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SERIES X: DATA NETWORKS, OPEN SYSTEM COMMUNICATIONS AND SECURITY

OSI networking and system aspects – Networking

Information technology – Enhanced communications transport protocol: Specification of QoS management for n-plex multicast transport

Recommendation ITU-T X.608.1

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INTERNATIONAL STANDARD ISO/IEC 14476-6
RECOMMENDATION ITU-T X.608.1

Information technology – Enhanced communications transport protocol: Specification of QoS management for n-plex multicast transport

Summary

This Recommendation | International Standard describes quality of service (QoS) management functions for the n-plex multicast transport over Internet where IP multicast is supported. Quality of service (QoS) management functions such as QoS negotiation, monitoring and maintenance features are specified. Protocol details such as packet format, parameter values and procedures are described. This protocol can be used for applications that require many-to-many data delivery service with QoS managing facility; the protocol is expected to provide transport service to multimedia conference service over IP multicast, etc.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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CONTENTS

Introduction

ECTP is designed to support tightly controlled multicast connections in simplex, duplex and n-plex applications. This part of ECTP (Recommendation ITU-T X.608.1 | ISO/IEC 14476-6) specifies the quality of service (QoS) management functions for the n-plex multicast transport protocol (ECTP-5: Recommendation ITU-T X.608 | ISO/IEC 14476-5).

In the n-plex multicast connection, the participants include one TC-Owner and many TS-users. TC-Owner will be chosen among the TS-users before the connection begins. TC-Owner is at the heart of multicast group communications. It is responsible for overall connection management by governing the connection creation and termination, multicast data transport, and the late join and leave operations. The multicast data transmissions are allowed by TS-users as well as the TC-Owner. Each TS-user is allowed to send multicast data to the group only if it gets a token from the TC-Owner. That is, the multicast data transmissions of TS-users are controlled by the TC-Owner.

For the stable QoS management of the n-plex multicast connection, this Specification provides the QoS management functions such as QoS negotiation, QoS monitoring and QoS maintenance.

The target QoS parameters are negotiated between the TC-Owner and TS-users before the connection creation. During the connection, the status of the connection is monitored by TS-users, and the monitoring result is delivered to Sending TS-users and the TC-owner via control packets. According to the QoS monitoring result, Sending TS-users may adjust their data transmission rate, and the TC-owner may pause or terminate the connection.

This QoS management Specification can be used in multicast applications that want to support various QoS requirements and the corresponding billing/charging models.

INTERNATIONAL STANDARD
RECOMMENDATION ITU-T

Information technology – Enhanced communications transport protocol: Specification of QoS management for n-plex multicast transport

1   Scope

This Recommendation | International Standard provides a specification of QoS management for accomplishing a desired quality of service in n-plex multicast transport connections. For this purpose, this Specification describes the QoS management operations in n-plex multicast transport connections such as QoS negotiation, QoS monitoring and QoS maintenance. This Recommendation | International Standard is an integral part of ECTP-5 (Rec. ITU-T X.608 | ISO/IEC 14476-5). All of the protocol components, including packet formats and protocol procedures specified in Rec. ITU-T X.608 | ISO/IEC 14476-5, are also valid in this Recommendation | International Standard.

2   Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

–   Recommendation ITU-T X.601 (2000), *Multi-peer communications framework.*

–   Recommendation ITU-T X.602 (2004) | ISO/IEC 16513:2005, *Information technology – Group management protocol.*

–   Recommendation ITU-T X.605 (1998) | ISO/IEC 13252:1999, *Information technology – Enhanced Communications Transport Service Definition.*

–   Recommendation ITU-T X.606 (2001) | ISO/IEC 14476-1:2002, *Information technology – Enhanced Communications Transport Protocol: Specification of simplex multicast transport.*

–   Recommendation ITU-T X.606.1 (2003) | ISO/IEC 14476-2:2003, *Information technology – Enhanced Communications Transport Protocol: Specification of QoS management for simplex multicast transport.*

–   Recommendation ITU-T X.607 (2007) | ISO/IEC 14476-3:2008, *Information technology – Enhanced communications transport protocol: Specification of duplex multicast transport.*

–   Recommendation ITU-T X.608 (2007) | ISO/IEC 14476-5:2008, *Information technology – Enhanced communications transport protocol: Specification of N-plex multicast transport.*

3   Definitions

3.1   Terms defined in Rec. ITU-T X.605 | ISO/IEC 13252

This Recommendation | International Standard is based on the concepts developed in Enhanced Communications Transport Service (Rec. ITU-T X.605 | ISO/IEC 13252):

a)   QoS parameters;

b)   QoS negotiation;

c)   QoS arbitration.

3.2   Terms defined in Rec. ITU-T X.606 | ISO/IEC 14476-1

This Recommendation | International Standard is described based on the concepts and terms developed in the specification of simplex multicast transport on ECTP-1 (Rec. ITU-T X.606 | ISO/IEC 14476-1):

a)   application;

b)   packet;

c) sender;

d) receiver;

e) tree;

f) parent;

g) child.

3.3 Terms defined in Rec. ITU-T X.606.1 | ISO/IEC 14476-2

This Recommendation | International Standard is described based on the concepts and terms developed in the specification of simplex multicast transport on ECTP-2 (Rec. ITU-T X.606.1 | ISO/IEC 14476-2).

a) QoS monitoring;

b) QoS maintenance.

3.4 Terms defined in Rec. ITU-T X.608 | ISO/IEC 14476-5

This Recommendation | International Standard is described based on the concepts and terms developed in the specification of n-plex multicast transport on ECTP-5 (Rec. ITU-T X.608 | ISO/IEC 14476-5).

a) TCN (TC-Owner):

An n-plex multicast connection has a single TCN. The TCN is responsible for connection management including connection creation/termination, late join, connection maintenance, and token management.

For example, in teleconferencing applications, the TCN may act as the 'conference server', which may be used for control of the conferencing without sending multicast data. In the example of a 'multi-user on-line game' application, the TCN may act as the 'game-control server'.

b) SU (Sending TS-user):

A TS-user who gets a token from the TCN. Only the SU is allowed to send multicast data to the group. In other words, before sending multicast data, each user must request a token from the TCN.

c) LO (Local Owner):

For a given subset of participants, an LO becomes a root of a locally configured shared tree in the local group. Each LO is also connected to other LOs in inter-group trees. Each LO will control the tree configuration for the local group. It will also perform error recovery as the parent for the local group.

d) Token:

It represents the right for a TS-user to transmit multicast data. A TS-user who has a token is called an SU. The tokens are managed by the TC-Owner.

e) Multicast data channel:

The TCN or an SU can send multicast data to all the other group members over an IP multicast address.

