Quality of Service Option for Proxy Mobile IPv6
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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 (MN).
   Users can access Internet Protocol (IP) based services from their
   mobile device by using various radio access technologies. Current
   standardization effort considers strong QoS classification and
   enforcement for cellular radio access technologies. 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 and the mobile access gateway, as
   well as by access network elements. Policy control and QoS
   differentiation for access to the mobile operator network through
   alternative non-cellular access technologies is not yet considered,
   even though some of these access technologies are able to support QoS
   by appropriate traffic prioritization techniques. However, handover
   and IP Flow Mobility using alternative radio access technologies,
   such as IEEE802.16 and Wireless LAN according to the IEEE802.11
   specification, are being considered by the standards [TS23.402],
   whereas inter-working with the cellular architecture to establish QoS
   policies in alternative access networks has not received much
   attention so far.

   In particular Wireless LAN (WLAN) has been identified as an
   alternative technology to complement cellular radio access. Since
   the 802.11e extension 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. Three functional operations have
   been identified to accomplish this:

      (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
this IP session. This document specifies fundamental QoS attributes
which apply on a per mobile node, mobility session or on a 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.

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 scope for
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 exceeding the
   AMBR limit will be discarded by the rate-shaping function where
   the AMBR parameter is enforced. Variants of 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 no sufficient
   resources for meeting all services 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 if it must be rejected by preempting an existing
   low-priority service.

Differentiated Services Code Point (DSCP)

   In 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] and [RFC4594] for a complete explanation.

Downlink (DL) Traffic

The mobile node's IP packets that the mobile access gateway
receives from the local mobility anchor is 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 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 (examples: Internet
Service, 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 is 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 "Uplink"

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 consistent throughout 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. These entities being the entry and exit
   points for the mobile node's IP traffic are the logical choice for
   being the QoS enforcement points. The basic QoS primitives 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) and as well for realizing relative performance treatment by the
   ways of class-based differentiation. The subscriber's policy and the
   charging profile is a key consideration 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 service
   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.

```
    +=======+
    |  MN-1 |
    +=======+
      | | |                                              Flow-6
      Flow-1<--(GBR: 64Kbps)                                |
      |                                             Flow-4 |
        Flow-2                                        | | |
      | |                                        Flow-1 | |
        | Flow-3                                       | | |
      |_|_|                                   DSCP-X   | | |
     (     )<--(Per-Session-AMBR: 1Mbps)         :     | | |
      | | |                                 DSCP-Z :   | | |
        | |                                       : :   | | |
      | | |               +=====+               +==:=v+ | | |
        | '- -- - - - --|     |                | : o|--' | |
      | '- - - --- - - -|     |          __     | v o|----' |
      '- - - - - -  - - -|     |       _--'  '--_ | o--|------'
                    |     |      ( Diffserv )  |   |
                    | MAG |=====(  enabled   )=====| LMA |
                    |     |      (IP Network)     |   |
     ,- - - - - - - - -|     |       '--__--'    | o|-- - -,
       ,- - -- - -- - -|     |                  | o|--- , |
      | | ,- - - - -- -|     |                  | o|--, | |
        | |               +=====+               +====^+ | | |
      |_|_|                                       :   | | |
     ( _ _ )<--(Per-Session-AMBR: 2Mbps)          :   | | |
      | | |                                  DSCP-Y   | | |
        | |                                           | | |
      | | |                                           | | |
        | Flow-6                              Flow-2 | |
      | |                                            | |
        Flow-5 (MBR: 100Kbps)                Flow-3 |
      |                                              |
      Flow-4  (GBR: 64Kbps)                  Flow-5
        | | |
    +=======+
    |  MN-2 |
    +=======+
```

Figure 1: QoS Support

Figure 1 explains 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. A Per-Session-AMBR of 1Mbps 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 64Kbps
for Flow-1 and Flow-5 is assured, a DSCP marking enforcement of "Z"

on Flow-6, and MBR of 100 Kbps on Flow-5;

3.1. Quality of Service Option - Usage Examples

Use Case 1: Figure 2 explains a scenario where a local mobility
anchor initiates a QoS service request to a mobile access gateway.

```
    +-----+              +-----+              +-----+
    | MN  |              | MAG |              | LMA |
    +-----+              +-----+              +-----+
       |                    |                    |
1)     |---- MN Attach ----|                    |
2)     |                    |------ PBU ------->|
3)     |                    |<----- PBA --------|
       |                    |                    |
4)     |                    |o===============o|
       |                    |    PMIPv6 Tunnel  |
       |                    |                    |
       |   (LMA initiates QoS Service Request)  |
5)     |                    |<----- UPN (QoS)---|
       |                    |                    |
       |   (MAG proposes a revised QoS Request) |
6)     |                    |------ UPA (QoS')->|
       |                    |                    |
7)     |                    |<----- UPN (QoS')--|
8)     |                    |------ UPA (QoS')->|
       |   QoS Rules     ---|                    |
9)     | Established <-|    |  QoS Rules     ---|
10)    |                 ---| Established <-|    |
       |                    |             ---|
11)    |<----------------->|                    |
```
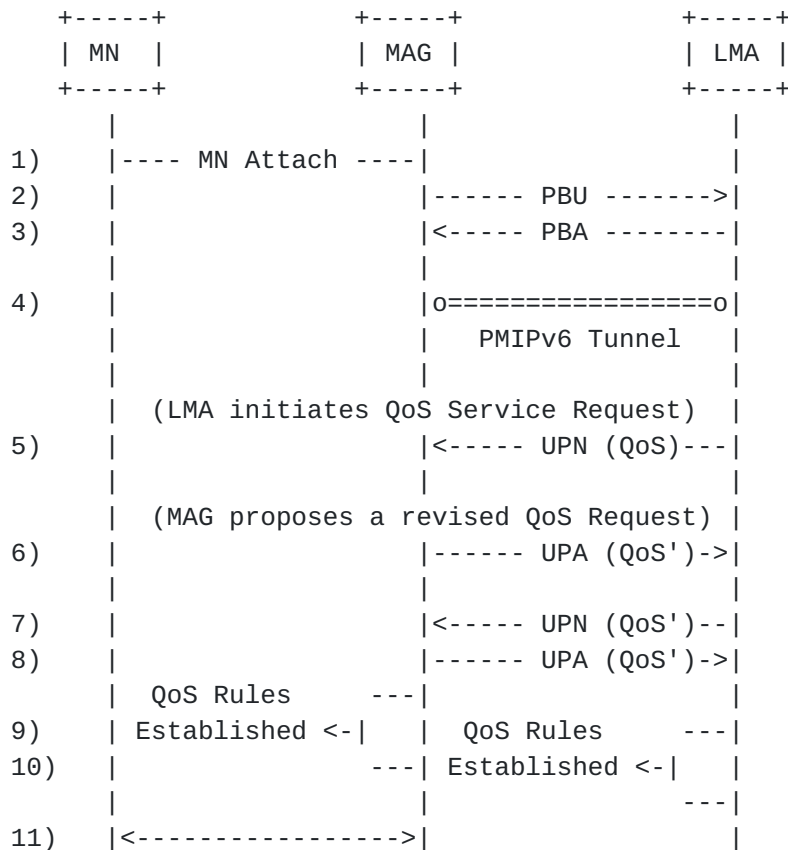
                 Figure 2: LMA Initiated QoS Service Request

o (1) to (4): MAG detects the mobile node's attachment to the access
   link and initiates the signaling with the local mobility anchor.
   The LMA and MAG upon completing the signaling 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 message [RFC7077] to the MAG. The message
   includes the QoS option Section 4.1 which includes a set of QoS
   parameters. The mobile access gateway on determining that it
   cannot support the requested QoS service request for that mobile
   sends an revised QoS option in the Update Notification

Acknowledgement message, which the LMA agrees to the proposed QoS parameters by sending a new Update Notification message with a modified 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) install the QoS rules on the access network.

