International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Q.3316

(02/2016)

SERIES Q: SWITCHING AND SIGNALLING

Signalling requirements and protocols for the NGN – Resource control protocols

Interface and signalling requirements and specification for cross stratum optimization

Recommendation ITU-T Q.3316

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Recommendation ITU-T Q.3316

Interface and signalling requirements and specification for cross stratum optimization

Summary

The cross stratum optimization (CSO) function is introduced to support carrier services for instance cloud services efficiently. The CSO function is aware of resource usage across the service stratum and transport stratum and is therefore able to optimize control and management of resource usage. Recommendation ITU-T Q.3316 defines interface and signalling aspects to fulfil this function.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Q.3316	2016-02-13	11	11.1002/1000/12699

Keywords

Cross stratum optimization, CSO, resource control and management function, virtual network for carriers, VNC, vRCMF.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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

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Interface and signalling requirements and specification for cross stratum optimization

1 Scope

This Recommendation defines the interface and signalling requirements and specification for cross stratum optimization (CSO) based on the resource control and management architecture defined in [ITU-T Y.3014].

2 References

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

[ITU-T Q.3302.1] Recommendation ITU-T Q.3302.1 (2010), *Resource control protocol No. 2 (rcp2) – Protocol at the Rp interface between transport resource control physical entities.*

[ITU-T T.50] Recommendation ITU-T T.50 (1992), *International Reference Alphabet (IRA) (Formerly International Alphabet No. 5 or IA5) – Information technology – 7-bit coded character set for information interchange.*

[ITU-T Y.3014] Recommendation ITU-T Y.3014 (2016), *Resource control and management function for virtual networks for carriers (vRCMF).*

[IEEE 754] IEEE 754 (2008), *Standard for Binary Floating-Point Arithmetic.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 carrier [ITU-T Y.3014].

3.1.2 customer [ITU-T Y.3014].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ACCT protocol connection establishment Accept

ASON Automatically Switched Optical Network

CLOSE protocol connection establishment Close

CRPFE Customer Request Processing Functional Element

CSO Cross Stratum Optimization

DNS Domain Name System

EN Event Notification

FE	Functional Entity
HMAC	Hash-based Message Authentication Code
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
KA	Keep-Alive
MIB	Management Information Base
OAM	Operation, Administration, and Maintenance
OPEN	protocol connection establishment Open
OTN	Optical Transport Network
PMFE	Profile Mapping Functional Element
QoS	Quality of Service
QREP	Query Reply
RA	Resource Acceptance
RCIP	Resource Connection Initiation Protocol
REJ	resource Rejection
RLP	Resource reLease Response
RLR	Resource reLease Request
RQ	Resource Query
RR	Resource Request
RSVP-TE	Resource reservation Protocol – Traffic Engineering
SRCM-FE	Service Resource Control and Management – Functional Entity
SRCM GFE	Service Resource Control and Management Gateway Functional Element
SRCM-PE	Service Resource Control and Management – Physical Entity
TCP	Transmission Control Protocol
TRCM-FE	Transport Resource Control and Management Functional Entity
TRCM GFE	Transport Resource Control and Management Gateway Functional Element
TRCM-PE	Transport Resource Control and Management Physical Entity
TRC-PE	Transport Resource Control – Physical Entity
TRMFE	Transport Resource Management Functional Element
TROFE	Transport Resource Optimization Functional Element
TRPFE	Transport Resource Provisioning Functional Element
TRRFE	Transport Resource Repository Functional Element
VM	Virtual Machine
VNC	Virtual Network for Carriers
vRCMF	Resource Control and Management Function for virtual networks for carriers
VRMFE	Virtual Resource Management Functional Element
VROFE	Virtual Resource Optimization Functional Element

VRPFE Virtual Resource Provisioning Functional Element

VTRFE Virtual Topology Repository Functional Element

5 Conventions

None.

6 Interface requirements for cross stratum optimization

A cross stratum optimization (CSO) function follows the resource control and management architecture shown in Figure 6-1 as defined in [ITU-T Y.3014] to support a virtual network for carriers (VNC).

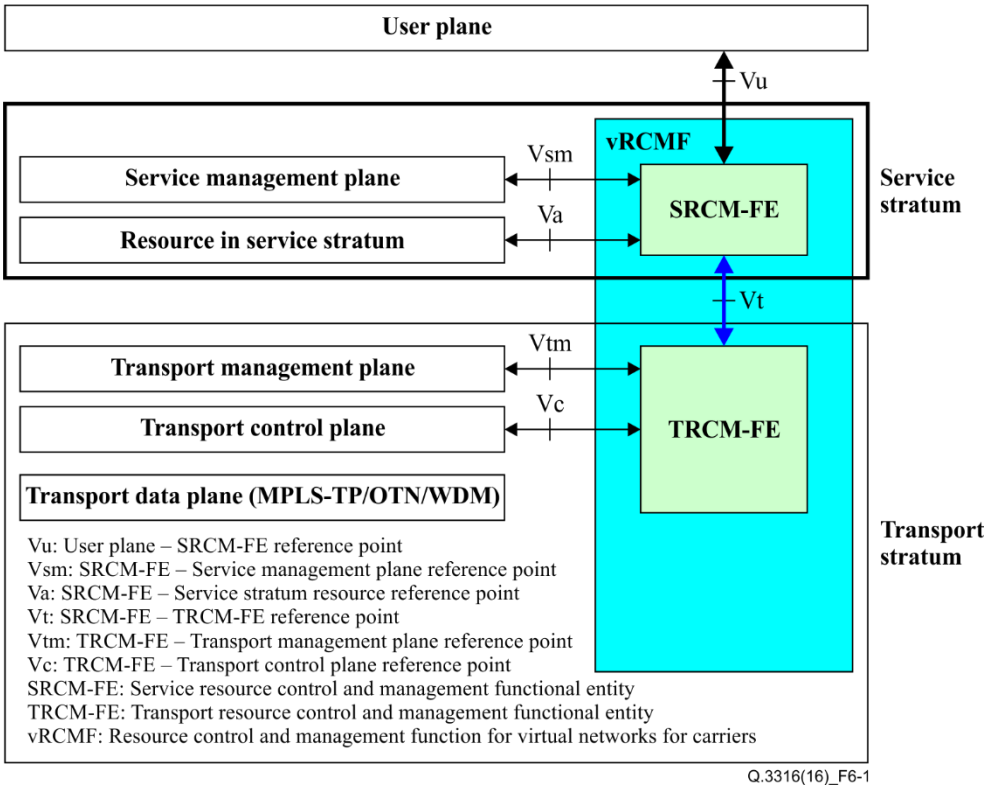

Figure 6-1 – Resource control and management high-level architecture for VNC

To accomplish the CSO function, the service resource control and management – functional entity (SRCM-FE) in the service stratum communicates with transport resource control and management – functional entity (TRCM-FE) in the transport stratum via Vt.

6.1 Vt reference model

In order to describe the signalling requirements of Vt, service resource control and management – physical entity (SRCM-PE) and transport resource control and management – physical entity (TRCM-PE) are used. Figure 6-2 shows the reference model for CSO signalling between SRCM-PE and TRCM-PE via Vt.

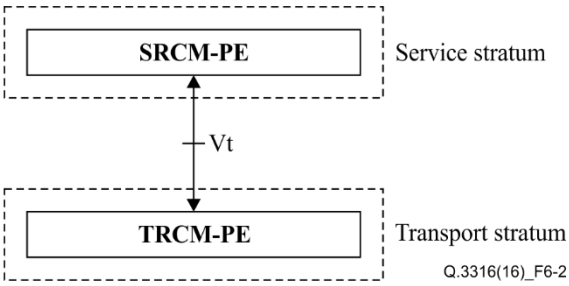

Figure 6-2 – Vt signalling reference model

The interface Vt allows resource queries from/to the service stratum to/from the transport stratum. It also allows reservation requests from the service stratum to the transport stratum for certain mission-critical applications that demand guaranteed bandwidth reservation with a minimal latency. In addition, Vt can be used to exchange status data for monitoring, control, and management purposes across the strata.

6.2 Functional elements and capabilities

6.2.1 SRCM-PE

SRCM-PE is able to receive and process user request to initiate the CSO function. The cross stratum optimization is performed based on the collected status of virtual resources (e.g., servers, storage) in the service stratum and the transport resource information received from TRCM-PE. Figure 6-3 shows the SRCM-PE functionality. The SRCM-PE functionality and its relationship with other neighbour functional entities are defined in clause 8.1 of [ITU-T Y.3014].