4 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply:

4.1 Packet types

ACK   Acknowledgment

CC   Connection Creation Confirm

CR   Connection Creation Request

CSR   Connection Status Report

CT   Connection Termination Request

DT   Data

JC   Late Join Confirm

JR   Late Join Request

TGC   Token Get Confirm

TGR   Token Get Request

TSR   Token Status Report

4.2 Miscellaneous

ADN   Active Descendant Number

CHQ   Controlled Highest Quality

Diffserv Differentiated Services

ECTP   Enhanced Communications Transport Protocol

ECTS   Enhanced Communications Transport Services

IP   Internet Protocol

LQA   Lowest Quality Allowed

MSS   Maximum Segment Size

OT   Operating Target

QoS   Quality of Service

RSVP   Resource Reservation Protocol

5 Conventions

None.

6 Overview

This Recommendation | International Standard provides a specification of QoS management for n-plex multicast transport connections. This Specification describes the following QoS management operations:

a) QoS negotiation, including reservation of network resources:

For QoS negotiation, this Specification assumes that a desired QoS level for multicast application service can be expressed in terms of a set of QoS parameters. QoS negotiation is performed via an exchange of control packets between the TCN (TC-owner) and TS-users for the multicast data channel. The TCN proposes the target values of QoS parameters obtained from the application's requirements in order for TS-users to send or receive multicast data, and each TS-user can propose modified values based on its system and/or network capacity and the application's requirements. The TCN arbitrates the modified values proposed by TS-users. Target values for QoS parameters can be used as input parameters for reservation of network resources.

b) QoS monitoring:

QoS control in ECTP-6 is based on feedback of control packets from TS-users. The feedback messages from TS-users enable the TCN to keep track of the number of TS-users and also to monitor the connection status for the multicast data channel. QoS monitoring is designed to allow TS-users and the TCN to diagnose the connection status in terms of QoS parameter values, and thus to take the necessary actions for maintaining the connection status at a desired QoS level. The monitored connection status will be reported to the application on the TCN side. The information conveyed could provide statistics useful for billing purposes, for example.

c) QoS maintenance:

Based on feedback information from TS-users, the TCN and SUs (Sending TS-users) take one or more actions so as to maintain the connection status at a desired QoS level. These QoS maintenance actions include adjustment of the data transmission rate, connection pause and resume, troublemaker ejection and connection termination operations. These QoS monitoring and maintenance functions, based on monitored parameter status, provide rate-based congestion control.

In the connection creation phase, the TCN informs TS-users whether QoS management is enabled. If QoS management is enabled, the TCN must also specify whether or not QoS negotiation will be performed in the connection. QoS monitoring and maintenance operations are performed only if QoS management is enabled.

Figure 1 illustrates these QoS management operations for the n-plex multicast connection. In the figure, the protocol operations marked as dotted lines are specified in Rec. ITU-T X.608 | ISO/IEC 14476-5 (ECTP-5).
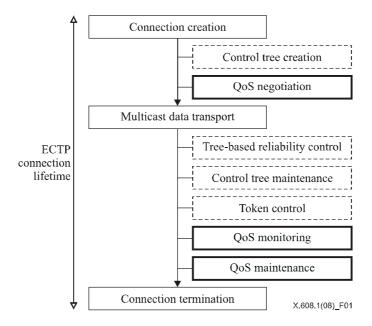
Figure 1 – QoS management in the n-plex connection

In this figure, it is noted that the basic control operations of the n-plex multicast connection are described in ECTP-5, such as control tree creation, tree-based reliability control, control tree maintenance and token control. In this Specification, the QoS negotiation, monitoring and maintenance operations for the n-plex multicast connection will be introduced.

From the requirements of the applications, the TCN will determine the target values for each QoS parameter. The procedures for mapping the requirements of an application to these target parameter values are outside the scope of this Specification. Application programs could be used to carry out such mappings.

QoS negotiation is performed in the connection creation phase. The TCN proposes the desired target values for each QoS parameter, used when sending multicast data to TS-users and receiving multicast data from SUs by multicast, via the CR packet. For the throughput parameter, three target values are specified: Controlled Highest Quality (CHQ), Operating Target (OT) and Lowest Quality Allowed (LQA). For the other parameters, such as transit delay, transit delay jitter and data loss rate, only two target values are specified: OT and LQA.

If QoS negotiation is enabled, each TS-user can propose modifications to the TCN's proposed parameter values. These modified values will be determined by considering the system capacity at the TS-user side and network environment. The following restrictions are imposed for modification of the parameter values by TS-users:

    a)   OT values must not be modified by TS-users;

    b)   the values modified by TS-users must be within the LQA and CHQ values proposed by the TCN.

The parameter values modified by TS-users are delivered to the TCN via CC messages. The TCN arbitrates different parameter values for various TS-users by taking a default range of values.

Figure 2 shows an abstract sketch of QoS negotiation that can occur in ECTP-6. From the requirements of the application, a set of target QoS parameter values for the multicast data channel will be configured at the TCN. The TCN informs TS-users about the target values for sending multicast data to TS-users and receiving multicast data from an SU (step 1). Based on these target values, each TS-user begins to make resource reservations with the help of RSVP [4] [5] or Diffserv [6] (step 2). If QoS negotiation is enabled in the connection, each TS-user may propose modified values for QoS parameters based on its system and/or network capacity and the requirements of the application for the multicast data channel (step 3). From these modified parameter values, the TCN determines the arbitrated values for sending multicast data to other TS-users and receiving multicast data from other TS-users (step 4). These arbitrated values are delivered to TS-users via subsequent TSR or JC packets and will be used for QoS monitoring and maintenance.
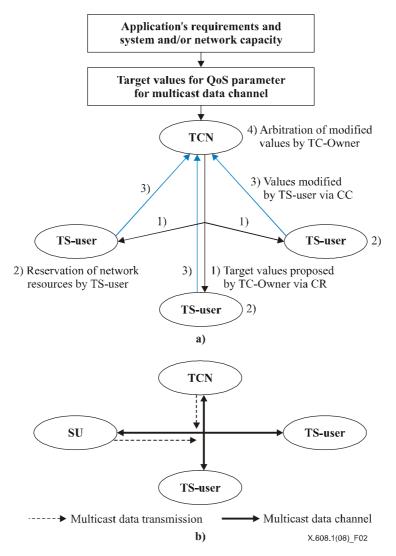
Figure 2 – a) QoS negotiation procedures; b) Multicast data transport in ECTP-5

After an ECTP connection is created and, consequently, if QoS management is enabled, the QoS monitoring and maintenance operations are performed for a multicast data channel. For QoS monitoring, each TS-user is required to measure the QoS parameter values experienced in the multicast data channel. Based on the measured values and the negotiated values, a TS-user determines a status value for each parameter as an integer: normal (0), reasonable (1), possibly abnormal (2) or abnormal (3). These status values will be delivered to the parent node via ACK packets along the control tree. Each TS-user aggregates the parameter status values reported by its child nodes and forwards the aggregated value(s) to its own parent using ACK packets. Finally, these status values are delivered to the SUs and the TCN.

Based on the monitored status values, an SU and the TCN invoke QoS maintenance actions to maintain the connection status at a desired QoS level. Specific rules are pre-configured to trigger QoS maintenance actions such as data transmission rate adjustment, connection pause and resume, troublemaker ejection and connection termination. These actions will be taken by observing how many TS-users are in an abnormal or possibly abnormal state.