Use Case 2: Figure 3 explains a scenario where a mobile access gateway initiates a QoS service request to a local mobility anchor.

```
   +-----+              +-----+              +-----+
   | MN  |              | MAG |              | LMA |
   +-----+              +-----+              +-----+
      |                    |                    |
1)    |---- MN Attach ----|                    |
2)    |                    |------ PBU ------->|
3)    |                    |<----- PBA --------|
      |                    |                    |
4)    |                    |o===============o|
      |                    |    PMIPv6 Tunnel   |
      |                    |                    |
      |   (MAG initiates QoS Service Request)   |
5)    |                    |------ PBU (QoS)-->|
6)    |                    |<----- PBA (QoS)---|
      |   QoS Rules     ---|                    |
7)    | Established <-|   |  QoS Rules     ---|
8)    |                ---| Established <-|   |
      |                    |                ---|
9)    |<----------------->|                    |
```
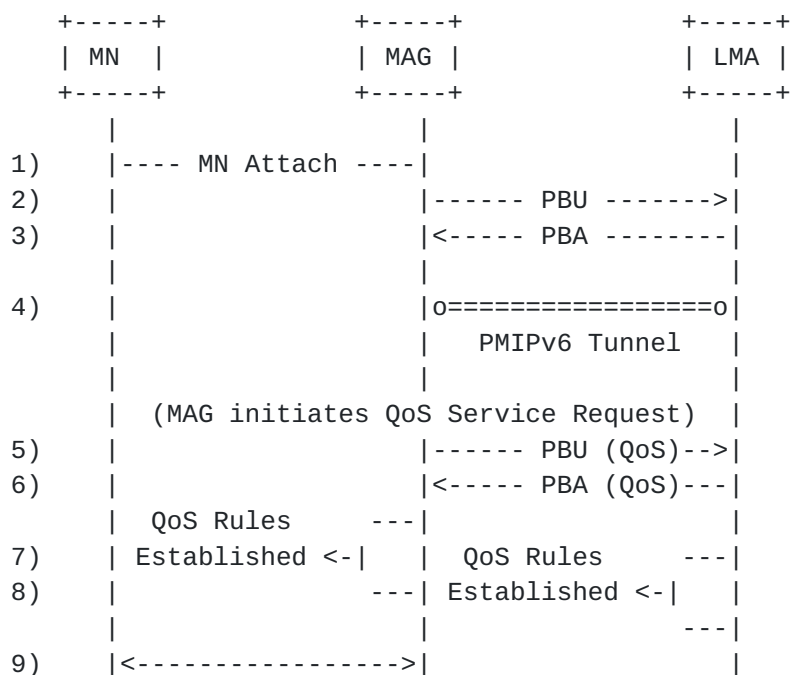
             Figure 3: MAG Initiated QoS Service Request

o (1) to (4): MAG detects the mobile node's attachment to the access link and initiates the signaling with the local mobility anchor. The LMA and MAG upon completing the signaling 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 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 Proxy

Binding Acknowledgement 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 install 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) are 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),
   Guaranteed-UL-Bit-Rate (Section 4.2.9) are 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), QoS-Traffic-Selector (Section 4.2.10) are used
   for this purpose.

o A service provider is required to ensure the application traffic
   associated with emergency services is not impacted under any
   network condition. 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 and in such cases the service provider may have
to revoke resources that have been allocated and be reassigned 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) are 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 anchor and mobile access gateway 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.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |    Length     |     SR-ID     |      TC       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      OC       |                  Reserved                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                        QoS Attribute(s)                       ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
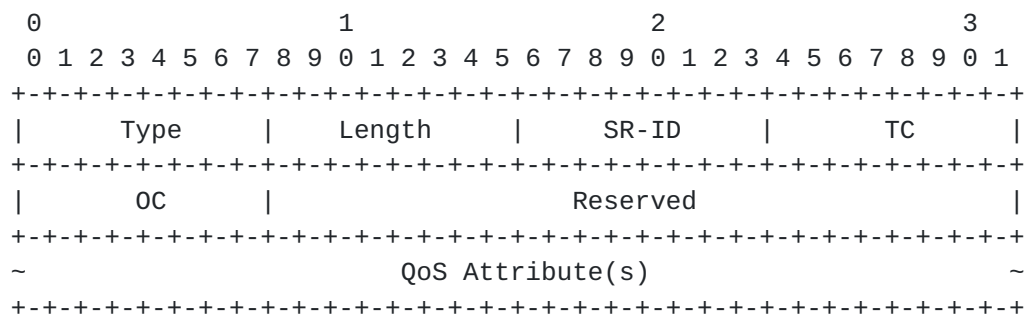
                        Figure 4: QoS Option

      Type

         <IANA-1>

      Length

         8-bit unsigned integer indicating the length of the option in
         octets, excluding the Type and Length fields.

      Service Request Identifier (SR-ID)

         A 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
         identifier value. When the QoS Service request is initiated by
         a mobile access gateway, it sets the value to (0) and the local
         mobility anchor allocates and includes the value in the

response. For any QoS service requests initiated by a local
mobility anchor, the Service Request Identifier is set to the
allocated value.

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 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.

Two-bit Reserved Field

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.

Operational Code (OC)

One-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
and that are still active

         NEGOTIATE: (5)
            Response to a QoS service request with a counter QoS
            proposal

         Reserved: (6) to (255)
            Currently not used. Receiver MUST ignore the option
            received with any value in this range.

      Reserved

         This field is unused for now. The value MUST be initialized to
         a value of (0) by the sender and MUST be ignored by the
         receiver.

      QoS Attribute(s)

         Zero or more Type-Length-Value (TLV) encoded QoS Attributes.
         The format of the QoS attribute is defined in Section 4.2.   The
         interpretation and usage of the QoS attribute is based on the
         value in the "Type" field.