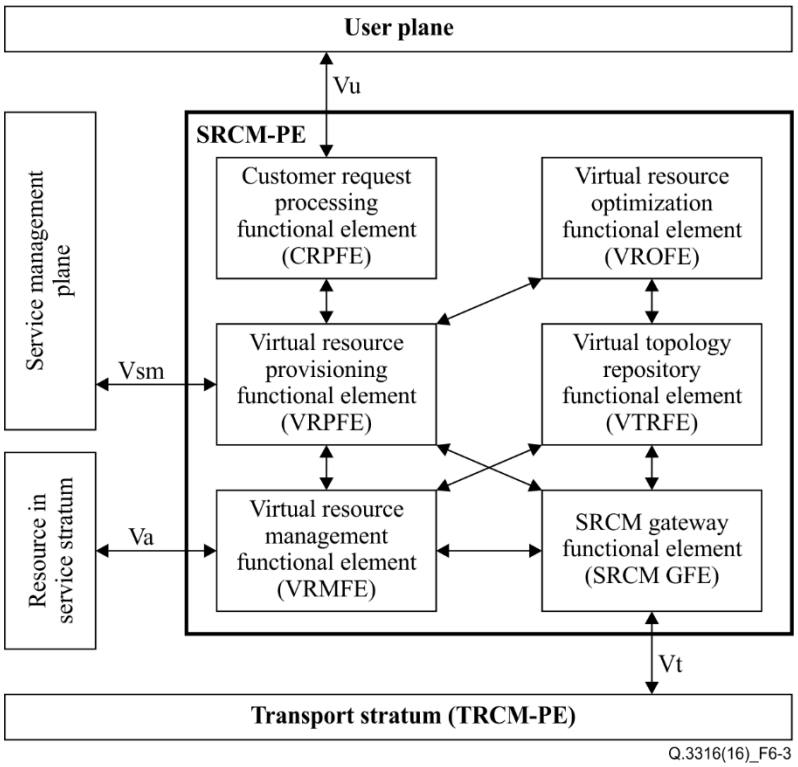

Figure 6-3 – SRCM-PE functionality

6.2.2 TRCM-PE

TRCM-PE receives a service profile/request from SRCM-PE and initiates provisioning of the transport resources (e.g., network elements and related capabilities) to meet the service requirements.

TRCM-PE is also able to provide abstract and virtualized information about the transport stratum to SRCM-PE. Figure 6-4 shows the TRCM-PE functionality. The TRCM-PE functionality and its relationship with other neighbour functional entities are defined in clause 8.1 of [ITU-T Y.3014].

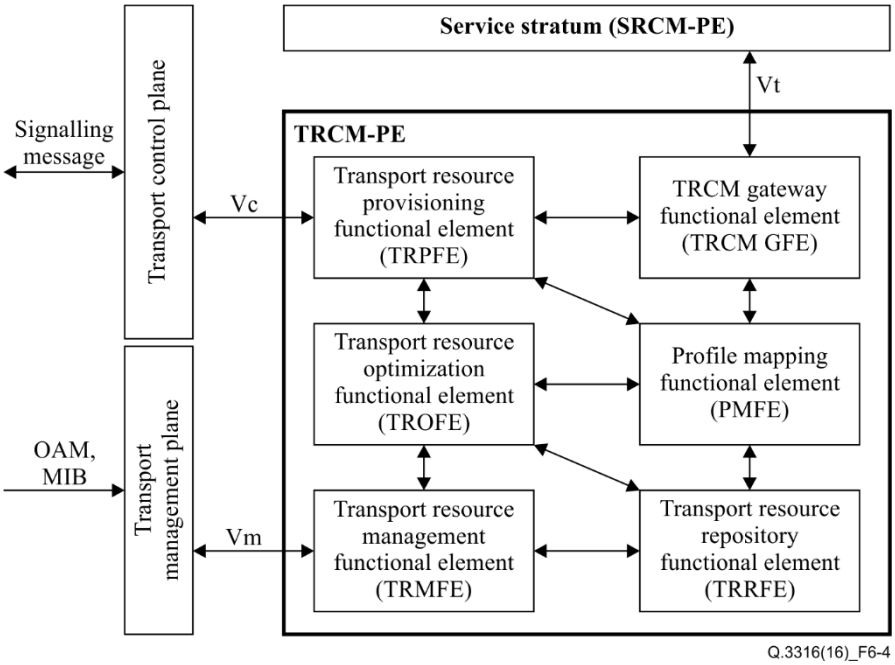

Figure 6-4 – TRCM-PE functionality

7 Signalling requirements for CSO

7.1 Query from SRCM-PE to TRCM-PE

SRCM-PE sends a query message to TRCM-PE to get the status of the resources in the transport stratum, with which SRCM-PE is able to do cross stratum optimization calculation. There is no actual resource reservation and allocation at this stage.

SRCM-PE sends a request message to TRCM-PE to set up a new path or modify an existing path in the transport stratum, with which resource reservation and allocation is required. All the requirements, together with the constraints for path reservation, such as bandwidth, latency and scheduling features, need to be specified in the request message.

7.2 Response from TRCM-PE to SRCM-PE

TRCM-PE sends a response message to the query message from SRCM-PE to feed back the status of the resources in the transport stratum.

TRCM-PE sends a response message to the request message from SRCM-PE to indicate if the request is committed successfully or not.

7.3 Network event and status notification to SRCM-PE

The resources, events and status of the network are reported from TRCM-PE to SRCM-PE, e.g., resource outage or connection failure.

When an alternative solution is found to satisfy a scheduled transport service after the resource reservation, but before the service initiation, TRCM-PE sends an event notification message to SRCM-PE to provide the alternative solution while reserving the resources for it. The choice between the alternative and previous solutions for re-optimization purposes will be determined by SRCM-PE.

After receiving the event notification message, SRCM-PE sends a message to TRCM-PE containing the selection of the chosen solution. This message applies only for scheduled transport services.

8 Procedures

8.1 Resource query

In order to support optimization across the service stratum and the transport stratum, the former needs to be aware of the abstracted resource information of the underlying transport network. The resource query mechanism can be used to collect such information.

– The service resource control and management gateway functional element (SRCM GFE) sends a transport resource query message to the transport resource control and management gateway functional element (TRCM GFE) in TRCM-PE. The message may contain a set of application source/destination locations through which the application can access to the transport network. The resource query message may also include other service constraints such as bandwidth, maximum latency and maximum jitter. Specifically, SRCM GFE can also query the scheduling related parameters, such as a specific time interval.

– The TRCM GFE performs the authentication and admission control on the message and then forwards it to the profile mapping functional element (PMFE).

– The PMFE maps: the set of application source/destination locations into addresses of network source/destination locations; the set of application time intervals into the network scheduled information; and the service constraints into technology-dependent network constraints. The mapping result is forwarded to the transport resource optimization functional element (TROFE).

– The TROFE estimates, on the basis of each pair of network source/destination locations:

  • whether there are enough transport resources to create a potential path that satisfies the constraints;

  • whether there is an appropriate time interval to support the creation of a potential path that satisfies the scheduling constraints;

  • the performance of a potential path, e.g., latency, jitter and load rate along the path.

– The estimation result, i.e., the set of potential paths with related information, is forwarded to the PMFE. Note that the detailed route of each path may be hidden for various reasons, e.g., a security policy restriction placed at the transport network or scalability considerations.

– The PMFE generates a query response message carrying the estimation result and forwards it to the TRCM GFE.

– The TRCM GFE sends the query response message to the SRCM GFE. Therefore, the SRCM-PE can store the estimation result in the virtual topology repository functional element (VTRFE) for the purpose of joint optimization.

8.2 Transport resource reservation

The service stratum can request resource reservation from the transport stratum for carrier services (e.g., cloud service). Such a procedure may be triggered by different application events, e.g., bulk virtual machine (VM) migration and backup or restore of storage:

– The virtual resource optimization functional element (VROFE) makes a joint optimization calculation based on the estimation result received from the TRCM-PE by the SRCM GFE and stored in the VTRFE and the virtual resource status managed by the virtual resource management functional element (VRMFE), and determines the optimal way to fulfil the application task. For example, to perform VM migration or data backup from a source cloud server, the VROFE may choose the optimal destination cloud server that has sufficient virtual

and transport resources between the source and the destination cloud servers that can satisfy the quality of service (QoS) requirements.

– The VROFE sends the optimization calculation result to the virtual resource provisioning functional element (VRPFE) to provision the virtual resources and to send the service profile to the SRCM GFE, which indicates the characteristics of the application from a network perspective and the QoS requirements that the application will require from the network.

– The SRCM GFE sends resource request (RR) message carrying the service profile to the TRCM-PE via the Vt interface.

– The TRCM GFE performs the authentication and admission control on the message and then forwards it to the PMFE.

– The PMFE maps the service profile into technology-dependent network resource requirements. The output of mapping, which may include the following information, will be forwarded to the TROFE:

  • addresses of network location;

  • technology-dependent bandwidth;

  • connection type (e.g., unidirectional or bidirectional point to point or point to multi-point);

  • scheduling feature constraint (e.g., the planned starting time or end time);

  • physical path constraint (e.g., maximum hops, latency or jitter);

  • recovery type (e.g., 1 + 1, 1:1 or reroute required).

