Y.1541-QOSM: Model for Networks Using Y.1541 Quality-of-Service Classes

Abstract

   This document describes a QoS-NSLP Quality-of-Service model (QOSM)
   based on ITU-T Recommendation Y.1541 Network QoS Classes and related
   guidance on signaling. Y.1541 specifies 8 classes of Network
   Performance objectives, and the Y.1541-QOSM extensions include
   additional QSPEC parameters and QOSM processing guidelines.

Status of This Memo

   This document is not an Internet Standards Track specification; it is
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   evaluation.

   This document defines an Experimental Protocol for the Internet
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   Task Force (IETF). It represents the consensus of the IETF
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than English.

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1. Introduction

   This document describes a QoS model (QOSM) for Next Steps in
   Signaling (NSIS) QoS signaling layer protocol (QoS-NSLP) application
   based on ITU-T Recommendation Y.1541 Network QoS Classes and related
   guidance on signaling. [Y.1541] currently specifies 8 classes of
   Network Performance objectives, and the Y.1541-QOSM extensions
   include additional QSPEC [RFC5975] parameters and QOSM processing
   guidelines. The extensions are based on standardization work in the
   ITU-T on QoS signaling requirements ([Y.1541] and [E.361]), and
   guidance in [TRQ-QoS-SIG].

   [RFC5974] defines message types and control information for the QoS-
   NSLP that are generic to all QOSMs. A QOSM is a defined mechanism
   for achieving QoS as a whole. The specification of a QOSM includes a
   description of its QSPEC parameter information, as well as how that
   information should be treated or interpreted in the network. The
   QSPEC [RFC5975] contains a set of parameters and values describing
   the requested resources. It is opaque to the QoS-NSLP and similar in
   purpose to the TSpec, RSpec, and AdSpec specified in [RFC2205] and
   [RFC2210]. A QOSM provides a specific set of parameters to be
   carried in the QSPEC object. At each QoS NSIS Entity (QNE), the
   QSPEC contents are interpreted by the resource management function
   (RMF) for purposes of policy control and traffic control, including
   admission control and configuration of the scheduler.

1.1. Requirements Language

   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. Summary of ITU-T Recommendations Y.1541 and Signaling Requirements

   As stated above, [Y.1541] is a specification of standardized QoS
   classes for IP networks (a summary of these classes is given below).
   Section 7 of [TRQ-QoS-SIG] describes the signaling features needed to
   achieve end-to-end QoS in IP networks, with Y.1541 QoS classes as a
   basis. [Y.1541] recommends a flexible allocation of the end-to-end
   performance objectives (e.g., delay) across networks, rather than a
   fixed per-network allocation. NSIS protocols already address most of
   the requirements; this document identifies additional QSPEC
   parameters and processing requirements needed to support the Y.1541
   QOSM.

2.1. Description of Y.1541 Classes

   [Y.1541] proposes grouping services into QoS classes defined
   according to the desired QoS performance objectives. These QoS
   classes support a wide range of user applications. The classes group
   objectives for one-way IP packet delay, IP packet delay variation, IP
   packet loss ratio, etc., where the parameters themselves are defined
   in [Y.1540].

   Note that [Y.1541] is maintained by the ITU-T and subject to
   occasional updates and revisions. The material in this section is
   provided for information and to make this document easier to read.
   In the event of any discrepancies, the normative definitions found in
   [Y.1541] take precedence.

   Classes 0 and 1 might be implemented using the Diffserv Expedited
   Forwarding (EF) Per-Hop Behavior (PHB), and they support interactive
   real-time applications [RFC3246]. Classes 2, 3, and 4 might be
   implemented using the Diffserv Assured Forwarding (AFxy) PHB Group,
   and they support data transfer applications with various degrees of
   interactivity [RFC2597]. Class 5 generally corresponds to the
   Diffserv Default PHB, and it has all the QoS parameters unspecified
   consistent with a best-effort service[RFC2474]. Classes 6 and 7
   provide support for extremely loss-sensitive user applications, such
   as high-quality digital television, Time Division Multiplexing (TDM)
   circuit emulation, and high-capacity file transfers using TCP. These
   classes are intended to serve as a basis for agreements between end-
   users and service providers, and between service providers. They
   support a wide range of user applications including point-to-point
   telephony, data transfer, multimedia conferencing, and others. The
   limited number of classes supports the requirement for feasible
   implementation, particularly with respect to scale in global
   networks.