4.2. Quality of Service Attribute

   This section identifies the format of a Quality of Service attribute.
   QoS attribute can be included in the Quality of Service option
   defined in Section 4.1. The latter part of this section identifies
   the QoS attributes defined by this specification.

```
   0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    Type       |    Length     |            Value              ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
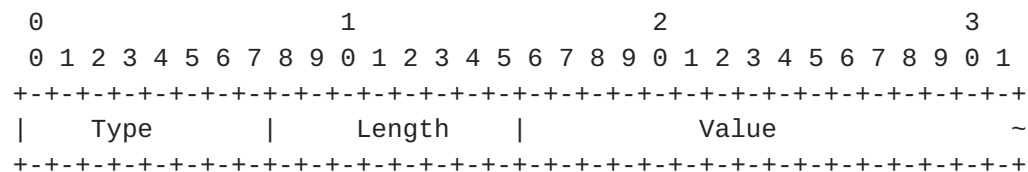
          Figure 5: Format of a Quality of Service Attribute

   Type: 8-bit unsigned integer indicating the type of the QoS
      attribute. This specification reserves the following values.

      (0) -   Reserved
         This value is reserved and cannot be used

   (1) -   Per-MN-Agg-Max-DL-Bit-Rate
      This QoS attribute, Per Mobile Node Aggregate Maximum Downlink
      Bit Rate, is defined in Section 4.2.1.

   (2) -   Per-MN-Agg-Max-UL-Bit-Rate
      This QoS attribute, Per Mobile Node Aggregate Maximum Uplink
      Bit Rate, is defined in Section 4.2.2.

   (3) -   Per-Session-Agg-Max-DL-Bit-Rate
      This QoS attribute, Per Mobility Session Aggregate Maximum
      Downlink Bit Rate, is defined in Section 4.2.3.

   (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 are reserved for future allocation.

   (255) -   Reserved
      This value is reserved and cannot be used

   Length: 8-bit unsigned integer indicating the number of octets
      needed to encode the Value, excluding the Type and Length fields.

   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 a 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 and with sessions anchored
   either on a single local mobility anchor, or when spread out across
   multiple local mobility anchors, then it depends on the operator's

policy and the specific deployment as how the total bandwidth for the
mobile node on each MAG-LMA pair is computed.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Per-MN-Agg-Max-DL-Bit-Rate                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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: is a 32-bit unsigned integer, and it
   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 and with sessions anchored
either on a single local mobility anchor, or when spread out across
multiple local mobility anchors, then it depends on the operator's
policy and the specific deployment as how the total bandwidth for the
mobile node on each MAG-LMA pair is computed.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Per-MN-Agg-Max-UL-Bit-Rate                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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: is of type unsigned 32-bit integer,
    and it 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.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |S|E|         Reserved          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Per-Session-Agg-Max-DL-Bit-Rate               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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 mobile node's other mobility sessions sharing the same service identifier. 3GPP Access Point Name (APN) is an example of 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 there is no special effect on the receiver.

   * 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 some flows 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 for excluding 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 applies is measured.

   * When the (E) flag is set to a value of (0), then there is no special effect on the receiver.

   * When the (S) flag and (E) flag are both set to a value of (1),
      then the request is for excluding 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: is a 32-bit unsigned integer, and
      it 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
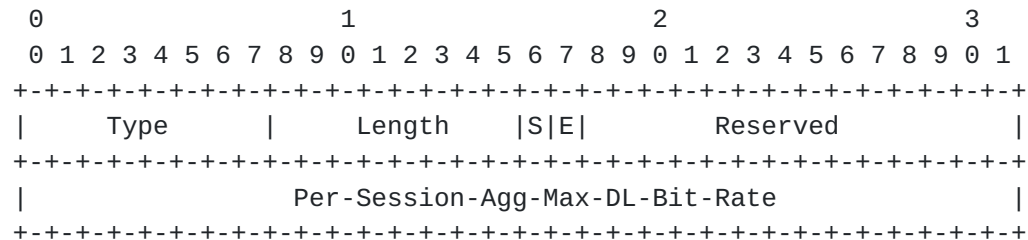   only be a single instance of this attribute present in a QoS option.

   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
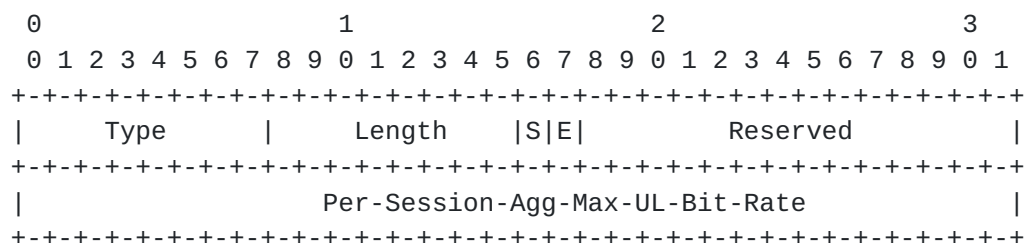   peer agrees to offer for that mobility session.

   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.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |     Length    |S|E|          Reserved         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Per-Session-Agg-Max-UL-Bit-Rate              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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 mobile node's
   other mobility sessions sharing the same service identifier. 3GPP
   Access Point Name (APN) is an example of 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 there is no
      special effect on the receiver.

   * 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 some flows be
   excluded from the target IP flows for which Per-Session-Agg-Max-
   UL-Bit-Rate is measured.

   * SGS When the (E) flag is set to a value of (1), then the
      request is for excluding 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 there is no
      special effect on the receiver.

   * When the (S) flag and (E) flag are both set to a value of (1),
      then the request is for excluding 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: is a 32-bit unsigned integer, and
   it 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 and Retention
Priority attribute and the QOS Traffic Selector attribute
(Section 4.2.8), then the Allocation and 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 and Retention Priority
attribute does not include the QOS Traffic Selector attribute
(Section 4.2.8), then the Allocation and Retention Priority attribute
is to be applied to all the IP flows associated with that mobility
session.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |     Reserved   |  PL  |PC |PV |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

o Type: 5

o Length: The length of the attribute in octets, excluding the Type
   and Length fields. This value is set to (10).

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): 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 pre-empt 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): 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): 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 higher
   priority level. The following values are defined:

   Enabled (0): This value indicates that the resources assigned to
   the IP data flow can be pre-empted 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 pre-empted 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 identifies 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.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Aggregate-Max-DL-Bit-Rate                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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: is a 32-bit unsigned integer, and it
   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 identifies 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.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |            Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Aggregate-Max-UL-Bit-Rate                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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 Per-Session-Agg-Max-UL-Bit-Rate: is a 32-bit unsigned integer, and
   it 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
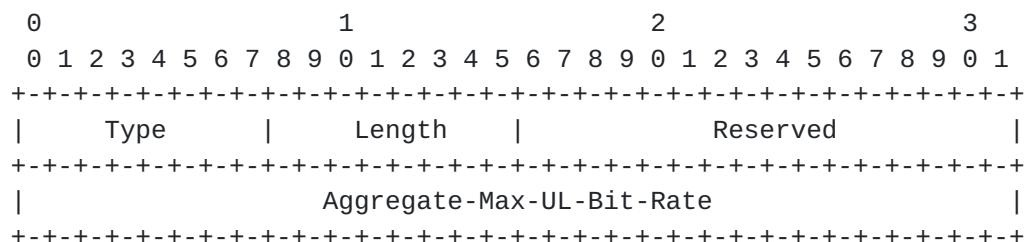   defined in Section 2.2.

   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 a 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 identifies 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.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |            Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Guaranteed-DL-Bit-Rate                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   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: is of type unsigned 32-bit integer, and it
      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 a 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 identifies 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.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |    Length     |             Reserved          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Guaranteed-UL-Bit-Rate                    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   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: is of type unsigned 32-bit integer, and it
   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
identifies those target flows. Furthermore, the DSCP marking in the
QoS option is to be applied only to partial set of mobile node's IP
flows and the traffic selectors present in the QoS-Traffic-Selector
attribute identifies those target flows.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |    Reserved   |   TS Format   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                     Traffic Selector ...                      ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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. Value (0) is reserved and MUST NOT be used.
   When the value of 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 is 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.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |            Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Vendor ID                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Sub-Type    |                  ...                          ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
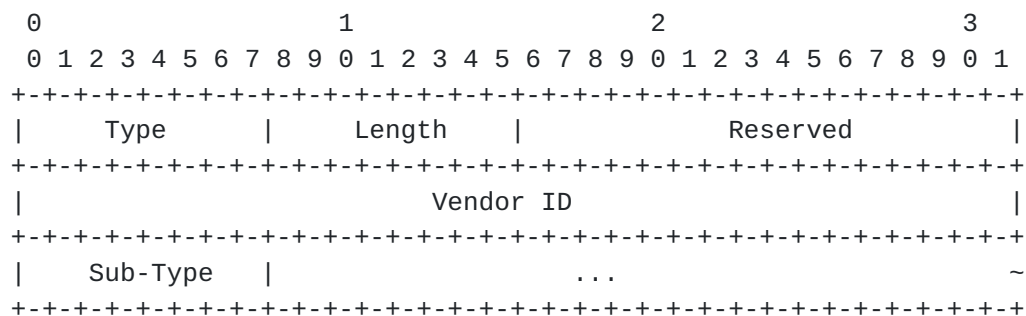
o Type: 11

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 name space 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):
   <IANA-2>

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): <IANA-3>

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):
   <IANA-4>

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
   entry must include the Service Request Identifier, DSCP value and
   the attributes defined in Section Section 4.2.

   LMA Receiving a QoS Service Request:

o On receiving a Proxy Binding Update message with one or more
   instances of Quality of Service option included in the message,
   the local mobility anchor MUST process the option(s) and determine
   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 based on
   other considerations.

o If the local mobility anchor can support the proposed QoS service
   requests in entirety, then it MUST send a Proxy Binding
   Acknowledgement message with a status code value of (0).

   * The message MUST include all the Quality of Service option
      instances copied (including all the option content) from the
      received Proxy Binding Update message. However, if the
      Operational Code field in the request is a QUERY, then the
      message MUST include 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) MUST be set to RESPONSE.

   * The local mobility anchor MUST 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, then it MUST reject the request
   and send a Proxy Binding Acknowledgement message with the status
   code value 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 Operational Code field in each of the Quality of Service
  option(s) MUST be set to RESPONSE.

* The Proxy Binding Acknowledgement message may include the
  Quality of Service option based on the following
  considerations.

  + If the local mobility anchor cannot support QoS services for
    that mobile node, then Quality of Service option MUST NOT be
    included in the Proxy Binding Acknowledgement message. This
    serves as an indication to the mobile access gateway that
    QoS services are not supported for that mobile node.

  + If the local mobility anchor can support QoS services for
    that mobile node, but for a downgraded/revised QoS service
    request, or for a partial set of QoS service requests, then
    the updated Quality of Service option(s) MUST be included in
    the Proxy Binding Acknowledgement message. This includes
    the case, where the Attributes in a QoS option have
    conflicting requirements, Ex: Per-Session-Agg-Max-UL-Bit-
    Rate is lower than the Guaranteed-UL-Bit-Rate. The contents
    of each of the option (including the QoS attributes) MUST
    reflect the QoS service parameters that the local mobility
    anchor can support for that mobile node. The Operational
    Code field in each of the Quality of Service option(s) MUST
    be 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 mobile node, by sending an Update Notification message
   [RFC7077]. The Notification Reason in the Update Notification
   message MUST be set to a value of QOS_SERVICE_REQUEST and the
   Acknowledgement Requested (A) flag set to a value of (1).

   * New QoS service request:

     + The message MUST include a Quality of Service option with
       one or more QoS attributes included in the option.

     + The Operational Code field in the Quality of Service option
       MUST be set to ALLOCATE.

+ The Service Request Identifier MUST be set to a value of
  (0).

+ The DSCP field in the Traffic Class (TC) field MUST reflect
  the requested DSCP value.

* Modification of an existing QoS Service Request:

+ The message MUST include a 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
  MUST be set to MODIFY.

+ The Service Request Identifier MUST be set to a value that
  was allocated for that QoS service request.

+ There can be more than one QOS service request in a single
  message, but there MUST be a instance of a Quality of
  Service option in the message for each of those service
  requests.

* Deletion of an existing QoS Service Request:

+ The Operational Code field in the Quality of Service option
  MUST be set to DE-ALLOCATE.

+ The Service Request Identifier MUST be set to a value that
  was allocated for that QoS service request.

+ The message MUST include a Quality of Service option with
  the QoS attributes reflecting the updated values for the
  attributes.

* Query for the previously negotiated QoS Service Requests:

+ The Operational Code field in the Quality of Service option
  MUST be set to QUERY.

+ The Service Request Identifier MUST be set to a value of
  (0).

+ The message MUST include a single instance of the Quality of
  Service option without including any QoS Attributes.

o Handling a Response to the QoS Service Request:

   * If the received Update Notification Acknowledgement [RFC7077]
      message has the status code field set to value of (0), the
      local mobility anchor MUST 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 is
      with the status code field set to value of
      (CANNOT_MEET_QOS_SERVICE_REQUEST), the local mobility anchor
      MUST apply the following considerations.

      + The denial of QoS service request MUST NOT result in removal
         of any of the mobile node's Binding Cache entries.

      + 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 Proxy Binding Update message with the updated Quality
         of Service option.

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 MUST be 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 MUST include
   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 an handover
   to a new mobile access gateway which 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 entry must include the Service Request Identifier,
      DSCP value and the attributes defined in Section Section 4.2.

   MAG Receiving a QoS Service Request:

   o On receiving a Update Notification message with one or more
      instances of Quality of Service option included in the message,
      the mobile access gateway MUST process the option(s) and determine
      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 based on
      other considerations.

   o If the mobile access gateway can support the proposed QoS service
      requests in entirety, then it MUST send a an Update Notification
      Acknowledgement message with status code value of (0).

      * The message MUST include 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 MUST include 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) MUST be set to RESPONSE.

      * The mobile access gateway MUST 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 MUST reject the request
      and send 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 Operational Code field in each of the Quality of Service
  option(s) MUST be set to RESPONSE.

* 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 Quality of Service option MUST NOT be
    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
    that mobile node, but for a downgraded/revised QoS service
    request, or for a partial set of QoS service requests, then
    the updated Quality of Service option(s) MUST be included in
    the Update Notification Acknowledgement message. This
    includes the case, where the Attributes in a QoS option have
    conflicting requirements, Ex: Per-Session-Agg-Max-UL-Bit-
    Rate is lower than the Guaranteed-UL-Bit-Rate. The contents
    of each of the option (including the QoS attributes) MUST
    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) MUST
    be 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 MUST include a Quality of Service option with
       one or more QoS attributes included in the option.

     + The Operational Code field in the Quality of Service option
       MUST be set to ALLOCATE.

     + The Service Request Identifier MUST be set to a value of
       (0).

        + The DSCP value in the Traffic Class field MUST reflect the
           requested DSCP value.

    * Modification of an existing QoS Service Request:

        + The message MUST include a 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
           MUST be set to MODIFY.

        + The Service Request Identifier MUST be set to a value that
           was allocated for that QoS service request.

        + There can be more than one QOS service request in a single
           message, but there MUST be a instance of a Quality of
           Service option in the message for each of those service
           requests.

    * Deletion of an existing QoS Service Request:

        + The Operational Code field in the Quality of Service option
           MUST be set to DE-ALLOCATE.

        + The Service Request Identifier MUST be set to a value that
           was allocated for that QoS service request.

        + The message MUST include a Quality of Service option with
           the QoS attributes reflecting the updated values for the
           attributes.

    * Query for the previously negotiated QoS Service Requests:

        + The Operational Code field in the Quality of Service option
           MUST be set to QUERY.

        + The Service Request Identifier MUST be set to a value of
           (0).

        + The message MUST include a single instance of the Quality of
           Service option without including any QoS Attributes.

  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 MUST 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
  MUST apply the following considerations.

  + The denial of QoS service request MUST NOT result in removal
    of any of the mobile node's Binding Update list entries.

  + 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, but there MUST be an instance of a Quality of
    Service option in the message for each of those service
    requests. Furthermore, the DSCP value MUST be 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 MUST to be 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, which 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 is
   provided by Differentiated Services techniques in the IP transport
   network and translated as appropriate into WLAN QoS specification in
   WLAN access, the details of which 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.