– The TROFE performs an optimal path computation based on the transport resources received from the transport resource management functional element (TRMFE) and sends the path computation result to the transport resource provisioning functional element (TRPFE).

– For unscheduled transport services, the TRPFE triggers the control plane via the Vc interface to start the signalling for connection setup in the transport plane immediately after the previous step is completed. For example, if automatically switched optical network (ASON) technology is used in the control plane, resource reservation protocol - traffic engineering (RSVP-TE) messages can be used by the TRPFE on the Vc interface. For scheduled transport services, the TRPFE will not trigger connection setup until the required time interval starts. Before the service starts, re-optimization may be possible and its corresponding mechanism is described in clause 8.4.

– The control plane responds to the TRPFE with the result of the connection setup. If the connection setup is successful, the TRCM-PE updates the status of the transport resource in the transport resource repository functional element (TRRFE).

– The TRPFE returns the connection setup result to the PMFE.

– The PMFE generates the resource response message carrying the connection setup result and forwards it to the TRCM GFE.

– The TRCM GFE responds with the resource reservation result to the SRCM-PE via the Vt interface.

8.3 Recovery

Carrier services may suffer from network level failures (e.g., link failure or resource outage) or service level failures (e.g., server failure or storage failure). In such cases, recovery procedures are needed in both the network stratum and the service stratum.

In the case of a network level failure that interrupts the network connection of a carrier service:

– The transport control plane and transport data plane will start the network connection recovery procedure if the recovery type has been configured. Such network recovery types include 1+1 or 1:1 protection and pre-planned rerouting restoration.

– Upon successful recovery, the transport control plane will report the network recovery success event to the TRCM-PE via the Vc interface. Therefore, the TRCM-PE can update the service information, including the current network recovery status and the current working path associated with the cloud service.

– If no recovery mechanisms are pre-configured for the network connection, or if the transport control plane and transport data plane recoveries fail (e.g., a pre-configured protection path is unavailable), the transport control plane will report the network recovery fail event to the TRCM-PE via the Vc interface.

– Notified by the network recovery fail event, the TRPFE, according to the recovery policy of the cloud service, may decide to start dynamic rerouting for the failed connection, for example, it may request the TROFE to compute a new path for the service. Once the path computation is completed, the TRPFE can then trigger the transport control plane to create a new connection and switch the service to the new connection.

– If dynamic rerouting fails (e.g., due to lack of resources) or if dynamic rerouting procedure is not supported, the TRPFE will notify the PMFE.

– PMFE then maps the technology-dependent network connection fail event into a technology-independent service event (e.g., service failure and service degradation), and sends this service event to the SRCM-PE via the TRCM GFE and Vt interface.

– On receipt of service event via the Vt interface and SRCM GFE, the VRMFE can select, for example, an alternative cloud server in a remote location to continue the cloud service. Joint optimization will be performed again to choose the optimal destination cloud server, and transport resources towards the new destination will be reserved, as described in clause 8.2.

In the case of a service level failure, the SRCM-PE will try to find alternative servers in the same host location. If alternative servers are available only in remote locations, then the SRCM-PE will perform the joint optimization calculation to choose the optimal destination cloud server, and transport resources towards the new destination will be reserved, as described in clause 8.2.

8.4 Scheduled service event notification

When a request for a scheduled service is accepted by the TRCM-PE, the TRPFE will not trigger a connection setup process until its scheduled starting time. During the time of service acceptance and service activation, events, such as resource optimization and resource release, may occur that will impact the resource availability for this scheduled service and thus require an event notification sent by the TRCM-PE to the SRCM-PE. Note that this feature is only applicable for scheduled services. Procedures for scheduled service event notification are described as follows.

– SRCM-PE schedules a service at time t1 by sending a request message to the TRCM-PE. This request carries the service holding interval parameter, for example [t2, t3], where t2 is the starting time of the service and t3 is the finishing time of the service. Once receiving the request, the TRCM-PE will check the availability of the transport resources to find a path that satisfies the requirement and then sends a reply message while reserving the corresponding resources on the path immediately. Before the previously mentioned scheduled service starts (but for which resources have already been reserved), another eligible path may be detected by the TRMFE which could also satisfy that scheduled service. The PMFE may find that it is a better path to carry the scheduled service and thus decide to report this new path (referred later as the alternative path) to the SRCM-PE, as described in the following steps.

– The PMFE reserves the scheduled resource upon detection by the TRMFE for this scheduled service, and sends the alternative path information to the TRCM GFE.
– The TRCM GFE forwards the alternative path information to the SRCM-PE via the Vt interface.
– The SRCM GFE receives the message from the TRCM GFE, and determines to select either the original path calculated at time t1 or the newly reported alternative path. After the selection is completed, a message with the selection result is sent in a reply to the TRCM-PE to avoid unnecessary resource reservation by releasing the unselected path.
– The TRCM GFE is notified by the SRCM GFE that one of the selections is accepted by the SRCM-PE. It then performs the authentication and admission control on the message and then forwards it to the PMFE.
– The PMFE will carry out the corresponding resource release. The TRRFE will start waiting until the scheduled starting time t2 or another scheduled service event notification occurs in [t1, t2].
– The scheduled service resource re-optimization may repeat until t2 arrives.
– When the starting time t2 arrives, the scheduled service should be carried on the latest selected path by the latest event notification or on the original path reserved at time t1, if there is no event notification during time interval [t1, t2].

It is worth noting that there might be multiple event notifications for a certain scheduled service. The scheduled service event notification may occur repeatedly until the scheduled service starts. In such cases, the procedures described above apply.

9 Message specification

The resource connection initiation protocol (RCIP) is defined in [ITU-T Q.3302.1] to enable resource control communication between two transport resource control – physical entities (TRC-PEs). This protocol is exploited and extended in this Recommendation to allow resource control across the service stratum and transport stratum at the Vt interface.

9.1 Message specification

This Recommendation re-uses the messages identified in Table 9-1, which are defined in [ITU-T Q.3302.1], and defines new messages to support the functions defined in this Recommendation. Other messages not listed but defined in [ITU-T Q.3302.1] are ignored by the SRCM-PE and TRCM-PE.

Table 9-1 – The RCIP message set for CSO

Function	Message	Directionality	Op-Code	Reference
Transport channel maintenance	Protocol Connection Establishment Open (OPEN; an RCIP message)	SRCM-PE => TRCM-PE	6	[ITU-T Q.3302.1]
	Protocol connection establishment accept (ACCT; an RCIP message)	TRCM-PE => SRCM-PE	7	[ITU-T Q.3302.1]
	Protocol connection establishment close (CLOSE; an RCIP message)	TRCM-PE <=> SRCM-PE	8	[ITU-T Q.3302.1]

Table 9-1 – The RCIP message set for CSO

Function	Message	Directionality	Op-Code	Reference
	Keep Alive (KA; an RCIP message)	TRCM-PE <=> SRCM-PE	9	[ITU-T Q.3302.1]
Resource control across stratum	Resource request (RR; an RCIP message)	SRCM-PE => TRCM-PE	11	[ITU-T Q.3302.1]
	Resource Acceptance(RA; an RCIP message)	TRCM-PE => SRCM-PE	12	[ITU-T Q.3302.1]
	Resource rejection (REJ; an RCIP message)	TRCM-PE => SRCM-PE	13	[ITU-T Q.3302.1]
	Resource release request (RLR; an RCIP message)	SRCM-PE => TRCM-PE	14	[ITU-T Q.3302.1]
	Resource release response (RLP; an RCIP message)	TRCM-PE => SRCM-PE	15	[ITU-T Q.3302.1]
	Resource query (RQ; an extension of an RCIP message)	SRCM-PE => TRCM-PE	20	This Recommendation.
	Query reply (QREP; an extension of an RCIP message)	TRCM-PE => SRCM-PE	21	This Recommendation
	Event notification (EN; an extension of an RCIP message)	TRCM-PE => SRCM-PE	22	This Recommendation

As defined in [ITU-T Q.3302.1], all the RCIP messages must be transmitted in network-byte order and the basic RCIP message format defined in clause 8.2 of [ITU-T Q.3302.1] is followed in this Recommendation. The message header (shown in Figure 9-1) is included here for information, and for the field definition and value setting specification, clause 8.2 of [ITU-T Q.3302.1] should be referred to.