   The QoS classes apply to a packet flow, where [Y.1541] defines a
   packet flow as the traffic associated with a given connection or
   connectionless stream having the same source host, destination host,
   class of service, and session identification. The characteristics of
   each Y.1541 QoS class are summarized here:

   Class 0:
   Real-time, highly interactive applications, sensitive to jitter.
   Mean delay <= 100 ms, delay variation <= 50 ms, and loss ratio <=
   10^{-3}. Application examples include VoIP and video teleconference.

   Class 1:
   Real-time, interactive applications, sensitive to jitter. Mean delay
   <= 400 ms, delay variation <= 50 ms, and loss ratio <= 10^-3.
   Application examples include VoIP and video teleconference.

   Class 2:
   Highly interactive transaction data. Mean delay <= 100 ms, delay
   variation is unspecified, loss ratio <= 10^-3. Application examples
   include signaling.

   Class 3:
   Interactive transaction data. Mean delay <= 400 ms, delay variation
   is unspecified, loss ratio <= 10^-3. Application examples include
   signaling.

   Class 4:
   Low Loss Only applications. Mean delay <= 1 s, delay variation is
   unspecified, loss ratio <= 10^-3. Application examples include short
   transactions, bulk data, and video streaming.

   Class 5:
   Unspecified applications with unspecified mean delay, delay
   variation, and loss ratio. Application examples include traditional
   applications of default IP networks.

   Class 6:
   Applications that are highly sensitive to loss. Mean delay <= 100
   ms, delay variation <= 50 ms, and loss ratio <= 10^-5. Application
   examples include television transport, high-capacity TCP transfers,
   and Time-Division Multiplexing (TDM) circuit emulation.

   Class 7:
   Applications that are highly sensitive to loss. Mean delay <= 400
   ms, delay variation <= 50 ms, and loss ratio <= 10^-5. Application
   examples include television transport, high-capacity TCP transfers,
   and TDM circuit emulation.

   These classes enable service level agreements (SLAs) to be defined
   between customers and network service providers with respect to QoS
   requirements. The service provider then needs to ensure that the
   requirements are recognized and receive appropriate treatment across
   network layers.

   Work is in progress to specify methods for combining local values of
   performance metrics to estimate the performance of the complete path.
   See Section 8 of [Y.1541], [RFC5835], and [COMPOSITION].

2.2. Y.1541-QOSM Processing Requirements

   [TRQ-QoS-SIG] guides the specification of signaling information for
   IP-based QoS at the interface between the user and the network (UNI)
   and across interfaces between different networks (NNI). To meet
   specific network performance requirements specified for the Y.1541
   QoS classes [Y.1541] , a network needs to provide specific user-plane
   functionality at the UNI and NNI. Dynamic network provisioning at a
   UNI and/or NNI node allows a traffic contract for an IP flow to be
   dynamically requested from a specific source node to one or more
   destination nodes. In response to the request, the network
   determines if resources are available to satisfy the request and
   provision the network.

   For implementations to claim compliance with this memo, it MUST be
   possible to derive the following service-level parameters as part of
   the process of requesting service:

   a. Y.1541 QoS class, 32-bit integer, range: 0-7

   b. rate (r), octets per second

   c. peak rate (p), octets per second

   d. bucket size (b), octets

   e. maximum packet size (MPS), octets, IP header + IP payload

   f. Diffserv PHB class [RFC2475]

   g. admission priority, 32-bit integer, range: 0-2

   Compliant implementations MAY derive the following service-level
   parameters as part of the service request process:

   h. peak bucket size (Bp), octets, 32-bit floating point number in
       single-precision IEEE floating point format [IEEE754]

   i. restoration priority, multiple integer values defined in
       Section 3 below

   All parameters except Bp and restoration priority have already been
   specified in [RFC5975]. These additional parameters are defined as

   o Bp, the size of the peak-rate bucket in a dual-token bucket
      arrangement, essentially setting the maximum length of bursts in
      the peak-rate stream. For example, see Annex B of [Y.1221]

   o restoration priority, as defined in Section 3 of this memo

   Their QSPEC Parameter format is specified in Section 3.