7 Components for QoS management

This clause describes the ECTP-6 protocol components required for QoS management operations. All of the components are extended from those already defined in Rec. ITU-T X.608 | ISO/IEC 14476-5.
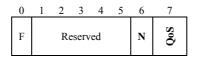
7.1 Base header

Figure 3 shows the base header specified in Rec. ITU-T X.608 | ISO/IEC 14476-5 (in case of ECTP-5 over IP). Note that the two 1-bit fields (Q and N) are inserted into the 'Reserved' field of the original base header of ECTP-5.

Figure 3 – Base header in ECTP-5

For QoS management, a TCN specifies the following two fields in the '*QoS'* and *'N'* bits:

a) *QoS* is a flag bit to indicate whether QoS management is enabled (1) or not (0) in the connection. If this bit is set to '1', all the procedures for QoS management are invoked. The default value is '0';

b) *N* (*Negotiation*) is a flag bit to indicate whether QoS negotiation is enabled (1) or not (0) in the connection. If this bit is set to '1', each TS-user is allowed to propose its own parameter values for the multicast data channel. The default value is '0'.

The QoS bit must be set to '1' (QoS enabled) before the N bit is valid. There are three possible cases.

a) QoS bit set to '1' and N bit set to '0' indicates that QoS is to be used in the connection, and QoS values will be imposed by the TCN. TS-users cannot negotiate it.

b) Both bits set to '1' indicates that QoS is to be used in the connection, and QoS parameter values may be negotiated between TS-users and the TCN.

c) QoS bit set to '0' indicates that QoS is not to be used in the connection. The N bit is not used in this case.

7.2   QoS parameters

In this Specification, the following four QoS parameters are defined for an n-plex connection:

a) throughput (bytes per second);

b) transit delay (milliseconds);

c) transit delay jitter (milliseconds);

d) data loss rate (percent).

The throughput parameter represents the amount of application data output over a specific time period. Target throughput means a throughput value required for desired display of application data. In multicast data transport, applications generate multicast data and the TCN or SUs will transmit them based on the target throughput value(s). The actual data reception rate at a TS-user's side will depend on the data transmission rate, network conditions, end system capacity, and so on.

For throughput, the TCN shall configure the following target values:

a) CHQ throughput;

b) OT throughput;

c) LQA throughput.

The following inequalities must be enforced: LQA throughput ≤ OT throughput ≤ CHQ throughput.

The transit delay represents end-to-end transmission time from a sender to a receiver. For desired QoS of a multicast data channel, the TCN may configure the following target values:

a) OT transit delay;

b) LQA transit delay.

The following inequalities must be enforced: OT transit delay ≤ LQA transit delay.

Transit delay jitter represents variations in the transit delay values. For desired QoS of a multicast data channel, the TCN may configure the following target values:

    a)   OT transit delay jitter;

    b)   LQA transit delay jitter.

The following inequalities must be enforced: OT transit delay jitter ≤ LQA transit delay jitter.

Data loss rate is defined as the ratio of the amount of lost data over the amount of total transmitted data. For desired QoS of a multicast data channel, the TCN may configure the following target values:

    a)   OT loss rate;

    b)   LQA loss rate.

The following inequalities must be enforced: OT loss rate ≤ LQA loss rate.

7.3 QoS extension element

QoS extension is a newly defined element for QoS management in this Specification. All the extension elements used in ECTP-6 are listed below.

Table 1 – Extension elements

Extension element	Encoding value (4 bits)	Length of extension element (bytes)
No element	0000	0
Connection	0001	4
Error bitmap	0010	Varied
Timestamp	0100	12
Token	0110	Varied
LO information	0111	Varied
QoS	0101	28

The QoS extension element specifies the maximum segment size (MSS) and the target values for ECTP-6 QoS parameters, which are described in 7.2. As shown in Figure 4, the QoS element has a length of 28 bytes.

Figure 4 – QoS extension element

The following parameters are specified:

    a)   *Next element* (4 bits) – Indicates the type of the next element immediately following this QoS element.

    b)   *Version* (4 bits) – Defines the current version of this element. Its current version is encoded as '0011':

        1)   0001 – simplex multicast connection (for ECTP-1 and ECTP-2);

        2)   0010 – duplex multicast connection (for ECTP-3 and ECTP-4);

        3)   0011 – n-plex multicast connection (for ECTP-5 and ECTP-6).

c) *QoS Flags* – Is a flag byte to specify if each of the QoS parameters, the MSS and the data channel type are used in the connection. Encoding of this byte is depicted in the following figure. If a bit is set to '1', then the corresponding QoS parameter, MSS or data channel type will be used. The default value is '0' for each bit. If the 'F' bit of *QoS Flags* is set to '1', then the values of the QoS parameters are configured for a multicast data channel sending multicast data. If the 'G' bit of *QoS Flags* is set to '1', then the values of the QoS parameters are configured for a multicast data channel receiving multicast data. It should be noted that both the 'F' bit and the 'G' bit cannot be set to '1' at the same time:

0	1	2	3	4	5	6	7
A	B	C	D	E	F	G	R

1) A – throughput;

2) B – transit delay;

3) C – transit delay jitter;

4) D – data loss rate;

5) E – maximum segment size (MSS);

6) F – multicast data channel for sending multicast data;

7) G – multicast data channel for receiving multicast data;

8) R – reserved for future use.

d) *Maximum segment size (MSS)* – Represents the maximum size of an ECTP segment or packet in units of bytes. If the 'E' bit of *QoS Flags* is set to '1', the MSS is subject to negotiation. Otherwise, the default MSS value of 1024 will be used.

e) *Throughput values* – Each value is a 32-bit unsigned integer in bytes per second. The following target values are valid only if the 'A' bit of *QoS Flags* is set to '1':

1) CHQ throughput – upper limit for throughput;

2) OT throughput – target throughput for desired display of multicast data;

3) LQA throughput – lower limit for throughput.

f) *Transit delay values* – Each value is a 16-bit unsigned integer representing milliseconds. The following target values are valid only if the 'B' bit of *QoS Flags* is set to '1':

1) OT transit delay – target transit delay for desired display of multicast data;

2) LQA transit delay – maximally allowed transit delay.

g) *Transit delay jitter values* – Each value is a 16-bit unsigned integer representing milliseconds. The following target values are valid only if the 'C' bit of *QoS Flags* is set to '1':

1) OT transit delay jitter – target transit delay jitter for desired display of multicast data;

2) LQA transit delay jitter – maximally allowed transit delay jitter.

h) *Data loss rate values* – Each value is an 8-bit unsigned integer ranging from 0 to 100 representing a percentage. The following target values are valid only if the 'D' bit of *QoS Flags* is set to '1':

1) OT loss rate – target loss rate for desired display of multicast data;

2) LQA loss rate – maximally allowed loss rate.

i) *Reserved* – Is reserved for future use.