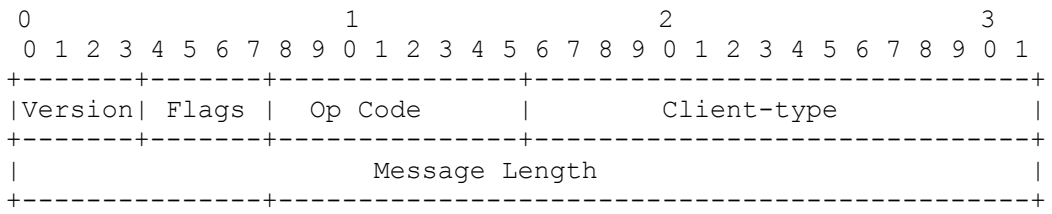

Figure 9-1 – RCIP message header

When applied in this Recommendation, the fields in the RCIP message header are updated as follows:

Version (4 bits): RCIP version number.

Flags (4 bits): Only Flags = 0x4 is used in this Recommendation for scheduled services. This field is set to 0x4 when the Resource Request (RR) message is used to re-select the transport connection (i.e., modify the transport connection) of a previously sent request. Under all other circumstances, including for non-scheduled services, this field is set to 0x0 and is ignored.

Op code (8 bits): Op codes from 16 to 18 are not used in this Recommendation. The following new codes are defined.

19 = reserved

20 = Resource Query (RQ)

21 = Query Reply (QREP)

22 = Event Notification (EN)

Client-type (16 bits): This field is set to 0, and not used in this Recommendation.

Message length (32 bits): The size of a message is in octets, which includes the standard RCIP header and all encapsulated objects. Messages are required to be aligned on 4-octet boundaries.

If the length is not an integral multiple of 4 bytes, filling is needed. The filling bits are all set to "0".

When sending to the network, the version is sent first; when receiving from the network, the version is received first.

9.1.1 Protocol connection establishment open (OPEN)

The OPEN message (Op code set to 6) is sent from the SRCM-PE to the TRCM-PE, in order to set up the RCIP transport channel. The RCIP transport channel is established and maintained between the SRCM-PE and TRCM-PE and reused by all traversing RCIP messages. For further explanation of the transport channel, refer to [ITU-T Q.3302.1].

As defined in [ITU-T Q.3302.1], the message format is as follows:

```
OPEN = <RCIP_HEADER>
       <Identity Identification>
       [Authentication Information]
       [Data Consistency Information]
```

9.1.2 Protocol connection establishment accept (ACCT)

The ACCT message (Op code set to 7) is sent from the TRCM-PE to the SRCM-PE, in response to an OPEN message with the value of Keep-Alive Timer. Upon receiving an ACCT message, the RCIP transport channel is set up.

As defined in [ITU-T Q.3302.1], the message format is as follows:

```
ACCT = <RCIP_HEADER>
       {Keep-Alive Timer}
       [Data Consistency Information]
```

9.1.3 Protocol connection establishment close (CLOSE)

The CLOSE message (Op code set to 8) is sent from the SRCM-PE or TRCM-PE to the other party, in order to close the corresponding RCIP transport channel.

As defined in [ITU-T Q.3302.1], the message format is as follows:

```
CLOSE = <RCIP_HEADER>
        {Reason Code}
        [Data Consistency Information]
```

9.1.4 Keep alive (KA)

The KA message (Op code set to 9) is sent from the SRCM-PE or TRCM-PE to the other party, in order to check data consistency between the SRCM-PE and TRCM-PE.

As defined in [ITU-T Q.3302.1], the message format is as follows:

```
KA = <RCIP_HEADER>
     [Data Consistency Information]
```

9.1.5 Resource request (RR)

The RR message (Op code set to 11) is sent by the SRCM-PE to the TRCM-PE, in order to request the setup of a transport connection/path.

This message is defined in [ITU-T Q.3302.1] with new objects defined in this Recommendation. This message format is as follows:

```
Resource Request = <RCIP_HEADER>
                 1*{Service Profile}
                   [Data Consistency Information]
```

When applied in this Recommendation, the RR message is always unidirectional, i.e., sent from the SRCM-PE to the TRCM-PE. However, this message can request the set up of either a unidirectional or bidirectional transport stratum connection.

9.1.6 Resource acceptance (RA)

The RA message (Op code set to 12) is sent by the TRCM-PE to the SRCM-PE, in response to the RR message.

This message is defined in [ITU-T Q.3302.1] with new objects defined in this Recommendation. The message format is as follows:

```
Resource Acceptance = <RCIP_HEADER>
                    1*{Connection Profile}
                      [Data Consistency Information]
```

9.1.7 Resource rejection (REJ)

The REJ message (Op code set to 13) is sent by the TRCM-PE to the SRCM-PE, in a rejection response to the RR message.

This message is defined in [ITU-T Q.3302.1] with additional objects defined in this Recommendation. The message format is as follows:

```
Resource Rejection = <RCIP_HEADER>
                       1*{Service ID}
                       1*{Reason Code}
                       [Data Consistency Information]
```

Note that the number of the Service ID and Reason Code Objects must be the same.

9.1.8 Resource release request (RLR)

The RLR message (Op code set to 14) is sent by the SRCM-PE to the TRCM-PE, in order to release the resource associated one or more transport connections.

This message is defined in [ITU-T Q.3302.1] with additional objects defined in this Recommendation. The message format is as follows:

```
Resource Release Request = <RCIP_HEADER>
                         1*{Connection ID}
                          1*[Reason Code]
                            [Data Consistency Information]
```

Note that the number of the Connection ID and Reason Code Objects must be the same.

9.1.9 Resource release response (RLP)

The RLP message (Op code set to 15) is sent from the TRCM-PE to the SRCM-PE, in response to the RLR message.

This message is defined in [ITU-T Q.3302.1] with additional objects defined in this Recommendation. The message format is as follows:

```
Resource Release Response = <RCIP_HEADER>
                            1*{Connection ID}
                            1*[Reason Code]
                              [Data Consistency Information]
```

Note that the number of the Connection ID and Reason Code Objects must be the same.

9.1.10 Resource query (RQ)

The RQ message (Op code set to 19) is sent from the SRCM-PE to the TRCM-PE, in order to check the availability of the transport stratum resource.

This message is defined by this Recommendation and its format is defined as follows:

```
Resource Query = <RCIP_HEADER>
                 1*{Service Profile}
               [Data Consistency Information]
```

9.1.11 Query reply (QREP)

The QREP message (Op code set to 20) is sent from the TRCM-PE to the SRCM-PE, in response to the Resource Query message.

This message is defined by this Recommendation and its format is defined as follows:

```
Query Reply = <RCIP_HEADER>
              1*{Connection Profile}
            [Data Consistency Information]
```

9.1.12 Event notification (Notify)

The Notify message (Op code set to 21) is sent from the TRCM-PE to the SRCM-PE, in order to notify the events, such as transport stratum connection failure, so that the SRCM-PE can take appropriate actions to remedy the affected services.

This message is defined by this Recommendation and its format is defined as follows:

```
Query Reply = <RCIP_HEADER>
              1*{EventNotify}
            [Data Consistency Information]
```

9.2 Object specification

Table 9-2 provides the objects defined in [ITU-T Q.3302.1] and re-used by this Recommendation, as well as new ones defined to fulfil the purpose of cross stratum resource control. Other objects not listed are ignored by SRCM-PE and TRCM-PE. The object format and field settings defined in clause 8.4 of [ITU-T Q.3302.1] apply in this Recommendation. The object format is included in Figure 9-2 just for information.

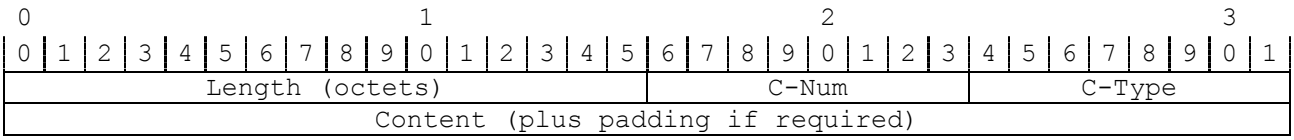

Figure 9-2 – RCIP object format

Length (two octets):

The length describes the number of octets (including the header) that makes up the object. If the length in octets does not fall on a 32-bit word boundary, padding must be added to the end of the object, so that it is aligned to the next 32-bit boundary before the object can be sent on the wire. On

the receiving side, a subsequent object boundary can be found by simply rounding up the previously stated object length to the next 32-bit boundary.

C-Num (8 bits):

C-Num identifies the class of information contained in the object.

C-Type (8 bits):

C-Type identifies the subtype or version of the information contained in the object. C-Type values identify variant structures within a specific class of information represented by a C-Num.