   It MUST be possible to perform the following QoS-NSLP signaling
   functions to meet Y.1541-QOSM requirements:

   a. accumulate delay, delay variation, and loss ratio across the end-
       to-end connection, which may span multiple domains.

   b. enable negotiation of Y.1541 QoS class across domains.

   c. enable negotiation of delay, delay variation, and loss ratio
       across domains.

   These signaling requirements are supported in [RFC5974], and the
   functions are illustrated in Section 4 of this memo.

3. Additional QSPEC Parameters for Y.1541 QOSM

   The specifications in this section extend the QSPEC [RFC5975].

3.1. Traffic Model (TMOD) Extension Parameter

   The traffic model (TMOD) extension parameter is represented by one
   floating point number in single-precision IEEE floating point format
   and one 32-bit reserved field.

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |M|E|N|r|         15            |r|r|r|r|         1             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Peak Bucket Size [Bp] (32-bit IEEE floating point number)   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
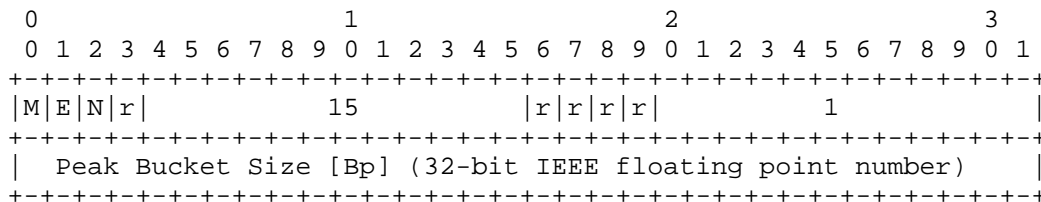
                      Figure 1: TMOD Extension

   The Peak Bucket Size term, Bp, is represented as an IEEE floating
   point value [IEEE754] in units of octets. The sign bit MUST be zero
   (all values MUST be non-negative). Exponents less than 127 (i.e., 0)
   are prohibited. Exponents greater than 162 (i.e., positive 35) are
   discouraged, except for specifying a peak rate of infinity. Infinity
   is represented with an exponent of all ones (255), and a sign bit and
   mantissa of all zeros.

The QSPEC parameter behavior for the TMOD extended parameter follows
that defined in Section 3.3.1 of [RFC5975]. The new parameter (and
all traffic-related parameters) are specified independently from the
Y.1541 class parameter.

3.2. Restoration Priority Parameter

Restoration priority is the urgency with which a service requires
successful restoration under failure conditions. Restoration
priority is achieved by provisioning sufficient backup capacity, as
necessary, and allowing relative priority for access to available
bandwidth when there is contention for restoration bandwidth.
Restoration priority is defined as follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|M|E|N|r|         16          |r|r|r|r|         1               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Rest. Priority|  TTR  |  EOR  |         (Reserved)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
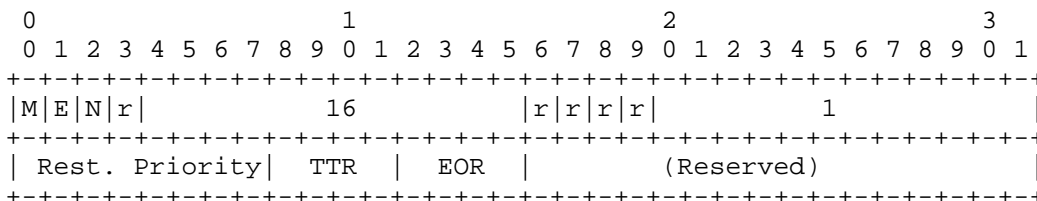
Figure 2: Restoration Priority Parameter

This parameter has three fields and a reserved area, as defined
below.

Restoration Priority Field (8-bit unsigned integer): 3 priority
   values are listed here in the order of lowest priority to highest
   priority:

      0 - best effort

      1 - normal

      2 - high

   These priority values are described in [Y.2172], where best-effort
   priority is the same as Priority level 3, normal priority is
   Priority level 2, and high priority is Priority level 1. There
   are several ways to elaborate on restoration priority, and the two
   current parameters are described below.