```
          Non-cellular access      | Cellular Core Network   Cellular
             (e.g. WLAN)           |      (e.g. EPC)          Access
                                   |                           (e.g.
                                   |          +-----------+     EUTRAN)
                                   |          |    PCF    |
                                   |          |(e.g. PCRF)|
        +----+                     |          +-----+-----+
        |WiFi|            (I)       |                |
        | AP |---+     +---+---+   |                |          ((O))
        +----+    |    |WiFi AR| | PMIPv6      +-----+      +---+   |
                  +----+ (MAG) +=|===========| LMA |=====|MAG+--|
                  |    | WLC  | |  tunnel    +-----+      +---+   |
        +----+    |    +-------+ |               //
        |WiFi|---+             |              //
        | AP |                 |             //
        +----+         (II)     |            //
                  +-------+ |          //
    +----+    +------+     |WiFi AR| |        //
    |WiFi+----+  WLC +------+ (MAG) |=|======//
    | AP |    |      |     |        | |
    +----+    +------+     +------ + |
          ^            ^      |
          |            |      |
          +------------+
          QoS inter-working
```
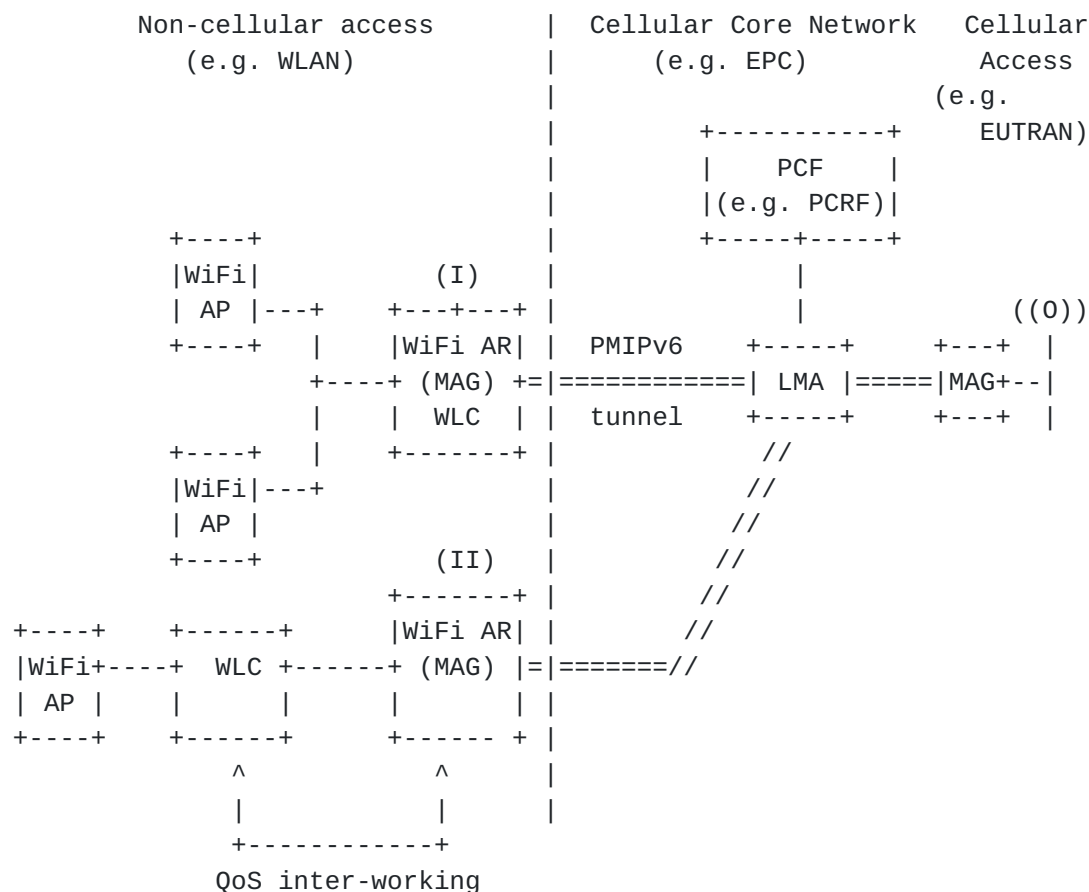
Figure 6: Architecture for QoS inter-working between cellular access
                     and non-cellular access

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 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 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 term of QoS characteristics (e.g. conversational
   voice, streaming video, signaling, best effort,...); more details on
   DSCP and QCI mapping are given on section 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,AF11/21/31/32}

      * 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 bitrate=MBR.

   o Dedicated, non-GBR bearer (QCI=5-9)

      * DSCP={BE,AF11/21/31/32}

      * 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.

For some optional QoS attributes the signaling can differentiate enforcement per mobility session and per IP flow. For the latter, the rule associated with the identified flow(s) overrules the aggregated rules which 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 left to their actual deployment.

7. IANA Considerations

   This document requires the following IANA 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 <IANA-1> for this
      mobility option needs to be allocated from the Mobility Options
      registry at <http://www.iana.org/assignments/mobility-parameters>.
      RFC Editor: Please replace <IANA-1> in Section 4.1 with the
      assigned value and update this section accordingly.

   o Action-2: This specification defines a new mobility attribute
      format, Quality of Service attribute. The format of this
      attribute is described in Section 4.2. This attribute can be
      carried in Quality of Service mobility option. The type values
      for this attribute needs to be managed by IANA, under the
      Registry, Quality of Service Attribute Registry. This registry
      should be created under "Mobile IPv6 Parameters" registry at
      <http://www.iana.org/assignments/mobility-parameters>. This
      specification reserves the following type values and all other
      values are reserved for future IANA allocations. Approval of new
      Quality of Service Attribute type values are to be made through
      IANA Expert Review.