Table 9-2 – The RCIP object set for CSO

Object Name	C-Num	Reference
Connection ID	1	[ITU-T Q.3302.1]
Authentication Information	6	[ITU-T Q.3302.1]
Reason Code	7	[ITU-T Q.3302.1]
Identity Identification	8	[ITU-T Q.3302.1]
Keep-Alive Timer	9	[ITU-T Q.3302.1]
Data Consistency Information	10	[ITU-T Q.3302.1]
Service ID	21	This Recommendation
Service Profile	22	This Recommendation.
Connection Profile	23	This Recommendation
EventNotify	24	This Recommendation
Service Attribute Object	25	This Recommendation
Constraint Object	26	This Recommendation
Connection Attribute Object	27	This Recommendation

Table 9-3 lists the objects found in each message. The clause numbers describing the messages and objects are shown in parentheses after the names. The final column indicates whether these objects are mandatory (M) or optional (O) in the given message, and adds the further qualifier "m" if multiple instances of the object are allowed. Table 9-3 is based on Table 8-1 of [ITU-T Q.3302.1] for use in this Recommendation.

Table 9-3 – Objects in each message type

Message Type	Objects	Mandatory/optional
OPEN (9.1.1)	Identity Identification (9.2.4) Authentication Information (9.2.2) Data Consistency Information (9.2.6)	M O O
ACCT (9.1.2)	Keep-Alive Timer (9.2.5) Data Consistency Information (9.2.6)	M O
CLOSE (9.1.3)	Reason Code (9.2.3) Data Consistency Information (9.2.6)	M O
KA (9.1.3)	Data Consistency Information (9.2.6)	O
RR (9.1.4)	Service Profile (9.2.8) Data Consistency Information (9.2.6)	Mm O
RA (9.1.5)	Connection Profile (9.2.9)	M

Table 9-3 – Objects in each message type

Message Type	Objects	Mandatory/optional
	Data Consistency Information (9.2.6)	O
REJ (9.1.6)	Service ID (9.2.7) Reason Code (9.2.3) Data Consistency Information (9.2.6)	Mm Mm O
RLR (9.1.7)	Connection ID (9.2.1) Reason Code (9.2.3) Data Consistency Information (9.2.6)	Mm Om O
RLP (9.1.8)	Connection ID (9.2.1) Reason Code (9.2.3) Data Consistency Information (9.2.6)	Mm Om O
RQ (9.1.10)	Service Profile (9.2.8) Data Consistency Information (9.2.6)	Mm O
QREP (9.1.11)	Connection Profile (9.2.9) Data Consistency Information (9.2.6)	Mm O
Notify (9.1.12)	EventNotify (9.2.10) Data Consistency Information (9.2.6)	Mm O
m: multiple		

9.2.1 Connection ID

In this Recommendation, the Connection ID Object is used to identify a transport connection or path. A unique value for Connection ID is set by the TRCM-PE.

When a TRCM-PE sees an RCIP message containing such an object, it can find the corresponding Connection ID internally, and performs the process corresponding to the resource associated with this particular Connection ID.

Two new C-Types are defined and used by this Recommendation.

9.2.1.1 IPv4 Transport Connection ID

See Figure 9-3.

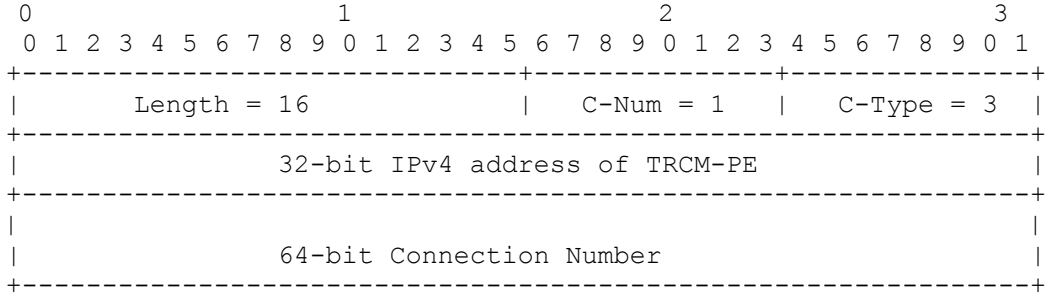

Figure 9-3 – IPv4 Transport Connection ID Object content

C-Num = 1

C-Type = 3, IPv4 transport connection ID.

The connection ID consists of two parts. One part is the 32-bit TRCM-PE identification (ordinarily the IPv4 address), the other part is the 64-bit connection number, allocated by the TRCM-PE.

The value 0x0 for 64-bit Connection Number is reserved. It denotes a null connection ID without corresponding resource allocation if used in RCIP. If this value is included in the QREP message sent by the TRCM-PE to the SRCM-PE, it should be interpreted as no transport resource available for a particular service. If this value is included in the RR message sent by the SRCM-PE to the TRCM-PE, it should be interpreted as the SRCM-PE expecting the TRCM-PE to choose a valid transport connection for this request.

9.2.1.2 IPv6 Transport Connection ID

See Figure 9-4.

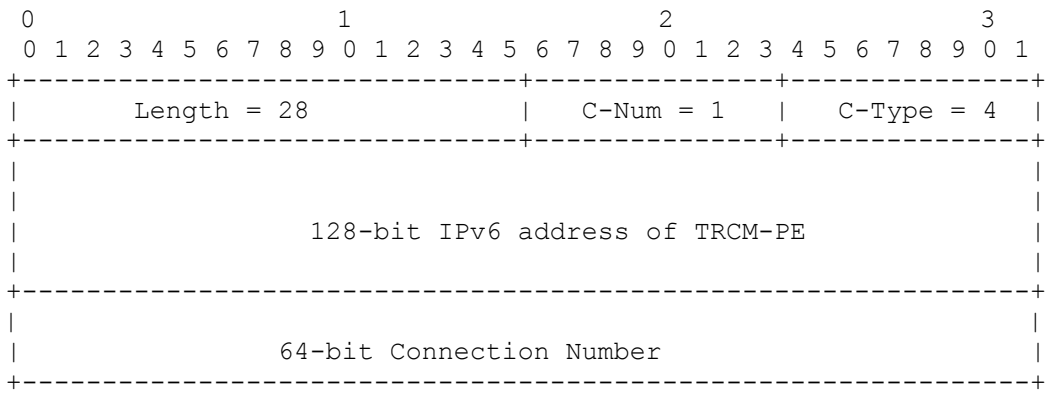

Figure 9-4 – IPv6 Transport Connection ID Object content

C-Num = 1

C-Type = 4, IPv6 transport connection ID.

The connection ID consists of two parts. One part is the 128-bit TRCM-PE identification (ordinarily the IPv6 address); the other part is the 64-bit connection number, allocated by TRCM-PE for the resource request.

The value 0x0 for the 64-bit Connection Number is reserved. It denotes a null connection ID without corresponding resource allocation if used in RCIP. If this value is included in the QREP message sent by the TRCM-PE to the SRCM-PE, it should be interpreted as no transport resource available for a particular service. If this value is included in the RR message sent by the SRCM-PE to the TRCM-PE, it should be interpreted as the SRCM-PE expecting the TRCM-PE to choose a valid transport connection for this request.

9.2.2 Authentication Information

The purpose of this object is to authenticate the peers (i.e., TRCM-PE and SRCM-PE).

The object format is defined in Figure 9-5 (see [ITU-T Q.3302.1]).

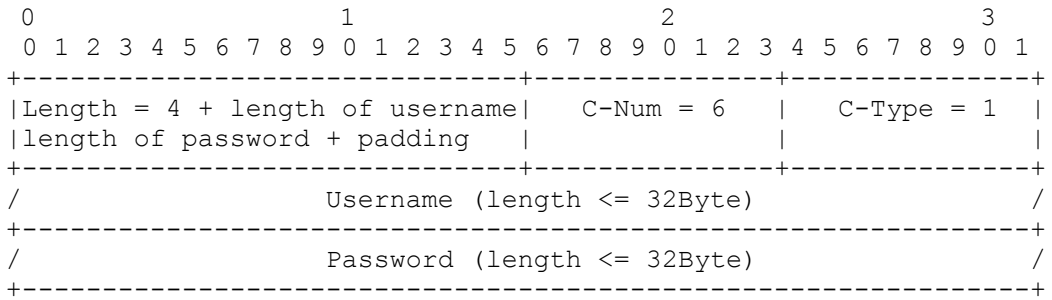

Figure 9-5 – Authentication Information Object content

C-Num = 6

C-Type = 1, Authentication Information.

Username and password should be carried in the OPEN message, for authentication of peers.

9.2.3 Reason Code

The purpose of this object is to specify the reason associated with a particular connection ID or service ID. It appears in the Protocol Connection Establishment Close (CLOSE), Resource Rejection (REJ), Resource Release Request (RLR) and Resource Release Response (PLP) messages.

The object format is defined in Figure 9-6 (see [ITU-T Q.3302.1]).