Time-to-Restore (TTR) Field (4-bit unsigned integer): Total amount
   of time to restore traffic streams belonging to a given
   restoration class impacted by the failure. This time period
   depends on the technology deployed for restoration. A fast
   recovery period of < 200 ms is based on current experience with

Synchronous Optical Network (SONET) rings and a slower recovery
period of 2 seconds is suggested in order to enable a voice call
to recover without being dropped. Accordingly, TTR restoration
suggested ranges are:

    0 - Unspecified Time-to-Restore

    1 - Best Time-to-Restore: <= 200 ms

    2 - Normal Time-to-Restore <= 2 s

Extent of Restoration (EOR) Field (4-bit unsigned integer):
   Percentage of traffic belonging to the restoration class that can
   be restored. This percentage depends on the amount of spare
   capacity engineered. All high-priority restoration traffic, for
   example, may be "guaranteed" at 100% by the service provider.
   Other classes may offer lesser chances for successful restoration.
   The restoration extent for these lower priority classes depend on
   SLAs developed between the service provider and the customer.

       EOR values are assigned as follows:

    0 - unspecified EOR

    1 - high priority restored at 100%;
        medium priority restored at 100%

    2 - high priority restored at 100%;
        medium priority restored at 80%

    3 - high priority restored >= 80%;
        medium priority restored >= 80%

    4 - high priority restored >= 80%;
        medium priority restored >= 60%

    5 - high priority restored >= 60%;
        medium priority restored >= 60%

Reserved: These 2 octets are reserved. The Reserved bits MAY be
   designated for other uses in the future. Senders conforming to
   this version of the Y.1541 QOSM SHALL set the Reserved bits to
   zero. Receivers conforming to this version of the Y.1541 QOSM
   SHALL ignore the Reserved bits.

4. Y.1541-QOSM Considerations and Processing Example

   In this section, we illustrate the operation of the Y.1541 QOSM, and
   show how current QoS-NSLP and QSPEC functionality is used. No new
   processing capabilities are required to enable the Y.1541 QOSM
   (excluding the two OPTIONAL new parameters specified in Section 3).

4.1. Deployment Considerations

   [TRQ-QoS-SIG] emphasizes the deployment of Y.1541 QNEs at the borders
   of supporting domains. There may be domain configurations where
   interior QNEs are desirable, and the example below addresses this
   possibility.

4.2. Applicable QSPEC Procedures

   All procedures defined in Section 5.3 of [RFC5975] are applicable to
   this QOSM.

4.3. QNE Processing Rules

   Section 7 of [TRQ-QoS-SIG] describes the information processing in
   Y.1541 QNEs.

   Section 8 of [Y.1541] defines the accumulation rules for individual
   performance parameters (e.g., delay, jitter).

   When a QoS NSIS initiator (QNI) specifies the Y.1541 QoS Class
   number, <Y.1541 QoS Class>, it is a sufficient specification of
   objectives for the <Path Latency>, <Path Jitter>, and <Path BER>
   parameters. As described in Section 2, some Y.1541 Classes do not
   set objectives for all the performance parameters above. For
   example, Classes 2, 3, and 4 do not specify an objective for <Path
   Jitter> (referred to as IP Packet Delay Variation). In the case that
   the QoS Class leaves a parameter unspecified, then that parameter
   need not be included in the accumulation processing.

4.4. Processing Example

   As described in the example given in Section 3.4 of [RFC5975] and as
   illustrated in Figure 3, the QoS NSIS initiator (QNI) initiates an
   end-to-end, interdomain QoS NSLP RESERVE message containing the
   Initiator QSPEC. In the case of the Y.1541 QOSM, the Initiator QSPEC
   specifies the <Y.1541 QOS Class>, <TMOD>, <TMOD Extension>,
   <Admission Priority>, <Restoration Priority>, and perhaps other QSPEC
   parameters for the flow. As described in Section 3, the TMOD

extension parameter contains the OPTIONAL Y.1541-QOSM-specific terms;
restoration priority is also an OPTIONAL Y.1541-QOSM-specific
parameter.