```
+=====+=================================+================+
|Value|           Description           |   Reference    |
+=====+=================================+================+
| 0   | Reserved                        | <this draft>   |
+=====+=================================================+
| 1   | Per-MN-Agg-Max-DL-Bit-Rate      | <this draft>   |
+=====+=================================================+
| 2   | Per-MN-Agg-Max-UL-Bit-Rate      | <this draft>   |
+=====+=================================================+
| 3   | Per-Session-Agg-Max-DL-Bit-Rate | <this draft>   |
+=====+=================================================+
| 4   | Per-Session-Agg-Max-UL-Bit-Rate | <this draft>   |
+=====+=================================================+
| 5   | Allocation-Retention-Priority   | <this draft>   |
+=====+=================================================+
| 6   | Aggregate-Max-DL-Bit-Rate       | <this draft>   |
+=====+=================================================+
| 7   | Aggregate-Max-UL-Bit-Rate       | <this draft>   |
+=====+=================================================+
| 8   | Guaranteed-DL-Bit-Rate          | <this draft>   |
+=====+=================================================+
| 9   | Guaranteed-UL-Bit-Rate          | <this draft>   |
+=====+=================================================+
| 10  | QoS-Traffic-Selector            | <this draft>   |
+=====+=================================================+
| 11  | QoS-Vendor-Specific-Attribtute  | <this draft>   |
+=====+=================================================+
| 255 | Reserved                        | <this draft>   |
+=====+=================================================+
```

o Action-3: This document defines a new status value,
   CANNOT_MEET_QOS_SERVICE_REQUEST (<IANA-2>) for use in Proxy
   Binding Acknowledgement message, as described in Section 4.3.
   This value is to be assigned from the "Status Codes" registry at
   <http://www.iana.org/assignments/mobility-parameters>. The
   allocated value has to be greater than 127. RFC Editor: Please
   replace <IANA-2> in Section 4.3 with the assigned value and update
   this section accordingly.

o Action-4: This document defines a new Notification Reason,
   QOS_SERVICE_REQUEST (<IANA-3>) for use in Update Notification
   message [RFC7077] as described in Section 4.4. This value is to
   be assigned from the "Update Notification Reasons Registry" at
   <http://www.iana.org/assignments/mobility-parameters>. RFC
   Editor: Please replace <IANA-3> in Section 4.4 with the assigned
   value and update this section accordingly.

o Action-5: This document defines a new Notification Reason,
   CANNOT_MEET_QOS_SERVICE_REQUEST (<IANA-4>) for use in Update
   Notification Acknowledgement message [RFC7077] as described in
   Section 4.5. This value is to be assigned from the "Update
   Notification Acknowledgement Status Registry" at
   <http://www.iana.org/assignments/mobility-parameters>. RFC
   Editor: Please replace <IANA-4> in Section 4.5 with the assigned
   value and update this section accordingly.

8. Implementation Status

   Note to RFC Editor: Please remove this section and the reference to
   [RFC6982] before publication.

   This section records the status of known implementations of the
   protocol defined by this specification at the time of posting of this
   Internet-Draft, and is based on a proposal described in [RFC6982].
   The description of implementations in this section is intended to
   assist the IETF in its decision processes in progressing drafts to
   RFCs. Please note that the listing of any individual implementation
   here does not imply endorsement by the IETF. Furthermore, no effort
   has been spent to verify the information presented here that was
   supplied by IETF contributors. This is not intended as, and must not
   be construed to be, a catalog of available implementations or their
   features. Readers are advised to note that other implementations may
   exist.

   According to [RFC6982], "this will allow reviewers and working groups
   to assign due consideration to documents that have the benefit of
   running code, which may serve as evidence of valuable experimentation
   and feedback that have made the implemented protocols more mature.
   It is up to the individual working groups to use this information as
   they see fit".

   Cisco Implementation

      Organization: Cisco

      Description: QoS Extensions to Cisco IOS-based MAG and LMA
      Implementations. Engineering prototype code under development.

      Coverage: Support includes QoS signaling from MAG to LMA based on
      PBU/PBA and LMA to MAG based on the recently standardized UPN/UPA
      messages. Implementation includes only a partial set of QoS
      attributes and support for other Attributes is under development.
      The QoS option is based on the Vendor-specific mobility option,
      but it has all the parameters defined in -07 version of the
      document. We have plans to show a demo in the next IETF.

      Licensing: Closed. However, cisco has plans to release the MAG
      portion of the code for Linux as open source.

      Implementation Experience: The feedback from the developer
      suggests that the protocol extensions needed for this
      specification proved to be reasonably straightforward. Numerous
      draft revisions were made based on the questions and comments from
      the developer. The effort to most part appears to be around

interfacing with the platform specific QoS features for enforcing
the negotiated QoS parameters for a subscriber's IP session/flows.
On Cisco IOS, there is a programmatic interface with rich
semantics for interfacing with IOS MQC. It needs to be seen as
how this can be realized on a Linux OS.

Contact: Sri Gundavelli (sgundave@cisco.com)

9. 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 message like any other mobility header
   option. [RFC5213] and [RFC7077] identify the security considerations
   for these signaling messages. The quality of service option when
   included in these signaling messages does not require additional
   security considerations.

[10]. Acknowledgements

The authors of this document thank the NetExt Working Group for the valuable feedback to different versions of this specification. In particular the authors want to thank Basavaraj Patil, Behcet Sarikaya, Charles Perkins, Dirk von Hugo, Mark Grayson, Tricci So, Ahmad Muhanna, Pete McCann, Byju Pularikkal, John Kaippallimalil, Rajesh Pazhyannur, Carlos J. Bernardos Cano, Michal Hoeft, Ryuji Wakikawa, Liu Dapeng, Seil Jeon, Georgios Karagiannis and Brian Haberman for their valuable comments and suggestions to improve this specification.

[11](). References

[11.1](). Normative References

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

[RFC5213] Gundavelli, S., Leung, K., Devarapalli, V., Chowdhury, K.,
           and B. Patil, "Proxy Mobile IPv6", [RFC 5213](), August 2008.

[RFC5844] Wakikawa, R. and S. Gundavelli, "IPv4 Support for Proxy
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[RFC6088] Tsirtsis, G., Giarreta, G., Soliman, H., and N. Montavont,
           "Traffic Selectors for Flow Bindings", [RFC 6088](),
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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             |  3GPP QoS   |
|       |        Attribute             |  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| APN AMBR-DL |
|       |        Flags: (S=1, E=1)      |            |
+-------+-------------------------------+------------+
| 4.2.4 |Per-Session-Agg-Max-UL-Bit-Rate| APN AMBR-UL |
|       |        Flags: (S=1, E=1)      |            |
+-------+-------------------------------+------------+
| 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

   This 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
   as shown in Appendix A.2.1 and Appendix A.2.2, and modification as
   show in Appendix A.2.3.

A.2.1. Handover of existing QoS rules

   In Figure 9, the MN is first connected to the LTE network, and having
   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 also the QoS is 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.