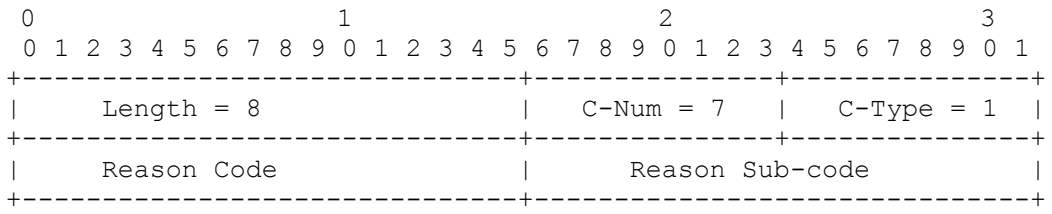

Figure 9-6 – Reason Code Object content

C-Num = 7, C-Type = 1

Reason codes, which are re-used in this Recommendation, are:

0 = Operating normally

2 = Connection interrupted

3 = Insufficient Resources

5 = Path unavailable

6 = Timeout

7 = Illegal operation

8 = Unknown object

9 = Upgrade needed

10 = Authentication failed

12 = Transmission control protocol (TCP) connection interrupted

13 = Abnormal interruption

14 = Message error

15 = Loop request

The reason sub-code field is reserved for more detailed client-specific reason codes.

Note that value 3 denotes insufficient transport resources in this Recommendation.

9.2.4 Identity Identification

Identity Identification adopts only International Reference Alphabet string format [ITU-T T.50]. In a general way, this is the static IP address of the SRCM-PE/TRCM-PE. When the SRCM-PE/TRCM-PE adopts dynamic IP address, the Identity Identification Object can use the domain name system (DNS) domain name. It is used in an OPEN message. The SRCM-PE/TRCM-PE should do a validity check including domain name, identifier and address.

The object format is defined in Figure 9-7 (see [ITU-T Q.3302.1]).

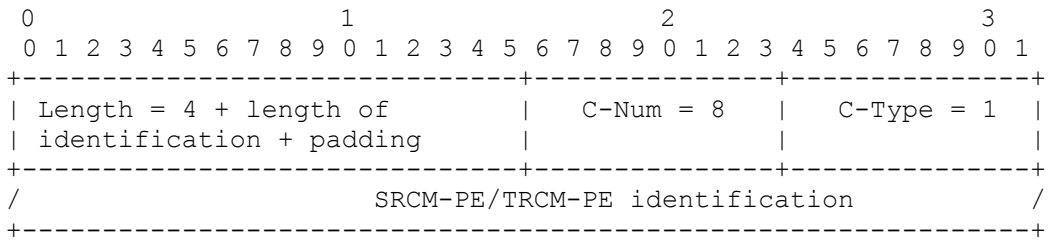

Figure 9-7 – Identity Identification Object content

C-Num = 8, C-Type = 1

This object when used by SRCM-PE, the identification should be its IP address. Similarly, when this object is used by TRCM-PE, the identification field should be set to the IP address of itself.

9.2.5 Keep-Alive Timer

This object is used to specify the recommended maximum time interval over which an RCIP transport channel message is sent or received. The unit is seconds. It is used in an ACCT message. Times are encoded as 2-octet integer values. The timer value is treated as a delta. The entity, upon receiving this object, compares the KA timer value that the ACCT message carries with the local KA timer value and selects the smaller value as the KA timer value. If the entity does not accept the KA timer value, the CLOSE message is sent to disconnect. The range of finite timeouts is 1 to 65535 s represented as an unsigned 2-octet integer.

The KA timer is used only on the RCIP transport channel, i.e., between the SRCM-PE and TRCM-PE.

Range of KA timer values: 0-65535

Default: 45 s

A value of 0 implies infinity, that means the SRCM-PE/TRCM-PE does not check the KA message, and does not send any KA message.

A KA message is sent per 1/3 KA timer.

This object format is defined in Figure 9-8 (see [ITU-T Q.3302.1]).

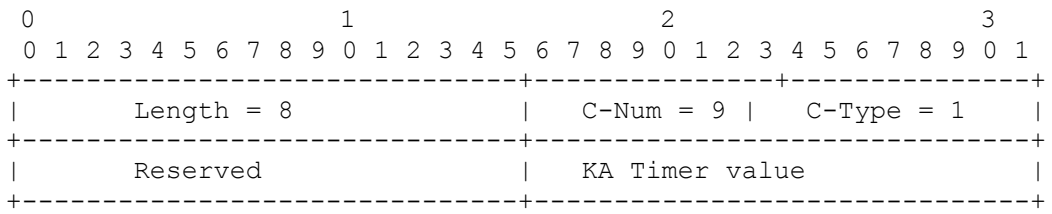

Figure 9-8 – Keep-Alive Timer Object content

C-Num =9,

C-Type = 1, Keep-alive timer value

9.2.6 Data Consistency Information

The purpose of this object is to verify the consistency of the RCIP message.

In order to ensure message integrity, the SRCM-PE/TRCM-PE adopt hash-based message authentication code (HMAC) technology [b-IETF RFC 2104] and compute the message digests to be appended at the end of an RCIP message, using the shared key and cryptographic algorithm to verify the consistency.

The data consistency message includes a 32-bit Key ID, a 32-bit sequence number and a 96-bit message digest. A 32-bit Key ID is used to identify a specific key shared between the SRCM-PE and TRCM-PE, and the cryptographic algorithm to be used.

The sequence number is initiated during an initial OPEN message and is then incremented by one each time a new message is sent over the TCP connection in the same direction. If the sequence number reaches the value of 0xFFFFFFFF, the next increment will simply roll over to a value of zero to avoid the replay attack.

This object format is defined in Figure 9-9 (see [ITU-T Q.3302.1]).

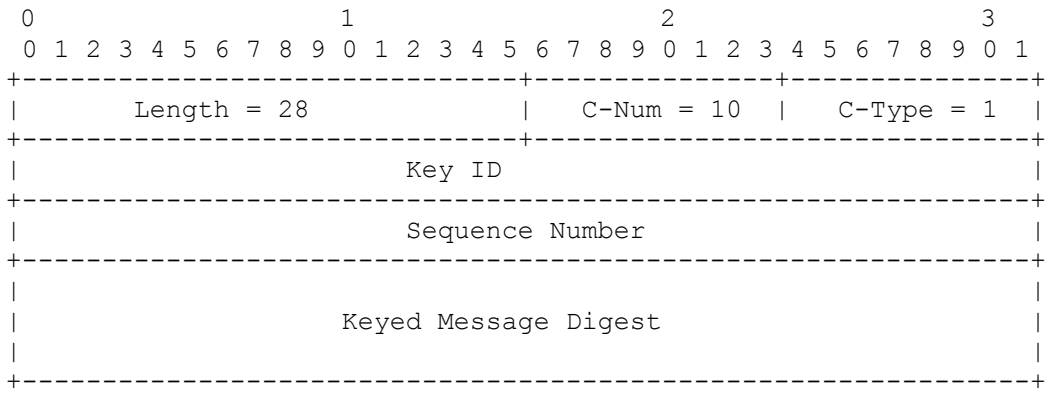

Figure 9-9 – Data Consistency Object content

C-Num = 10,

C-Type = 1, HMAC digest

9.2.7 Service ID

This object is used to identify a service and a unique value should be set for each service by SRCM-PE.

9.2.7.1 IPv4 Service ID

See Figure 9-10.

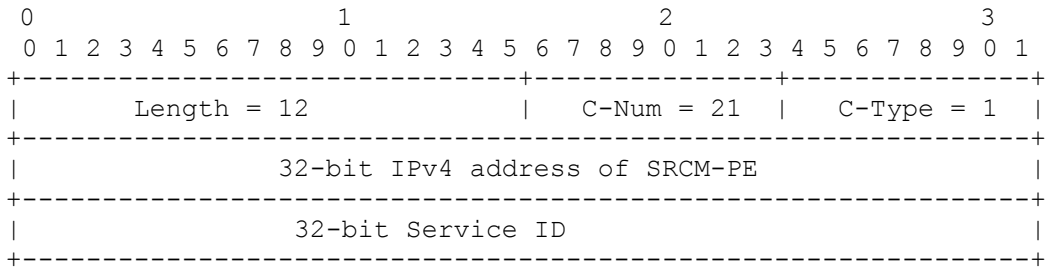

Figure 9-10 – IPv4 Service ID Object content

C-Num = 21

C-Type = 1, IPv4 Service ID.

The Service ID consists of two parts. One part is the 32-bit SRCM-PE identification (ordinarily the IPv4 address), the other part is the 32-bit service ID, allocated by SRCM-PE. The value 0x0 is reserved and it denotes a null service ID, which is not a valid service ID assigned by the SRCM-PE but a value used by the TRCM-PE to denote that no service is associated with a transport connection.

9.2.7.2 IPv6 Service ID

See Figure 9-11.