In the connection phase, if QoS is enabled, the TCN can propose the target values of QoS parameters, used for sending multicast data and receiving multicast data, to TS-users via the CR packet. This CR packet format is as follows:

CR packet = base header + connection element + QoS element + QoS element

In the above CR packet, the first QoS element is used for sending multicast data and the second QoS extension element is used for receiving multicast data. The value of the 'F' bit of *QoS Flags* in the first QoS element is '1', and the '*Next Element*' byte in the first QoS element indicates the QoS element for receiving multicast data.

The QoS element is used for the TCN to inform the TS-users about the target values for QoS parameters by sending a CR packet in the connection creation phase. In QoS negotiation, the QoS element is also used when a TS-user proposes

its own modified values to the TCN. The negotiated QoS values will be announced to late-joiners via the JC packet and to existing TS-users via TSR packets.
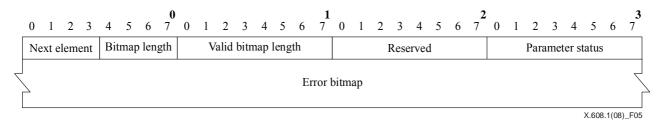
These QoS values are also referred to in the QoS monitoring and maintenance operations.
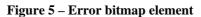
7.4   Error bitmap element

For QoS monitoring, each TS-user is required to measure the parameter values that have been experienced. A measured parameter value is mapped to a parameter status value. A status value is an integer such as 0, 1, 2 or 3. A larger status value indicates a worse status for the connection.

The status values are delivered to SUs via ACK packets. The error bitmap element of the ACK packet contains the status values for QoS parameters used in the connection.

The error bitmap element specified in Rec. ITU-T X.608 | ISO/IEC 14476-5 is shown below. In the figure, the '*parameter status*' byte is newly defined in this Specification for QoS.

Figure 5 – Error bitmap element

The '*parameter status*' byte has the following structure:

a)   A – represents two bits to indicate the status value for the measured throughput;

b)   B – represents two bits to indicate the status value for the measured transit delay;

c)   C – represents two bits to indicate the status value for the measured transit delay jitter;

d)   D – represents two bits to indicate the status value for the measured packet loss rate.

A status value consisting of two bits has one of the following values:

a)   00 – indicates '0' as a status value;

b)   01 – indicates '1' as a status value;

c)   10 – indicates '2' as a status value;

d)   11 – indicates '3' as a status value.

The detailed mapping schemes from a measured parameter value to a status value are described in 8.2.3.

7.5   Packets used for QoS management

Table 2 lists the ECTP-5 packets used for QoS management. Note that the CSR packet is newly defined in this Specification for QoS management.

Table 2 – ECTP-5 packets used for QoS management

Packet type	Extension element					
	Connection	Error Bitmap	Timestamp	Token	LO Information	QoS
DT			O			
CR	O					O
CC						O
TSR				O	O	O
ACK		O				
JC	O					O
CSR		O				

The CR packet contains a QoS element. This is used by the TCN to propose (or impose) the target values of QoS parameters used in the connection. These values can be referenced by resource reservation mechanisms and protocols, such as RSVP, if they are enabled in the network. If QoS negotiation is enabled, each TS-user responds to TCN with its own proposed values for QoS parameters via a CC packet. The TCN will arbitrate the returned proposals, and the arbitrated values for the QoS parameters will be delivered to TS-users via TSR packets. For a late joiner, the target QoS parameter values currently being used in the connection (whether imposed or negotiated originally) are notified via a JC packet (see 8.1).

The target or negotiated values will be referred to in QoS monitoring and maintenance operations. ACK packets are used to convey the status values for QoS parameters experienced on the TS-user side (see 8.2).

The status values of QoS parameters are aggregated by TS-users along the control tree and finally delivered to SUs. Using this information, an SU determines the connection status and periodically reports it to the TCN via a CSR packet.

A DT packet contains a Timestamp element which is used to measure end-to-end transit delay.

7.6   Packet format

In this Recommendation | International Standard, one control packet is defined.

Table 3 – ECTP-6 packets newly defined for QoS management

Full name	Acronym	Transport	From	To
Connection Status Report	CSR	Unicast	SU	TCN

The encoding value and packet structure are shown for each of the ECTP-6 packets in Table 4. The extension elements are attached to the base header in the order specified in the table.

Table 4 – Format of ECTP-6 packets

Packet type	Encoding value	Extension elements or user data (packet structure)	Length (bytes)	Operational protocol stage
CSR	0100 0001	Error Bitmap	48	QoS monitoring

7.6.1   Connection Status Report (CSR)

The CSR packet is used by an SU to inform the TCN of the current connection status. SUs can determine the current connection status by exploiting parameter status values obtained from ACK packets. These values must also be reported to the TCN so that it can perform further connection maintenance actions such as connection pause/resume and termination. An SU sends the CSR packet to the TCN over the following source and destination addresses:

    a)   Source IP: IP address of the SU.

    b)   Source Port: local port number of the SU.

    c)   Destination IP: IP address of the TCN.

    d)   Destination Port: group port number.

The CSR packet contains a 16-byte base header and a 32-byte error bitmap element with an empty 'Error Bitmap' field. The base header of a CSR packet must be encoded as follows:

  a) *Next Element*: '0010' (error bitmap element);

  b) *CT*: '11';

  c) *Packet Type*: '0100 0001' (CSR);

  d) *Checksum*: to be calculated;

  e) *Source Port*: local port number of the SU (or connection ID);

  f) *Destination Port*: group port number (or connection ID).

All fields other than those specified above will be set to '0' and ignored at the receiver side.

The error bitmap element must be encoded as follows:

  a) *Next element*: '0000'.

  b) *Parameter status*: a connection status value determined by the SU: 00, 01, 10 or 11 (see 7.4).

All fields other than those specified above will be set to '0' and ignored at the receiver side.

8   Procedures for QoS management

In ECTP-6, QoS management includes the following operations:

  a) QoS negotiation, possibly with reservation of network resources;

  b) QoS monitoring;

  c) QoS maintenance.

QoS negotiation is performed in the connection creation phase, while QoS monitoring and maintenance operations are done in the data transmission phase.

If QoS management is enabled in the connection, QoS monitoring and maintenance operations are performed by default. On the other hand, QoS negotiation is enabled only when the N bit in the '*QN*' byte of the ECTP-5 base header is set to '1'.

8.1   QoS negotiation

The TCN transmits a CR packet to all TS-users to start the connection creation phase. The CR packet contains the proposed (or imposed) target values for each QoS parameter such as CHQ, OT and LQA for the multicast data channel. Each TS-user can refer to these target values for resource reservation (see 8.1.3). If QoS negotiation is enabled in the connection, the negotiation procedures are activated (see 8.1.1). The imposed or negotiated target values are subsequently used in QoS monitoring and maintenance (see 8.2 and 8.3).