```
                                          +--------+
                                          |Policy  |
                                          |Control |
                                          |Function|
                                          +---+----+
                                              |
        +----+         +-------+          +---+----+
  +--+  |LTE |_____|  SGW   |          |  PGW   |
  |MN|~~|eNB |       |        |=============| (LMA)  |
  +--+  +----+       +-------+          //+--------+
   :                                   //
   :                                  //
   V     +----+         +-------+ PMIPv6  //
  +--+  |WiFi|_____|  WLC   |=========
  |MN|~~| AP |       | (MAG) | tunnel
  +--+  +----+       +-------+
```
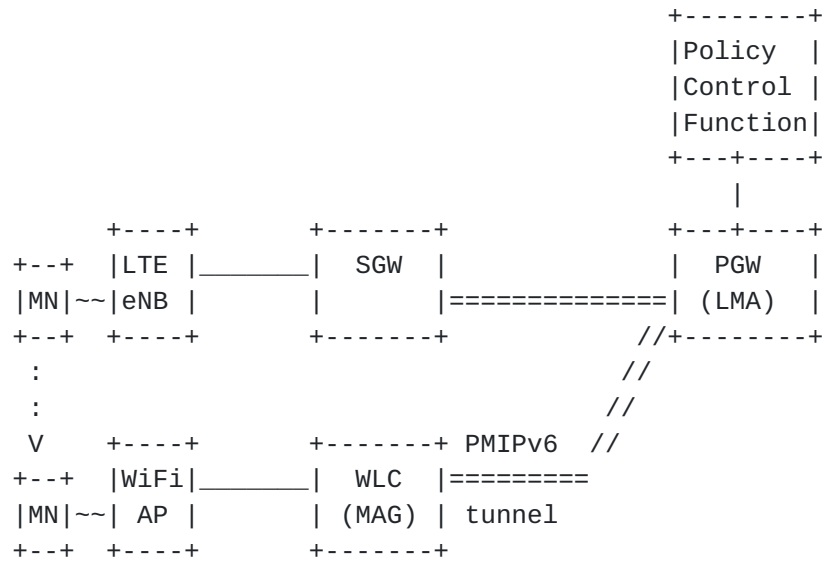
                Figure 9: Handover Scenario (from LTE to WLAN)

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

```
   +--+               +--+               +---+                        +---+
   |MN|               |AP|               |MAG|                        |LMA|
   +--+               +--+               +---+                        +---+
    ||                 |                  |        To                  |data
    |+--detach         |                  |   cellular<-==data[DSCP]==-|<----
     +----attach-----+ |                  |    access          [QoS rules]
    |               |-INFO[MNattach]->|                          |
    |               |                  |-------PBU[handover]------>|
    |               |                  |                          |
    |               |                  |<--PBA[QoS option(OC=1 )]--|
    |               |<-INFO[QoSrules]-|                          |
    |               |                  |                          |
    |            Apply           Establish              Update
    |            mapped          MN's uplink         MN's downlink
    |            QoS rules       DSCP rules            DSCP rules
    |               |                   +=========================+
    |               |                  |                          |
    |               |(B)                |(A)                       |data
    |<--data[QC]----|<---data[DSCP]---|<-======data[DSCP]========-|<----
    |               |                  |                          |
    |               |                  |                          |data
    |---data[QC]--->|-->data[DSCP]--->|-======data[DSCP]=======->|--->
    |               |(C)                |(D)                       |
    |               |                  |                          |
```
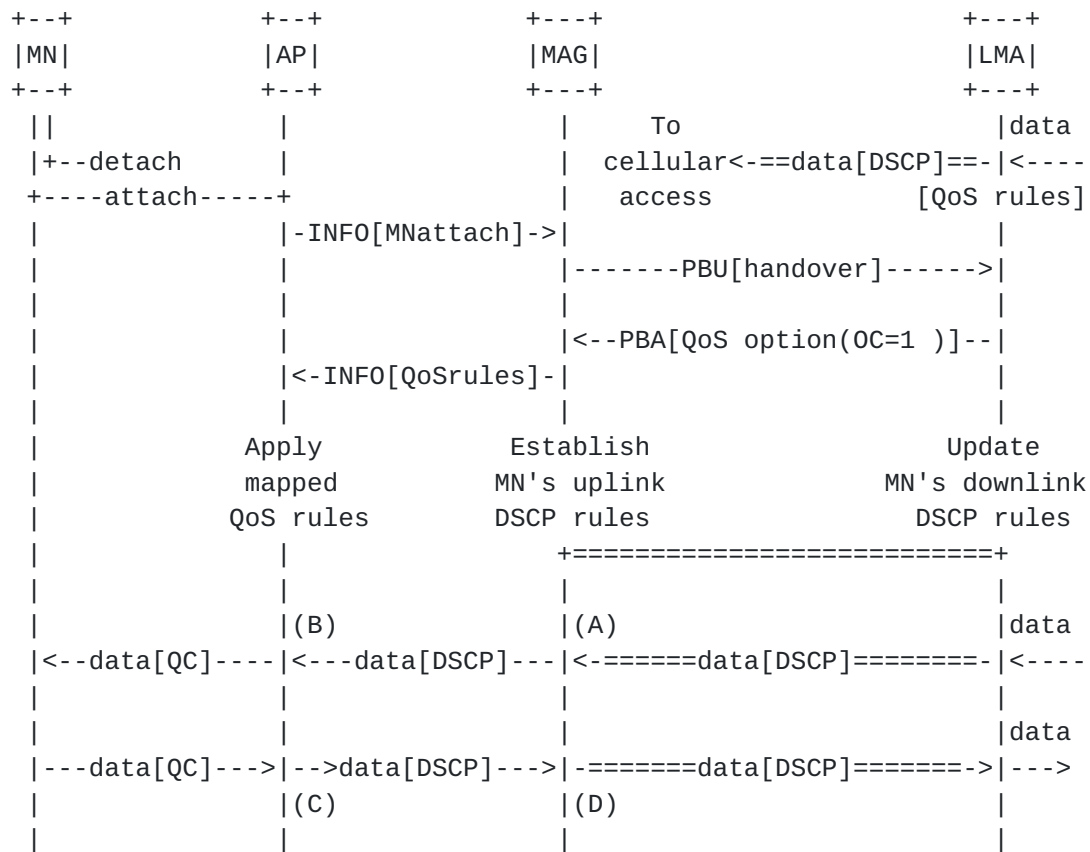
   (A): Apply DSCP at link to AP
   (B): Enforce mapped QoS rules to access technology
   (C): Map MN-indicated QoS Class (QC) to DSCP on the AP-MAG link, or
        validate MN-indicated QC and apply DSCP on the AP-MAG link
        according to QoS rules
   (D): Validate received DSCP and apply DSCP according 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. The MN may
request traffic resources be reserved using L2 signaling, e.g.,
sending an 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 co-ordination 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.

