effort (AC_BE): Medium-priority queue with medium throughput and delay. Most traditional IP data is sent to this queue.

Background (AC_BK): Lowest-priority queue with high throughput. Bulk data that requires maximum throughput but is not time-sensitive (for example, FTP data) is sent to the queue.

The access point uses the 802.11e indicator to prioritize traffic on the WLAN interface. On the wired side, the access point uses the 802.1p priority tag and DSCP. To allow consistent QoS management on both wireless and wired interfaces, the access point relies on the 802.11e specification, which defines mapping between the 802.11e access categories and the IEEE 802.1D priority (802.1p tag). The end-to-end QoS architecture is depicted in Figure 13, and the 802.11e /802.1D priority mapping is shown in the following table:

802.1e AC	802.1D priority
AC_VO	7,6
AC_VI	5,4
AC_BE	0,3
AC_BK	2,1

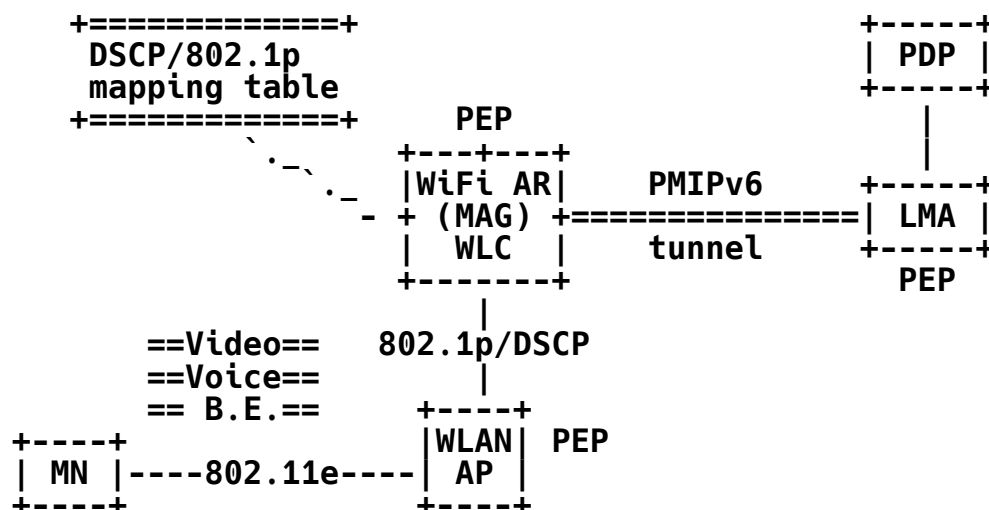


Figure 13: End-to-End QoS Management with 802.11e

When receiving a packet from the MN, the AP checks whether the frame contains 802.11e markings in the L2 header. If not, the AP checks the DSCP field. If the uplink packet contains the 802.11e marking, the access point maps the access categories to the corresponding 802.1D priority as per the table above. If the frame does not contain 802.11e marking, the access point examines the DSCP field.

If DSCP is present, the AP maps DSCP values to a 802.1p value (i.e., 802.1D priority). This mapping is not standardized and may differ between operators; a mapping example is given in the following table.

Type of traffic	802.1p	DSCP value
Network Control	7	56
Voice	6	46 (EF)
Video	5	34 (AF 41)
Voice Control	4	26 (AF 31)
Background Gold	2	18 (AF 21)
Background Silver	1	10 (AF 11)
Best Effort	0,3	0 (BE)

The access point prioritizes ingress traffic on the Ethernet port based on the 802.1p tag or the DSCP value. If the 802.1p priority tag is not present, the access point checks the DSCP/802.1p mapping table. The next step is to map the 802.1p priority to the appropriate egress queue. When 802.11e support is enabled on the wireless link, the access point uses the IEEE standardized 802.1p/802.11e correspondence table to map the traffic to the appropriate hardware queues.

When the 802.11e-capable client sends traffic to the AP, it usually marks packets with a DSCP value. In that case, the MAG/LMA can come into play for QoS renegotiation and call flows depicted in Appendix A apply. Sometimes, when communication is initiated on the WLAN access, the application does not mark upstream packets. If the uplink packet does not contain any QoS marking, the AP/MAG could determine the DSCP field according to traffic selectors received from the LMA. Figure 14 gives the call flow corresponding to that use case and shows where QoS tags mapping does come into play. The main steps are as follows:

(A): During the MN attachment process, the MAG fetches QoS policies from the LMA. After this step, both the MAG and LMA are provisioned with QoS policies.