If QoS negotiation is enabled in the connection, each TS-user can propose a new modified value for the multicast data channel to send and receive multicast data in response to a target parameter value proposed by the TCN. To propose a new value, a TS-user is required to be able to identify the system or network resources to be used. For example, a modified throughput value may be assessed from line rates of transmission links accessible at the TS-user site (e.g., DSL, cable modem, wireless networks, and so on). The modified value may also be determined by considering the end user's requirement for receiving and sending multicast data at a TS-user site. It is possible for an end host to use a software program to determine the modified parameter value for negotiation, based on network and system resources, as well as end user's requirements. However, in real world scenarios, it is not easy to precisely identify the resource capacity of the networks involved with a receiver. Accordingly, at least in the near future, QoS negotiation will be done based on the end user's requirements at the application level or on the system capacity of the end host.

In this Specification, a TCN is required to specify via the QoS extension element whether each QoS parameter is subject to negotiation (see 7.3). For parameters that are negotiable, a TS-user can propose modified values. If a TS-user does not wish to modify a QoS parameter, it will just return the same QoS element received from the TCN.

8.1.1   Negotiation procedures

If QoS negotiation is enabled in the connection, each TS-user responds to the TCN with a CC packet containing the modified target values for the respective QoS parameters.

This clause describes the QoS negotiation procedures for the throughput parameter, which has three target values: LQA, OT and CHQ. The negotiation procedures for the other parameters such as delay, jitter and loss rate are all the same except that these parameters have no CHQ values.

During QoS negotiation, TS-users must not modify the OT value for each parameter. The detailed procedures for QoS negotiation are described below and illustrated in Figure 6.
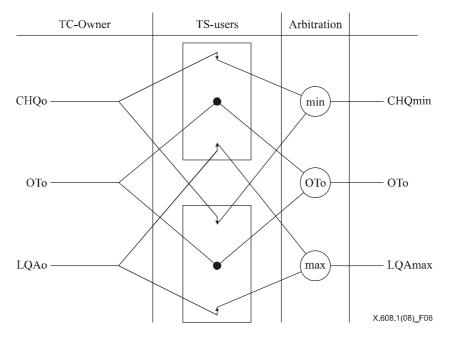

Figure 6 – QoS negotiation procedure

a) The TCN proposes target parameter values for the multicast data channel to send and receive multicast data

From application requirements and system and/or network capacity, the TCN determines the target parameter values for multicast data: $LQAo$, OTo, $CHQo$, where $LQAo < OTo < CHQo$, and then transmits a CR packet with two QoS extension elements for sending multicast data to TS-users and receiving multicast data from TS-users.

b) TS-users can modify the parameter values for the multicast data channel sending and receiving multicast data

In response to the target values proposed by the TCN, each TS-user i can propose the modified values for sending and receiving multicast data: LQA_i and CHQ_i. OTo value must not be changed. Thus, the following inequalities are enforced: $LQAo < LQA_i < OTo < CHQ_i < CHQo$ for each TS-user i. Each TS-user delivers the modified values to the TCN via a CC packet with two QoS extension elements for sending and receiving multicast data.

c) The TCN arbitrates the modified parameter values for sending multicast data to other TS-users and receiving multicast data from other TS-users

TCN arbitrates the modified parameter values proposed by TS-users as follows:

$$CHQmin = min\ CHQ_i, \text{ for each TS-user } i;$$

$$LQAmax = max\ LQA_i, \text{ for each TS-user } i.$$

LQAmax and CHQmin are the negotiated parameter values that have resulted from QoS negotiation.

d) The TCN announces the negotiated parameter values

TCN announces LQAmax, CHQmin and OT values to TS-users via TSR and JC packets.

For delay, jitter and loss rate parameters, an LQAmin value will be obtained instead of LQAmax, since CHQ values are not used and OT value < LQA value for these parameters. That is,

$$LQAmin = min\ LQA_i, \text{ for each TS-user } i.$$

Note that QoS negotiation is not performed for late-joining TS-users. The TCN just notifies the negotiated parameter values to the late-joining TS-user via a JC packet.

Note that the negotiated QoS parameter values will be referred to in the QoS monitoring and maintenance operations and are not modified in the data transport phase.

8.1.2 MSS negotiation

The MSS represents the maximum packet size, which depends on the maximum transmission unit (MTU) for link layer transmissions. Typical MTU values are 1500 bytes for Ethernet, 1492 bytes for IEEE 802, 4352 bytes for FDDI, 576 bytes for X.25, and so on. The MTU determines the frame size for link layer transmissions, and hence the MSS value.

The default MSS value in ECTP-5 is 1024 bytes, which supports most link types except X.25. If sender and/or receiver cannot identify its MSS value, it takes the default MSS value of 1024 bytes.

In ECTP-6, if MSS negotiation is indicated (see 7.3), the following procedures are performed:

a)   TCN writes its MSS value into the CR packet, and then transmits it to all the TS-users.

b)   Each TS-user proposes its own MSS value via the CC packet. The MSS will be affected by the MTU of the local network that a TS-user belongs to. If a TS-user's MSS is larger than the TCN's MSS, TS-user uses the TCN's MSS.

8.1.3 Resource reservation

ECTP-6 itself cannot guarantee the QoS levels required by applications. However, the target values of QoS parameters can be used in the reservation of network resources such as integrated services with RSVP and differentiated services (Diffserv).

The RSVP model is a good match with the ECTP-6 protocol, since resource reservation is done in an end-to-end manner. In networks where RSVP is enabled, senders transmit periodic RSVP PATH messages downstream along the multicast data path. In response to the PATH message, each receiver sends RSVP RESV messages upstream towards the senders to request resource reservation.

If RSVP is used with ECTP-6, the target values of ECTP-6 QoS parameters will be referenced in the configuration of RSVP traffic descriptors for the RSVP TSPEC (or FLOWSPEC) contained in the PATH message. An initial PATH message can be sent by an SU before sending data. Since a TS-user is allowed to send data as an SU after getting a token from the TCN, the initial PATH message must be issued after receiving a TGC message from the TCN. The subsequent PATH messages are sent for each received TSR packet by the TCN periodically. It should be noted that the RSVP modules are managed separately from ECTP-6 in end systems. This means that the resource reservation and control functions in RSVP will only be performed by the RSVP daemons concerned.

The differentiated service model provides differentiated classes of service for IP traffic to support various types of applications and specific business requirements. A small bit-pattern in each packet, in the IPv4 TOS (or DSCP) octet or the IPv6 Traffic Class octet, is used to mark a packet to receive a particular forwarding treatment, or per-hop behaviour, at each network node. A common understanding of the use and interpretation of this bit-pattern is required for inter-domain use, multi-vendor interoperability, and consistent reasoning about expected service behaviours in a network. Up to the present, a specific interworking scheme between ECTP and Diffserv has not been identified.

ECTP-6 will need to utilize underlying network QoS mechanisms such as RSVP and Diffserv to establish network connections delivering the required QoS levels. However, the potential use of ECTP-6 is not limited to current network QoS methods. ECTP-6 is designed to be used for QoS improvement under a variety of different QoS models in the future.