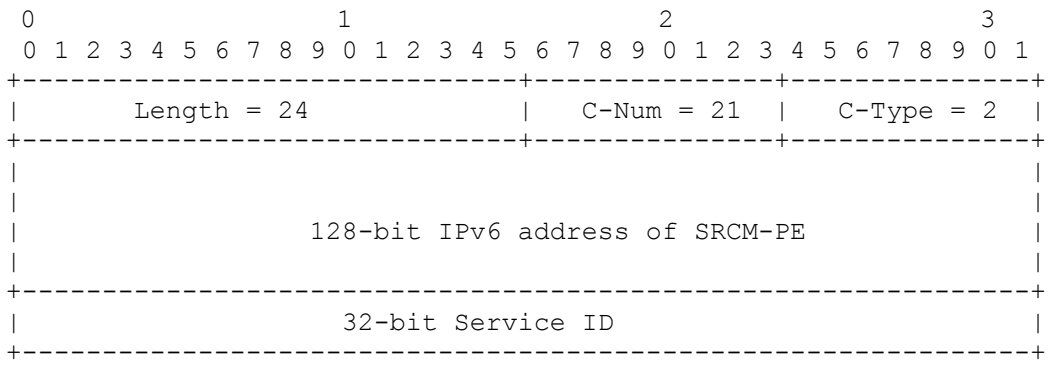

Figure 9-11 – IPv6 Service ID Object content

C-Num = 21

C-Type = 2, IPv6 Service ID.

The Service ID consists of two parts. One part is the 128-bit SRCM-PE identification (ordinarily the IPv6 address), the other part is the 32-bit service ID, allocated by the TRCM-PE. The value 0x0 is reserved and it denotes a null service ID, which is not a valid service ID assigned by the SRCM-PE but a value used by the TRCM-PE to denote that no service is associated with a transport connection.

9.2.8 Service Profile

The purpose of this object is to describe a service profile generated by the SRCM-PE for a service request. It can appear one or more times in the RR and RQ messages. See Figure 9-12.

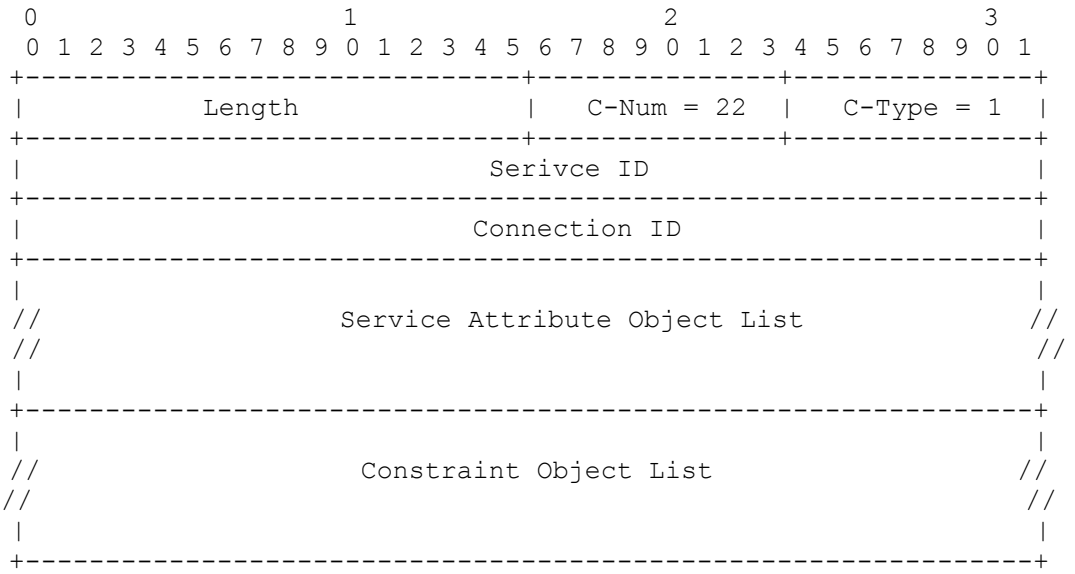

Figure 9-12 – Service Profile Object content

C-Num = 22

C-Type = 1, Service Profile

The content includes the Service ID, Connection ID, a list of Service Attribute objects and a list of Constraint Objects. The Service Attribute Object and Constraint Object are defined in clauses 9.2.8.1

and 9.2.8.2, respectively. The connection ID is used to denote the connection resource with which a service is associated if this information is known before this object is sent. Otherwise, this field is set to 0x0, to denote that no transport resource is assigned/chosen for this service request.

The length of this object is 12 + the length of (Service Attribute Object list) + the length of (Constraint Object list).

9.2.8.1 Service Attribute Object

The purpose of this object is to describe the attributes associated with the service profile. It is a sub-object of the Service Profile Object and it can appear one or more times (with distinctive C-Type values) in the Service Profile Object.

Currently, the following C-Types are defined and they are described in detail in clauses 9.2.8.1.1 to 9.2.8.1.3:

C-Type = 1: IPv4 Service Node Pair Attribute

C-Type = 2: IPv6 Service Node Pair Attribute

C-Type = 3: Service Holding Time

Others: unassigned

For a Service Profile Object, either an IPv4 or IPv6 Service Node Pair Attribute must be present. C-Type 3 is only used for scheduled services and it can appear one or multiple times within the Service Profile Object.

9.2.8.1.1 IPv4 Service Node Pair Attribute

See Figure 9-13.

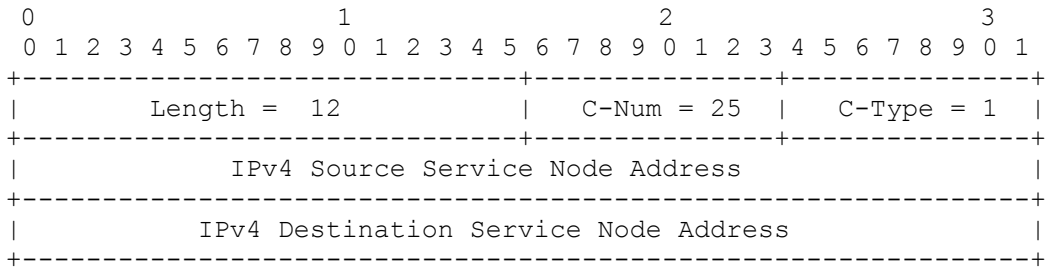

Figure 9-13 – IPv4 Service Node Pair Attribute content

C-Num = 25

C-Type = 1, IPv4 service node pair attribute

The content includes the source and destination service node IPv4 addresses. If this object is received by the TRCM-PE, it can exploit this information to find the corresponding nodes associated with this service node pair in the transport stratum and use them for path computation in its stratum.

9.2.8.1.2 IPv6 Service Node Pair Attribute

See Figure 9-14.

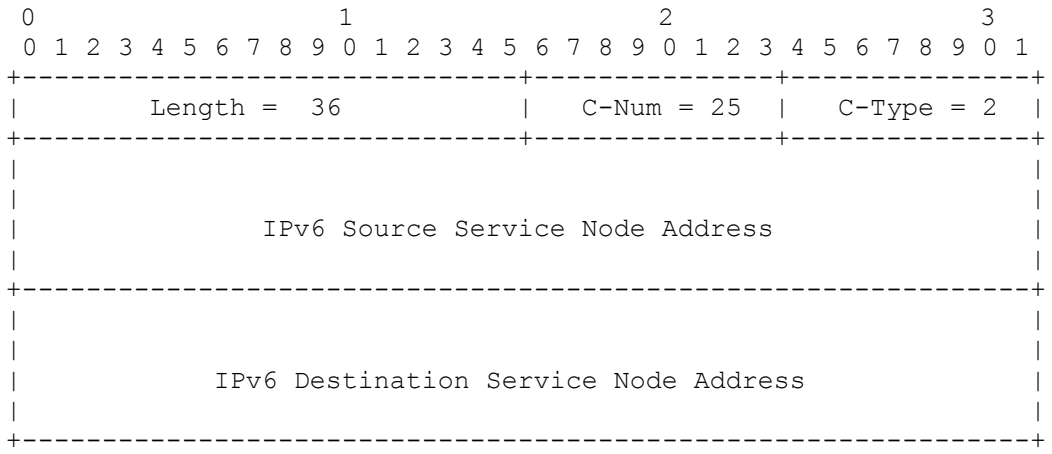

Figure 9-14 – IPv6 Service Node Pair Attribute content

C-Num = 25

C-Type = 2, IPv6 service node pair attribute

The content includes the source and destination service node IPv6 addresses. If this object is received by the TRCM-PE, it can exploit this information to find the corresponding nodes associated with this service node pairs in the transport stratum and use for path computation in its stratum.

9.2.8.1.3 Service holding time

See Figure 9-15.