As Figure 3 below shows, the RESERVE message may cross multiple
domains supporting different QOSMs. In this illustration, the
Initiator QSPEC arrives in a QoS NSLP RESERVE message at the ingress
node of the local-QOSM domain. As described in [RFC5974] and
[RFC5975], at the ingress edge node of the local-QOSM domain, the
end-to-end, interdomain QoS-NSLP message may trigger the generation
of a Local QSPEC, and the Initiator QSPEC is encapsulated within the
messages signaled through the local domain. The Local QSPEC is used
for QoS processing in the local-QOSM domain, and the Initiator QSPEC
is used for QoS processing outside the local domain. As specified in
[RFC5975], if any QNE cannot meet the requirements designated by the
Initiator QSPEC to support an optional QSPEC parameter (i.e., with
the M bit set to zero for the parameter), the QNE sets the N flag
(not supported flag) for the parameter to one. For example, if the
QNE cannot support the accumulation of end-to-end delay with the
<Path Latency> parameter, where the M flag for the <Path Latency>
parameter is set to zero denoting <Path Latency> as an optional
parameter, the QNE sets the N flag (not supported flag) for the <Path
Latency> parameter to one.

Also, the Y.1541-QOSM requires negotiation of the <Y.1541 QoS Class>
across domains. This negotiation can be done with the use of the
existing procedures already defined in [RFC5974]. For example, the
QNI sets <Desired QoS>, <Minimum QoS>, and <Available QoS> objects to
include <Y.1541 QoS Class>, which specifies objectives for the <Path
Latency>, <Path Jitter>, and <Path BER> parameters. In the case that
the QoS Class leaves a parameter unspecified, then that parameter
need not be included in the accumulation processing. The QNE/domain
SHOULD set the Y.1541 class and cumulative parameters, e.g., <Path
Latency>, that can be achieved in the <QoS Available> object (but not
less than specified in <Minimum QoS>). This could include, for
example, setting the <Y.1541 QoS Class> to a lower class than
specified in <QoS Desired> (but not lower than specified in <Minimum
QoS>). If the <Available QoS> fails to satisfy one or more of the
<Minimum QoS> objectives, the QNE/domain notifies the QNI and the
reservation is aborted. Otherwise, the QoS NSIS Receiver (QNR)
notifies the QNI of the <QoS Available> for the reservation.

When the available <Y.1541 QoS Class> must be reduced from the
desired <Y.1541 QoS Class> (say, because the delay objective has been
exceeded), then there is an incentive to respond with an available
value for delay in the <Path Latency> parameter. If the available
<Path Latency> is 150 ms (still useful for many applications) and the
desired QoS is Class 0 (with its 100 ms objective), then the response

would be that Class 0 cannot be achieved, and Class 1 is available
(with its 400 ms objective). In addition, this QOSM allows the
response to include an available <Path Latency> = 150 ms, making
acceptance of the available <Y.1541 QoS Class> more likely. There
are many long paths where the propagation delay alone exceeds the
Y.1541 Class 0 objective, so this feature adds flexibility to commit
to exceed the Class 1 objective when possible.