8.2 QoS monitoring

The QoS monitoring function provides an SU and the TCN with information about how well the connection is operating. To do this, each TS-user is required to measure the parameter values experienced and report these values back to SUs.

For the QoS parameters used in the connection, each TS-user measures the parameter values that have been experienced. The measured value is mapped to a parameter status value for each parameter. A parameter status is an integer having a value of 0, 1, 2 or 3. This status value is recorded in the acknowledgement element and conveyed to SUs via a subsequent ACK packet (see 7.4). Each TS-user aggregates the parameter status values from its child TS-users and delivers the aggregated values to its parent node, and subsequently to the SU. These status values are further forwarded by the SU to the TCN periodically to inform the TCN of the current connection status via the CSR packet.

The purpose of QoS monitoring is to provide SUs and the TCN with information on the QoS status for the connection. Based on the monitored status information, SUs and the TCN can also invoke any necessary QoS maintenance actions.

8.2.1 Generation of ACK

Each TS-user reports the parameter status values to its parent by generating ACK packets. In ECTP-6, each TS-user generates an ACK packet by *ACK_GENERATION_NUM (AGN)*. At every *AGN* number of DT packets, it aggregates the status of QoS parameters for itself and its child nodes and sends it with an ACK packet to its parent by piggybacking on the QoS extension element.

Each ACK packet conveys the measured parameter status value as described in 8.2.2.

8.2.2 Measurement of QoS parameter values

For multicast data transmission, each TS-user measures the experienced values for each QoS parameter. All the parameter values are measured, recorded and calculated, until a new ACK packet is generated according to the ACK generation rule described above. When it is time to send an ACK, a TS-user calculates the parameter status value for the data packets received and collected until then. After transmitting an ACK, the collected data is cleared and then new data will be gathered and recorded for generating a new ACK.

Throughput is measured as the data reception rate in units of bytes per second. The data reception rate is calculated by:

Amount of received data packets in bytes / Time taken to receive AGN DT packets.

To measure the throughput value, a receiver needs to keep information about how many data packets (bytes) have been received during a specific time period.

Each time a new throughput value is obtained, the value is mapped to the *parameter status value*, an integer value of 0, 1, 2 or 3, according to the mapping rule that is described in 8.2.3.

The data loss rate represents the packet loss rate, and it is expressed in percent. The packet loss rate is calculated by

Number of lost packets / Number of data packets received.

To measure the throughput value, a TS-user needs to keep information about how many data packets have been lost. When a TS-user generates an ACK packet, the currently measured loss rate value is mapped to the *parameter status value*.

To measure end-to-end transit delay, SUs are required to transmit DT packets with a timestamp element. Another requirement is the synchronization of clocks between the TCN and TS-users. Without an adequate resolution of these requirements, it is hard to get exact information about transit delay and jitter. In this clause, it is assumed that each TS-user can measure end-to-end transit delay of a DT packet from an SU or the TCN.
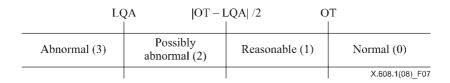
The transit delay is measured for each data packet received. These transit delay values are averaged over *AGN* DT packets received. Transit delay jitter is measured as the difference between the maximum and minimum transit delay values of these received data packets.
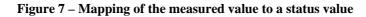
Before receiving *AGN* DT packets, the transit delay is calculated every time a new DT packet arrives, and the averaged delay and jitter values are updated. Just before a TS-user generates an ACK packet, the currently measured value will be mapped to the *parameter status value*.

8.2.3 Mapping to a parameter status value

The measured parameter value is mapped to a parameter status value for each QoS parameter. The subsequent ACK packet will contain the status value. Note again that measurement of a QoS parameter is activated only if the use of the parameter in the connection is indicated (see 7.3).

Figure 7 illustrates the mapping from the measured value to a status value.

	LQA	|OT – LQA| /2	OT
Abnormal (3)	Possibly abnormal (2)	Reasonable (1)	Normal (0)

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Figure 7 – Mapping of the measured value to a status value

As shown in the figure, the mapping from the measured parameter value to a status value is done based on OT and LQA parameter values. ECTP-6 also uses a *threshold* value to classify the status into normal (0), reasonable (1), possibly abnormal (2) and abnormal (3). The *threshold* value is set to a medium value between OT and LQA parameter values (i.e., |LQA – OT| / 2), as shown in the figure.

An initial *parameter status value* is set to '0'. Once the measured value is obtained, the mapping to a *parameter status value* is done as follows:

> IF '*measured parameter value* > OT,' then status = 0,
>
> ELSE IF '*threshold* < *measured parameter value* ≤ OT,' then status = 1,
>
> ELSE IF '*LQA* < *measured parameter value* ≤ threshold,' then status = 2,
>
> ELSE IF '*measured parameter value* ≤ LQA,' then status = 3.

In the above mapping rules, the inequalities hold true only for the throughput parameter. For other parameters, such as delay, jitter and loss rate, these inequalities must be reversed, because OT values ≤ LQA values.

8.2.4 Reporting toward SUs and TCN

Each TS-user reports the obtained *parameter status values* to its parent via ACK packets. Each parent TS-user aggregates the ACK packets from its children. This aggregation will proceed just before the parent generates its own ACK. After aggregation of the ACK packets, the parent takes average values of the parameter status values weighted by the number of descendants of each child. The weighted average value of a parameter status value can be obtained by:

$$Weighted\ average\ value = \Sigma_{i=1,..,N}\ \{ADN(i) \times parameter\ status\ value(i)\}\ /\ \Sigma_{i=1,..,N}\ ADN(i),$$

where *ADN(i)* (*Active Descendant Number)* represents the number of descendants of child *i*.

The parent TS-user simply takes an average value of the aggregated parameter status value with its own measured value. It rounds this average value to 0, 1, 2 or 3 for each QoS parameter, and composes its ACK packet. In this fashion, the aggregated parameter status values will be delivered toward SUs along the tree hierarchy.

An SU also performs aggregation of ACK packets reported from its children for every *AGN* DT packets. Aggregation of the parameter status values by SUs is the same as that by TS-users but SUs do not have their own measured status values.

An SU obtains an aggregated status value for each QoS parameter. More specifically, an SU will have the following aggregated status values (if each of the parameters is used in the connection):

> a)   Aggregated status for throughput, denoted by *Tvalue*.
>
> b)   Aggregated status for transit delay, denoted by *Dvalue*.
>
> c)   Aggregated status for transit delay jitter, denoted by *Jvalue*.
>
> d)   Aggregated status for data loss rate, denoted by *Lvalue*.

Each of the aggregate values also ranges between 0 and 3.

An SU forwards the aggregated parameter status values to the TCN via a CSR packet. The SU sends periodic CSR packets for every *CSR_PACKET_INT* seconds to the TCN. SUs may also forward this status information to the applications. The monitored status information is beneficial for sending applications to diagnose how well the connection is being operated in terms of QoS, which may further be useful for designing a billing/charging model.