(B): The MN starts a new IP communication without making IP packets with DSCP tags. The MAG uses the traffic selector to determine the DSCP value; it then marks the IP packet and forwards within the PMIP tunnel.

(C): The LMA checks the DSCP value with respect to the traffic selector. If the QoS policies are valid, the LMA forwards the packet without renegotiating the QoS rules.

(D): When receiving a marked packet, the MAG, the AP, and the MN use 802.11e (or WMM), 802.1p tags, and DSCP values to prioritize the traffic.

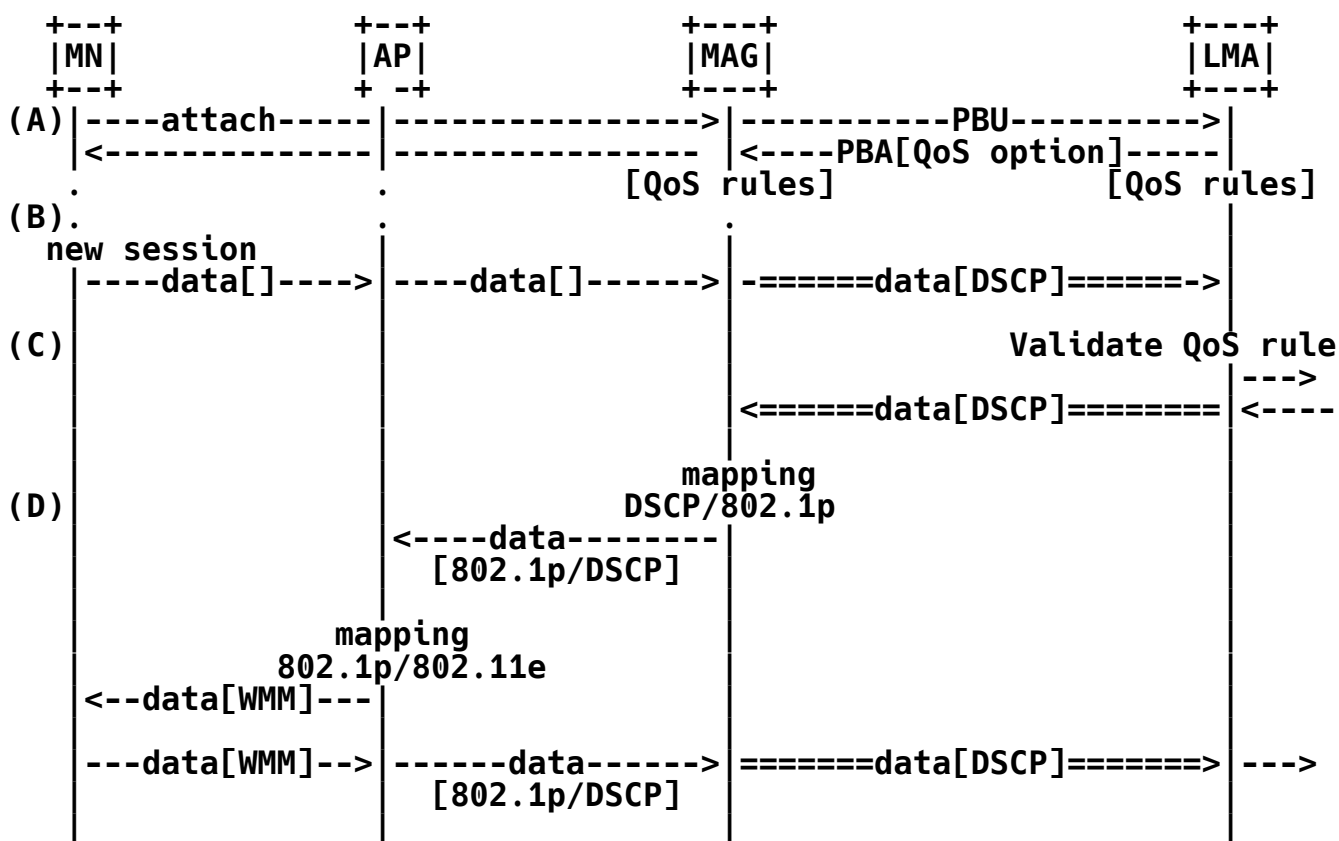


Figure 14: Prioritization of a Flow Created on the WLAN Access

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