This example illustrates Y.1541-QOSM negotiation of <Y.1541 QoS
Class> and cumulative parameter values that can be achieved end-to-
end. The example illustrates how the QNI can use the cumulative
values collected in <QoS Available> to decide if a lower <Y.1541 QoS
Class> than specified in <QoS Desired> is acceptable.

```
     |------|   |------|                                 |------|   |------|
     | e2e  |<->| e2e  |<----------------------------->| e2e  |<->| e2e  |
     | QOSM |   | QOSM |                                 | QOSM |   | QOSM |
     |      |   |------|   |-------|   |-------|         |------|   |      |
     | NSLP |   | NSLP |<->| NSLP  |<->| NSLP  |<->| NSLP |   | NSLP |
     |Y.1541|   |local |   |local  |   |local  |   |local |   |Y.1541|
     | QOSM |   | QOSM |   | QOSM  |   | QOSM  |   | QOSM |   | QOSM |
     |------|   |------|   |-------|   |-------|   |------|   |------|

     ----------------------------------------------------------------------
     |------|   |------|   |-------|   |-------|   |------|   |------|
     | NTLP |<->| NTLP |<->| NTLP  |<->| NTLP  |<->| NTLP |<->| NTLP |
     |------|   |------|   |-------|   |-------|   |------|   |------|
       QNI        QNE        QNE        QNE        QNE        QNR
      (End)  (Ingress Edge) (Interior) (Interior) (Egress Edge) (End)
```
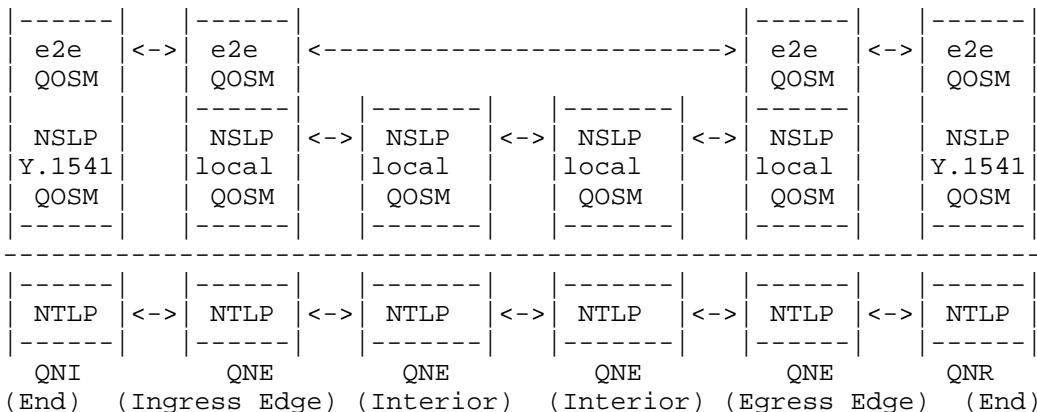
                  Figure 3: Example of Y.1541-QOSM Operation

4.5. Bit-Level QSPEC Example

   This is an example where the QOS Desired specification contains the
   TMOD-1 parameters and TMOD extended parameters defined in this
   specification, as well as the Y.1541 Class parameter. The QOS
   Available specification utilizes the Latency, Jitter, and Loss
   parameters to enable accumulation of these parameters for easy
   comparison with the objectives desired for the Y.1541 Class.

   This example assumes that all the parameters MUST be supported by the
   QNEs, so all M-flags have been set to 1.

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Vers.|QType=I|QSPEC Proc.=0/1|0|R|R|R|       Length = 23     |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |E|r|r|r|  Type = 0 (QoS Des.)  |r|r|r|r|       Length = 10     |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|E|0|r|    ID = 1 <TMOD-1>     |r|r|r|r|       Length = 5      |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  TMOD Rate-1 [r] (32-bit IEEE floating point number)          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  TMOD Size-1 [b] (32-bit IEEE floating point number)          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Peak Data Rate-1 [p] (32-bit IEEE floating point number)     |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Minimum Policed Unit-1 [m] (32-bit unsigned integer)         |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Maximum Packet Size [MPS] (32-bit unsigned integer)          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|E|N|r|          15           |r|r|r|r|          1            |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  Peak Bucket Size [Bp] (32-bit IEEE floating point number)    |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|E|N|r|          14           |r|r|r|r|          1            |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Y.1541 QoS Cls.|              (Reserved)                       |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |E|r|r|r|  Type = 1 (QoS Avail) |r|r|r|r|       Length = 11     |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|E|N|r|           3           |r|r|r|r|          1            |
     +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
     |                Path Latency (32-bit integer)                 |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|E|N|r|           4           |r|r|r|r|          4            |
     +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
     |         Path Jitter STAT1(variance) (32-bit integer)         |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |         Path Jitter STAT2(99.9%-ile) (32-bit integer)        |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |      Path Jitter STAT3(minimum Latency) (32-bit integer)     |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |      Path Jitter STAT4(Reserved)       (32-bit integer)      |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|E|N|r|           5           |r|r|r|r|          1            |
     +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
     |            Path Packet Loss Ratio (32-bit floating point)    |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|E|N|r|          14           |r|r|r|r|          1            |
```

```
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Y.1541 QoS Cls.|                  (Reserved)                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
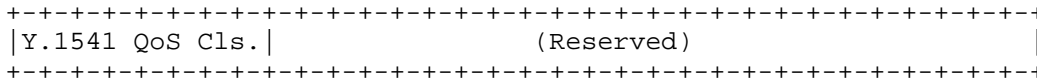
                  Figure 4: An Example QSPEC (Initiator)

   where 32-bit floating point numbers are as specified in [IEEE754].