The monitored status information is also used in QoS maintenance. Among the monitored values, *Lvalue* is used for adjustment of the transmission data rate by SUs. A weighted sum value for all the status values, *Tvalue*, *Dvalue*, *Jvalue* and *Lvalue*, can be used to trigger connection pause, troublemaker ejection and termination by the TCN.

8.3   QoS maintenance

QoS maintenance is performed to maintain the quality of a connection at a desired level and to prevent the connection quality from being degraded below the negotiated QoS level.

Based on the monitored parameter status values, the TCN will invoke the following QoS maintenance actions:

> a)   connection pause and resume;
>
> b)   troublemaker ejection;
>
> c)   connection termination.

And SUs will invoke the following QoS maintenance actions:

a) adjustment of data transmission rate.

Data rate adjustment is performed by SUs and is related to rate-based flow and congestion control. Connection pause/resume and termination are actions which can be taken to manage the connection by the TCN. These events will be announced to all TS-users via TSR packets with the 'F' bit set to '1' in the base header and CT packets transmitted by the TCN.

To trigger these QoS maintenance actions, the TCN and SUs need to configure the following threshold values:

a) *threshold_rate_increase* and *threshold_rate_decrease* for adjustment of data transmission rate;

b) *threshold_connection_pause*.

All the threshold values are real numbers ranging between 0 and 3.

8.3.1 Adjustment of data transmission rate

ECTP-6 uses a fixed-sized window-based flow control. The TCN or SUs can maximally transmit the window size data packets at the rate of *Data Transmission Rate (DTR)*. ECTP-6 performs congestion control by dynamically adjusting *DTR*, based on the loss rate status values *Lvalue* (see 8.2.4).

Adjustment of the data transmission rate is based on *threshold_rate_increase* and *threshold_rate_decrease*, which are preconfigured by the TCN or SUs according to application requirements. These values range as follows:

$$0 \leq threshold\_rate\_increase \leq threshold\_rate\_decrease \leq 3.$$

The default values are *threshold_rate_increase* = 1.0 and *threshold_rate_decrease* = 2.0.

In the data transmission phase, the TCN or an SU starts with *DTR* = LQA throughput, and *DTR* can be adjusted as follows:

$$LQA\ throughput \leq DTR \leq CHQ\ throughput.$$

When receiving every *AGN* DT packets, the TCN or an SU adjusts *DTR*, based on *threshold_rate_increase*, *threshold_rate_decrease*, and the monitored *Lvalue* as follows:

IF   *Lvalue < threshold_rate_increase*

THEN   *DTR* = Min {CHQ, *DTR + Transmission Rate Increase (TRI)*}

ELSE IF *threshold_rate_increase ≤ Lvalue ≤ threshold_rate_decrease*

THEN   *DTR* is not changed

ELSE IF *Lvalue > threshold_rate_decrease*

THEN   *DTR* = Max {LQA, *DTR – Transmission Rate Decrease (TRD)*}

Rate adjustment variables such as *TRI* and *TRD* may be set based on CHQ and LQA throughput. For example:

TRI = (*CHQ – LQA*) x 1/20
TRD = (*CHQ – LQA*) x 1/5

8.3.2 Connection pause and resume

Connection pause can be performed by the TCN to suspend multicast data transmission temporarily so as to prevent the connection quality from being more severely degraded.

Connection pause and resume may be performed according to a request by an application. In this case, the sending application on the TCN side will trigger the connection pause based on monitored parameter status values such as *Tvalue*, *Dvalue*, *Jvalue* and *Lvalue*. If a connection pause is triggered, the TCN transmits periodic TSR packets with the 'F' bit set to '1' in the base header. When receiving TSR packets with the 'F' bit set to '1' in the base header from the TCN, SUs must stop sending new DT packets.

A connection pause may also be triggered based on the pre-configured *threshold_connection_pause*. In this case, only if the monitored connection status value is larger than *threshold_connection_pause* will the TCN trigger the connection pause. The suggested *threshold_connection_pause* value is 2.5.

For this purpose, *Connection Status* value is calculated for all the monitored parameter status values as follows.

$$Connection\ Status = Tweight \times Tvalue + Dweight \times Dvalue + Jweight \times Jvalue \times Lweight \times Lvalue$$

Each of the weight values must also be configured, along with *threshold_connection_pause*, where the following constraints are imposed:

$$0 \leq \textit{Tweight, Dweight, Jweight, Lweight} \leq 1,$$
$$\textit{Tweight} + \textit{Dweight} + \textit{Jweight} + \textit{Lweight} = 1.$$

A weight value is set to '0' if the corresponding QoS parameter is not enabled in the connection.

A connection pause is triggered if

Connection Status ≥ threshold_connection_pause.

After a connection pause is indicated, and if a *Connection Pause Time (CPT)* interval has elapsed, then a connection resume is triggered and SUs or the TCN begin to transmit multicast data at the transmission rate of LQA. When a connection resume is indicated, TSR packets will set the 'F' bit of the header to '0'.

8.3.3 Troublemaker ejection

The TCN may invoke troublemaker ejection to maintain the QoS status at a desired level and also to prevent the connection status from being more severely degraded. A detailed scheme for troublemaker ejection can be different in each implementation based on the parameter status values provided in this Specification.

For example, a TS-user may be ejected if it has reported a *parameter status value* larger than *threshold_connection_pause* several times more than a pre-configured threshold. The design and implementation of the troublemaker ejection scheme must be done carefully, since the ejection operation may have significant impact on the overall ECTP-6 protocol behaviour.

8.3.4 Connection termination

The default option for a connection termination is to terminate a connection when all the forward multicast data have been transmitted. In QoS management operations, connection termination is also triggered if the connection status is perceived as 'unrecoverable.'

Connection termination may be performed at the request of the application. If connection termination is triggered, the TCN transmits a CT packet to all TS-users and closes the connection.

Connection termination may also be triggered based on the pre-configured *Connection Termination Time (CTT)*. In this case, connection termination is triggered if:

Subsequent connection pause occurs again within CTT from connection resume.

The *CTT* timer is activated when a connection resume is indicated. Connection termination may not be supported in some applications.

9 Timers and variables

The following are timers and variables used for QoS management in this Specification.

9.1 Timers

    a) Connection Pause Time (*CPT*) in seconds: Once a connection pause is indicated, the connection will pause during *CPT* interval (see 8.3.2).

    b) Connection Termination Time (*CTT*) in seconds: After a connection resume is indicated, and if a connection pause occurs again within a *CTT* interval, connection termination is triggered (see 8.3.4).

    c) QoS Monitoring Time (*QMT*) in seconds: Each receiver measures the experienced values for QoS parameters every *QMT* interval (see 8.2.2).