```
                                           |
                                           |
                                           | +--------+
                                           | |Policy  |
                                           | |Control |
                                           | |Function|
                                           | +---+----+
                                           |     |
                                           | +---+----+
          +----+        +-------+ PMIPv6 | |  PGW   |
    +--+  |WiFi|_____|  WLC  |=======|=| (LMA)  |
    |MN|~~| AP |        | (MAG) | tunnel | +--------+
    +--+  +----+        +-------+          |
                                           |
                 Wi-Fi Access             |
                    Network               |  Cellular
                                           |   Network
                                           |
```
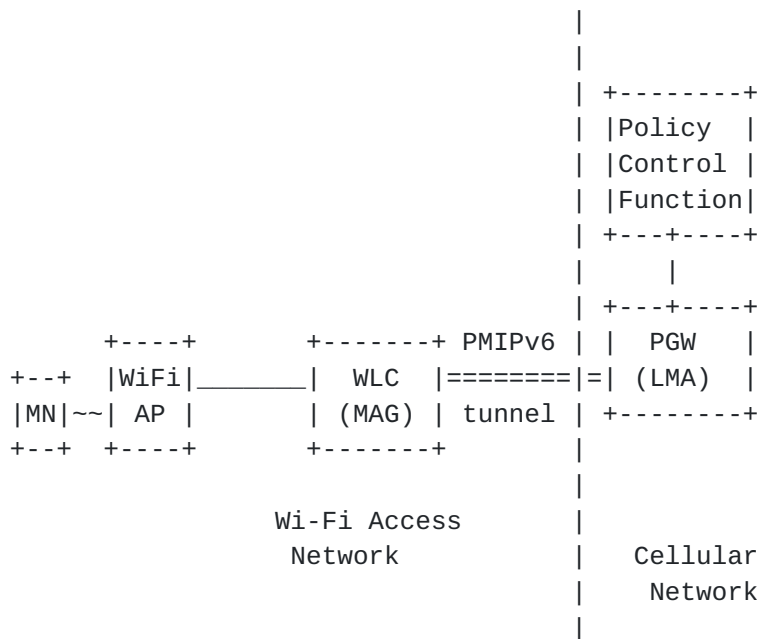
Figure 11: QoS policy provisioning

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.

```
   +--+              +--+              +---+                        +---+
   |MN|              |AP|------------|MAG|----------------------|LMA|
   +--+              +--+              +---+                        +---+
    |                 |                 |                          |
    |                 |                 |                          |
   +----attached---+  |                 |             [QoS rules]
    |                 |                 |                          |
   new session      |(E)              |(F)                        |data
    |----data[QC]-->|---data[DSCPa]-->|-======data[DSCPb]=======->|--->
    |                 |                 |--PBU[update,QoS option]-->|
    |                 |                 |     (ReReg) (OC=1) Validate and
    |                 |                 |                      add QoS rule
    |                 |                 |<----PBA[QoS option]----|
    |                 |<-INFO[QoSrules]-|      (OC=1, SR-ID)[QoS rules']
    |                 |                 |                          |
    |             Apply           Establish                       |
    |            adapted          MN's uplink                     |
    |            QoS rules        DSCP rules                       |
    |                 |                 |                          |
    |                 |                 |                          |
    |                 |                 |                          |data
    |<--data[QC]----|<---data[DSCP]---|<-======data[DSCP]========-|<----
    |                 |                 |                          |
    |                 |                 |                          |data
    |---data[QC]--->|-->data[DSCP]--->|-======data[DSCP]=======->|--->
    |                 |                 |                          |
    |                 |                 |                          |
```

   (E): AP may enforce uplink QoS rules according to priority class
        set by the MN
   (F): MAG can enforce a default QoS class until local mobility anchor
        has classified the new flow (notified with PBA) or 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. 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". The MAG, on receiving the Update Notification
message, 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 network
function again notifies the PCF function for removing the established
QoS parameters. The PCF notifies the LMA for withdrawing 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". The MAG on receiving this message
Update Notification Acknowledgement and 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 (AC):

      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 DiffServ code point (DSCP). To allow
   consistent QoS management on both wireless and wired interfaces, the
   access point relies on the 802.11e specification which define mapping
   between the 802.11e access categories and the IEEE 802.1D priority
   (802.1p tag). The end-to-end QoS architecture is depicted on
   Figure 13 and the 802.11e/802.1D priority mapping is reminded 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        |
                +-----------+------------------+
```

```
               +=============+                        +-----+
                DSCP/802.1p                           | PDP |
                mapping table                         +-----+
               +=============+      PEP                   |
                    `._        +---+---+                  |
                       `._     |WiFi AR|    PMIPv6     +-----+
                         - + (MAG) +==============| LMA |
                            |  WLC  |    tunnel      +-----+
                            +-------+                   PEP
                                 |
            ==Video==   802.1p/DSCP
            ==Voice==          |
            == B.E.==      +----+
      +----+               |WLAN| PEP
      | MN |----802.11e----| AP |
      +----+               +----+
```
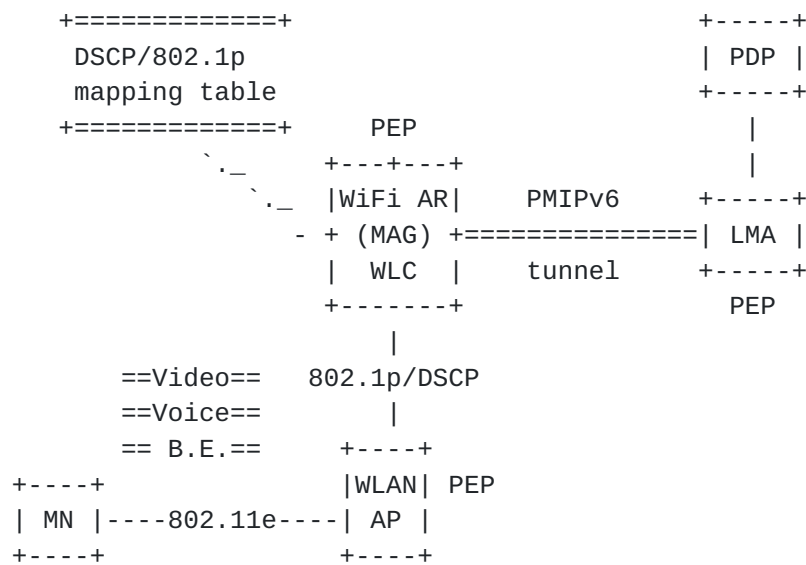
                Figure 13: End-to-end QoS management with 802.11e