4.6. Preemption Behavior

   The default QNI behavior of tearing down a preempted reservation is
   followed in the Y.1541 QOSM. The restoration priority parameter
   described above does not rely on preemption.

5. IANA Considerations

   This section defines additional codepoint assignments in the QSPEC
   Parameter ID registry and establishes one new registry for the
   Restoration Priority Parameter (and assigns initial values), in
   accordance with BCP 26 [RFC5226]. It also defines the procedural
   requirements to be followed by IANA in allocating new codepoints for
   the new registry.

5.1. Assignment of QSPEC Parameter IDs

   This document specifies the following QSPEC parameters, which have
   been assigned in the QSPEC Parameter ID registry created in
   [RFC5975]:

      <TMOD Extension> parameter (Section 3.1, ID=15)

      <Restoration Priority> parameter (Section 3.2, ID=16)

5.2. Restoration Priority Parameter Registry

   The Registry for Restoration Priority contains assignments for 3
   fields in the 4-octet word and a Reserved section of the word.

   This specification creates the following registry with the structure
   as defined below.

5.2.1. Restoration Priority Field

   The Restoration Priority Field is 8 bits in length.

   The following values are allocated by this specification:

   0-2: assigned as specified in Section 3.2:

      0: best-effort priority

      1: normal priority

      2: high priority

   Further values are as follows:

   3-255: Unassigned

   The registration procedure is Specification Required.

5.2.2. Time to Restore Field

   The Time to Restore Field is 4 bits in length.

   The following values are allocated by this specification:

   0-2: assigned as specified in Section 3.2:

      0 - Unspecified Time-to-Restore

      1 - Best Time-to-Restore: <= 200 ms

      2 - Normal Time-to-Restore <= 2 s

   Further values are as follows:

   3-15: Unassigned

   The registration procedure is Specification Required.

5.2.3. Extent of Restoration Field

   The Extent of Restoration (EOR) Field is 4 bits in length.

   The following values are allocated by this specification:

   0-5: assigned as specified in Section 3.2:

       0 - unspecified EOR

      1 - high priority restored at 100%;
          medium priority restored at 100%

        2 - high priority restored at 100%;
            medium priority restored at 80%

        3 - high priority restored >= 80%;
            medium priority restored >= 80%

        4 - high priority restored >= 80%;
            medium priority restored >= 60%

        5 - high priority restored >= 60%;
            medium priority restored >= 60%

   Further values are as follows:

   6-15: Unassigned

   The registration procedure is Specification Required.

6. Security Considerations

   The security considerations of [RFC5974] and [RFC5975] apply to this
   document.

   The restoration priority parameter raises possibilities for theft-of-
   service attacks because users could claim an emergency priority for
   their flows without real need, thereby effectively preventing serious
   emergency calls from getting through. Several options exist for
   countering such attacks, for example:

   - only some user groups (e.g., the police) are authorized to set the
      emergency priority bit

   - any user is authorized to employ the emergency priority bit for
      particular destination addresses (e.g., police or fire
      departments)

   There are no other known security considerations based on this
   document.

7. Acknowledgements

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Authors' Addresses

   Gerald Ash
   AT&T Labs
   200 Laurel Avenue South
   Middletown, NJ 07748
   USA

   EMail: gash5107@yahoo.com

   Al Morton
   AT&T Labs
   200 Laurel Avenue South
   Middletown, NJ 07748
   USA

   Phone: +1 732 420 1571
   Fax: +1 732 368 1192
   EMail: acmorton@att.com
   URI: http://home.comcast.net/~acmacm/

Martin Dolly
AT&T Labs
200 Laurel Avenue South
Middletown, NJ 07748
USA

EMail: mdolly@att.com

Percy Tarapore
AT&T Labs
200 Laurel Avenue South
Middletown, NJ 07748
USA

EMail: tarapore@att.com

Chuck Dvorak
AT&T Labs
180 Park Ave Bldg 2
Florham Park, NJ 07932
USA

Phone: + 1 973-236-6700
EMail: cdvorak@att.com

Yacine El Mghazli
Alcatel-Lucent
Route de Nozay
Marcoussis cedex 91460
France

Phone: +33 1 69 63 41 87
EMail: yacine.el_mghazli@alcatel.fr