9.2 Operation variables

    a) Aggregated parameter status values: Sender aggregates the parameter status values reported from receivers, which results in *Tvalue, Dvalue, Jvalue* and *Lvalue* (see 8.2).

    b) ACK Generation Number (*AGN*): Each receiver generates an ACK packet when receiving every *AGN* DT packets.

c) Connection Status: For triggering a connection pause/resume, all the aggregated parameter status values can be averaged weighted by the pre-configured parameters such as *Tweight*, *Dweight*, *Jweight* and *Lweight*. This results in a Connection Status that represents the overall status of the connection (see 8.3.2).

d) Data Transmission Rate (*DTR*): Sender transmits multicast data at the rate of *DTR* (see 8.3.1).

e) Measured parameter value: Each receiver is required to measure the experienced value for QoS parameters used in the connection. This results in a measured parameter value (see 8.2).

f) Parameter status value: The measured parameter value is mapped onto a parameter status value, which is an integer such as 0, 1, 2 or 3 (see 8.2).

g) Transmission Rate Decrease (*TRD*): *DTR* is decreased by *TRD* (see 8.3.1).

h) Transmission Rate Increase (*TRI*): *DTR* is decreased by *TRI* (see 8.3.1).

i) *Threshold_rate_increase*: Threshold to increase data transmission rate (see 8.3.1).

j) *Threshold_rate_decrease*: Threshold to decrease data transmission rate (see 8.3.1).

k) *Threshold_connection_pause*: Threshold to trigger a connection pause (see 8.3.2).

Annex A

Implementation considerations

(This annex does not form an integral part of this Recommendation | International Standard)

The implementation of ECTP-6 shall be done based on ECTP-5 and ECTP-2.

In particular, the following materials in ECTP-5 will be useful for the implementation of ECTP-6:

    a)   Annex A: Application program interfaces;

    b)   Annex B: State transition diagrams;

    c)   Annex C: An example of system parameters values.

In addition, the following materials in ECTP-2 will also be useful for the implementation of ECTP-6:

    a)   Annex A: Interworking between ECTP and RSVP for resource reservation;

    b)   Annex B: Application programming interfaces.

The informative materials described above will be commonly used in the implementation of ECTP-6. Due to different protocol procedures and messages between ECTP-2 and ECTP-6, however, the internetworking scenario between ECTP and RSVP, which is described in clause A.4 of ECTP-2 (Rec. ITU-T X.606.1 | ISO/IEC 14476-2), needs to be considered in different manners as follows.

A.1   A scenario of interworking between ECTP-6 and RSVP

The target values for each ECTP QoS parameter can be used to construct an RSVP SENDER_TSPEC object. To do this, an interface between ECTP and RSVP is required so that the ECTP QoS parameter values are informed to the RSVP processor. The SENDER_TSPEC object will be delivered to receivers via RSVP PATH messages.

The time when ECTP calls RSVP depends on the implementation, but it is recommended that the ECTP sender (SU) invoke RSVP after receiving a TGC packet and that a receiver (a TS-user) do so after reception of CR or JC packets. Figure A.1 illustrates a model of interworking between ECTP and RSVP.
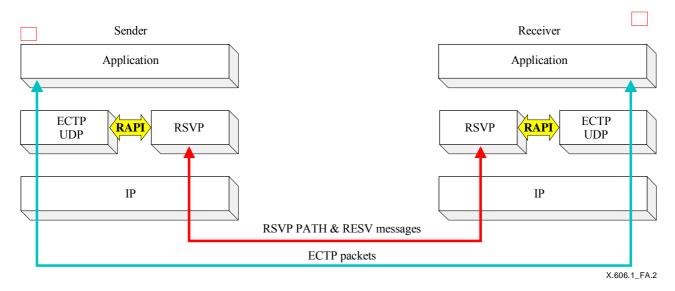

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Figure A.1 – Interworking model between ECTP and RSVP

As shown in the figure, communications between ECTP and RSVP are done via the RSVP API (RAPI). The ECTP sender transfers information on QoS parameters to RSVP via RAPI when it invokes the RSVP daemon. Once RSVP is triggered by ECTP, RSVP communications will be done between the sending and receiving RSVP daemons. That is, RSVP peering relationships will be established between the sender and receivers.

During the ECTP connection, each RSVP module reports the status on the network resource reservation to its associated ECTP daemon via RAPI. Such status will inform whether the reservation has been done successfully or ended in an error condition. An example set of RSVP status codes is as follows:

– Status code 0: PATH events are indicated (used by the receiving RSVP).

– Status code 1: PATH error events are indicated (used by the sending RSVP).

– Status code 2: RESV events are indicated (used by the sending RSVP).

– Status code 3: RESV error events are indicated (used by the receiving RSVP).

– Status code 4: RESV_CONFIRM events are indicated (used by the receiving RSVP).
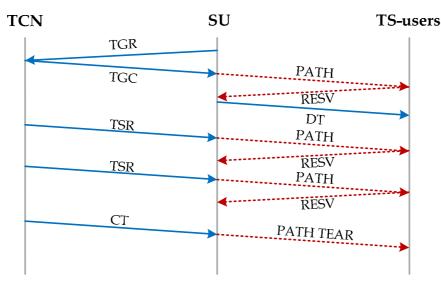
The ECTP protocol core can obtain these status codes by using the RSVP asynchronous upcall functions from the RSVP daemon.

The procedures performed by ECTP and RSVP modules for interworking between them can be summarized as follows:

a) The ECTP sender receives a TGC packet from the TCN in response to a TGR packet to get a token before sending data.

b) The ECTP sender invokes its associated RSVP daemon.

c) The RSVP sender constructs a PATH message that contains TSPEC parameters based on the ECTP QoS parameters, which can be obtained from CR or TSR packets received by the ECTP sender.

d) The RSVP sender transmits the PATH messages downstream along the multicast data path periodically.

e) If an RSVP PATH error is indicated, the RSVP sender reports the corresponding status code to the ECTP sender.

f) As soon as an ECTP receiver receives a CR packet or a JC packet, it invokes its associated RSVP receiver daemon.

g) Based on the PATH message received from the sender, the RSVP receiver constructs the corresponding RESV messages, including RSPEC parameters. Part of the information for RSPEC such as R (bandwidth) and S (slack term) may be configured by interaction between the RSVP receiver and the ECTP receiver.

h) The RSVP receiver transmits the corresponding RESV message upstream towards the sender.

i) When an RSVP RESV error is indicated, the RSVP receiver reports the corresponding status code to the ECTP receiver.

When an ECTP module receives a status code from its associated RSVP module, it may indicate the information to its application. The detailed use of status codes depends on the implementation.

Figure A.2 illustrates the ECTP and RSVP message flows among the TCN, SUs and TS-users. After receiving a TGC packet, the ECTP sender can invoke an initial RSVP PATH message. When the corresponding RSVP RESV message arrives from the ECTP receivers, the ECTP sender can start sending data (in order to mitigate synchronization problems, it is recommended that SUs start sending data after receiving one or more RESV messages from receivers). The subsequent RSVP PATH messages will be triggered and repeated along with the periodic ECTP TSR packets.

Figure A.2 – Interworking model between ECTP and RSVP

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