   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 operator; a mapping example 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 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 MN attachment process, the MAG fetches QoS policies
   from the LMA. After this step, both 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, then it 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 is 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.

```
   +--+             +--+              +---+                    +---+
   |MN|             |AP|              |MAG|                    |LMA|
   +--+             + -+              +---+                    +---+
 (A)|----attach-----|---------------->|-----------PBU---------->|
    |<-------------|--------------- |<----PBA[QoS option]-----|
    .              .               [QoS rules]          [QoS rules]
 (B).              .                .                        |
   new session     |                |                        |
    |----data[]---->|----data[]------>|-======data[DSCP]======->|
    |               |                |                        |
 (C)|               |                |              Validate QoS rule
    |               |                |                        |--->
    |               |                |<======data[DSCP]=======|<----
    |               |                |                        |
    |               |               mapping                   |
 (D)|               |              DSCP/802.1p                 |
    |               |<----data--------|                       |
    |               |  [802.1p/DSCP]  |                       |
    |               |                |                        |
    |            mapping             |                        |
    |          802.1p/802.11e        |                        |
    |<--data[WMM]---|                |                        |
    |               |                |                        |
    |---data[WMM]-->|------data------>|======data[DSCP]======>|--->
    |               |  [802.1p/DSCP]  |                       |
    |               |                |                        |
```
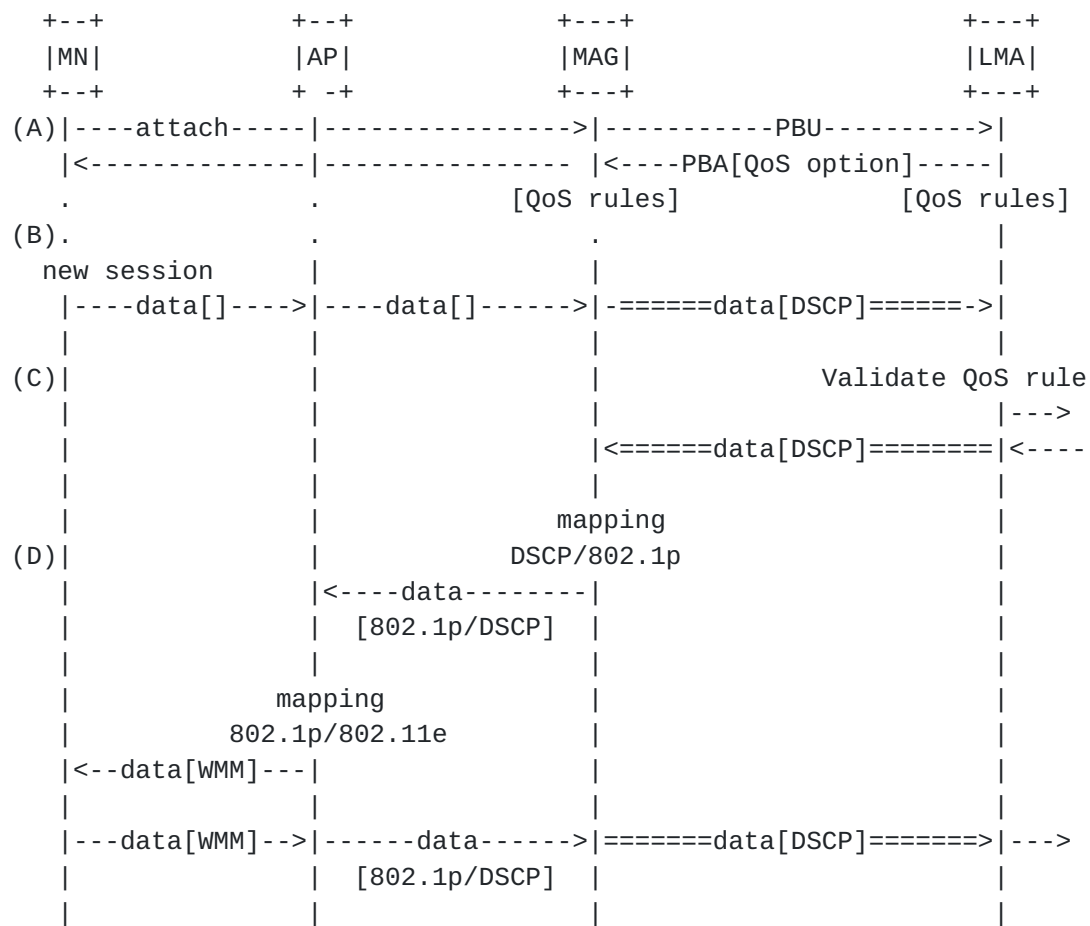
            Figure 14: Prioritization of a flow created on the WLAN access

Appendix C. **Information when implementing with a Broadband Network**
             Gateway

   This section shows an example of QoS interworking between the PMIPv6
   domain and the broadband access. The Broadband Network Gateway (BNG)
   or Broadband Remote Access Server (BRAS) has the MAG function and the
   CPE (Customer Premise Equipment) or Residential Gateway (RG) is
   connected via the broadband access network. The MN is attached to
   the RG via e.g., Wi-Fi AP in the broadband home network. In the
   segment of the broadband access network, the BNG and RG are the
   Policy Enforcement Point (PEP) for the downlink and uplink traffic,
   respectively. The QoS information is downloaded from the LMA to the
   BNG via the PMIPv6 with the QoS option defined in this document.
   Based on the received QoS parameters (e.g., DSCP values), the
   broadband access network and the RG provide appropriate QoS treatment
   to the downlink and uplink traffic to/from the MN.

```
                                                   +-----+
                                                   | PDP |
                                                   +-----+
                              PEP                      |
                           +-------+                   |
                           | BNG/  |    PMIPv6      +-----+
                           | BRAS  +===============| LMA |
                           | (MAG) |    tunnel     +-----+
                           +-------+                  PEP
                 Broadband  (   |   )
                   Access   (  DSCP  )
                  Network   (   |   )
                            +-----+
         +----+             | CPE | PEP
         | MN |-------------| /RG |
         +----+  Broadband  +-----+
                Home Network
```

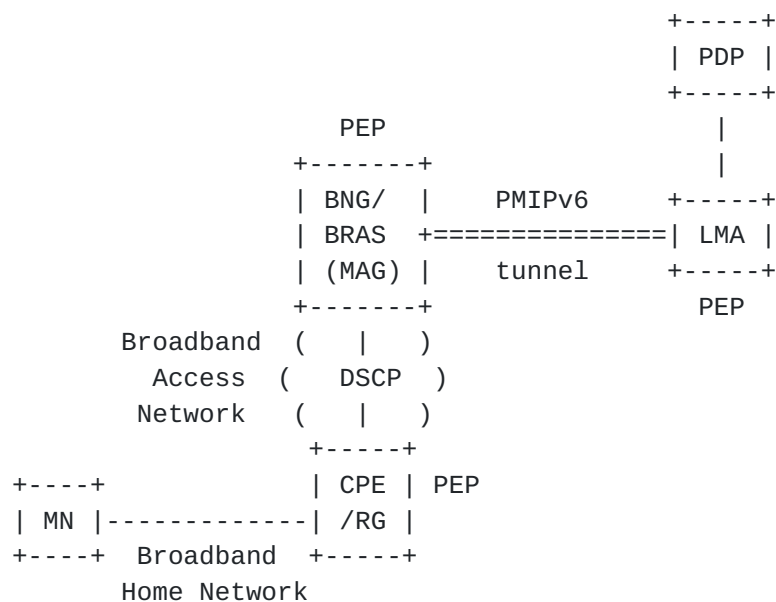   Figure 15: End-to-end QoS management with the broadband access
                                  network

   In the segment of the broadband access network, QoS mapping between
   3GPP QCI values and DSCP described in Section 6.2 is applied. In the
   segment of the broadband home network, if the MN is attached to the
   RG via Wi-Fi, the same QoS mapping as described in Appendix B can be
   applied.

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