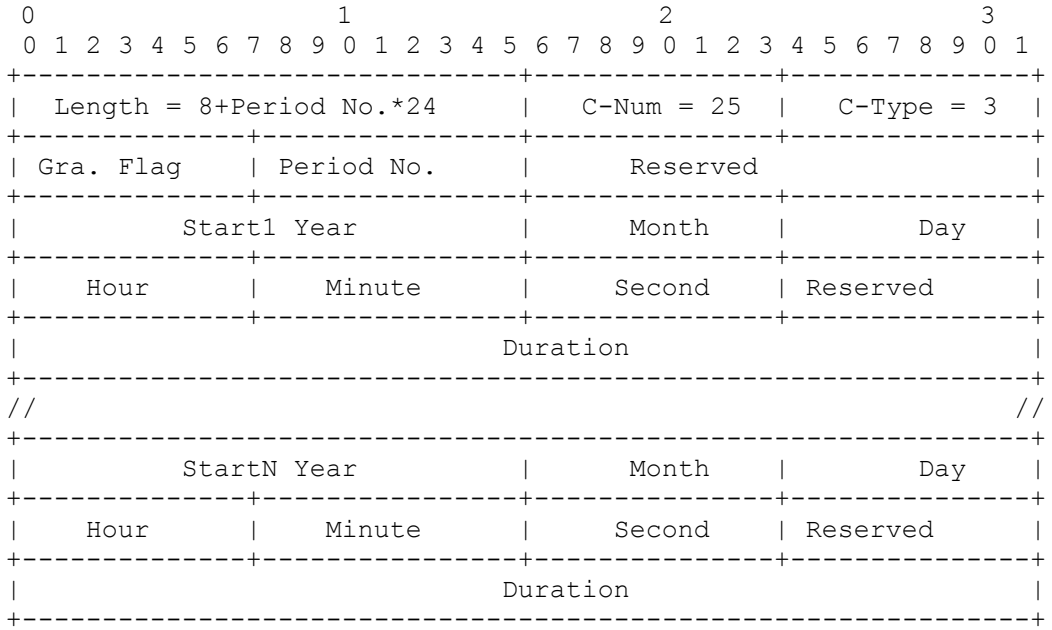

Figure 9-15 – Service holding time content

C-Num = 25

C-Type = 3, Service holding time

Gra. Flag (8 bits): this is the granularity flag for the time.

0x00: Reserved

0x01: Year; other values are ignored (and set to 0) and the duration is in unit of a year.

0x02: Month; smaller values are ignored (and set to 0) and the duration is in the unit of a month.

0x04: Day; smaller values are ignored (and set to 0) and the duration is in the unit of a day.

0x08: Hour; smaller values are ignored (and set to 0) and the duration is in the unit of an hour.

0x16: Minute; smaller values are ignored (and set to 0) and the duration is in the unit of a minute.

0x32: Second; the duration is in the unit of a second.

Others: unassigned

Period No. (8 bits): this specifies the number of time period a service holds.

The rest of the content includes one or more numbers of the starting time and ending time of a service (the granularity is confined by the Gra. Flag field.

9.2.8.2 Constraint Object

The purpose of this object is to describe the constraint imposed by a service. It is a sub-object of the Service Profile Object and it can appear one or more times (with different C-Type values) in the Service Profile Object.

Currently, the following C-Types are defined and they are described in detail in clauses 9.2.8.2.1 to 9.2.8.2.4:

C-Type =1: Bandwidth

C-Type =2: Connection constraints

C-Type =3: Latency Bound

C-Type =4: Jitter Bound

Others: unassigned

For a Service Profile Object, Bandwidth and Connection constraints must be present. C-Type 3 and 4 are optional and depending on the property of the service.

9.2.8.2.1 Bandwidth

See Figure 9-16.

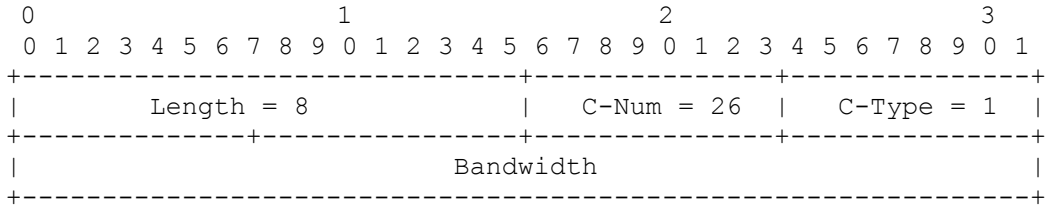

Figure 9-16 – Bandwidth content

C-Num = 26

C-Type = 1, Bandwidth

The content includes bandwidth information, encoded using IEEE floating point [IEEE 754].

9.2.8.2.2 Connection Constraints

See Figure 9-17.

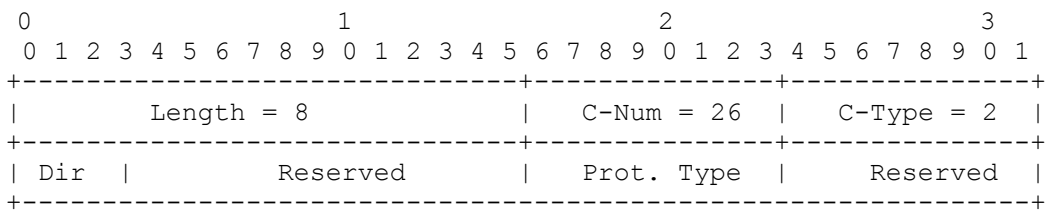

Figure 9-17 – Connection constraints content

C-Num = 26

C-Type =2, Connection Constraints

Dir (3 bits): Directionality requirement of the undertaking transport connection

0x00: Reserved

0x01: Unidirectional

0x02: Bidirectional

Others: unassigned

Prot. Type (8 bits): Protection type of the undertaking transport connection

0x00: Reserved

0x01: 1+1 protection

0x02: 1:1 protection

Others: unassigned

9.2.8.2.3 Latency bound

See Figure 9-18.

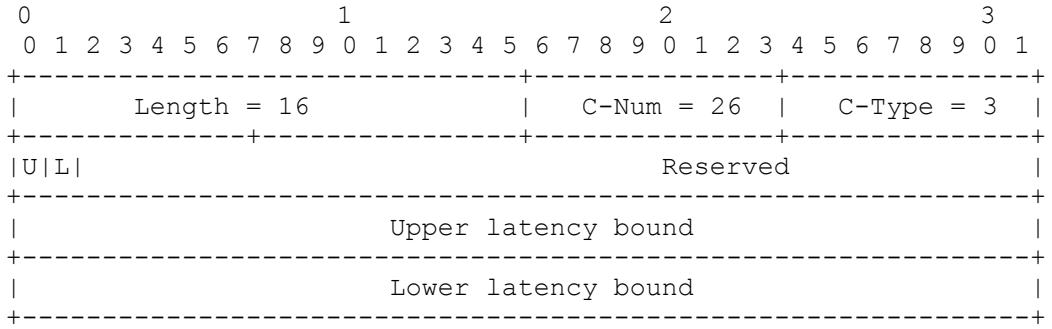

Figure 9-18 – Latency bound

C-Num = 26

C-Type =3, Latency bound

U bit (1 bit): Upper bound flag, when set to 1, it denotes the upper latency bound is set

L bit (1 bit): Lower bound flag, when set to 1, it denotes the upper latency bound is set

The rest of the content includes the upper and lower latency bounds associated with a service.

9.2.8.2.4 Jitter bound

See Figure 9-19.

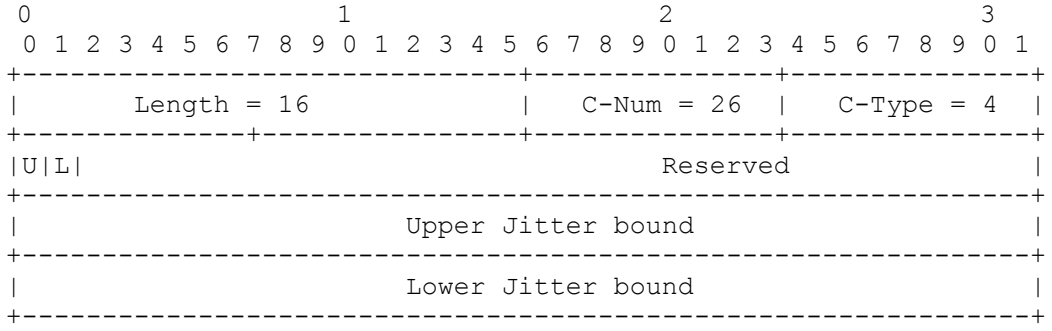

Figure 9-19 – Jitter bound

C-Num = 26

C-Type =4, Jitter bound

U bit (1 bit): Upper bound flag, when set to 1, it denotes the upper jitter bound is set

L bit (1 bit): Lower bound flag, when set to 1, it denotes the upper jitter bound is set

The rest of the content includes the upper and lower jitter bounds associated with a service.

9.2.9 Connection Profile

The purpose of this object is to describe a connection that can be set up or has already been set up by the TRCM-PE. It can appear one or more times in the RA and QREP messages. See Figure 9-20.

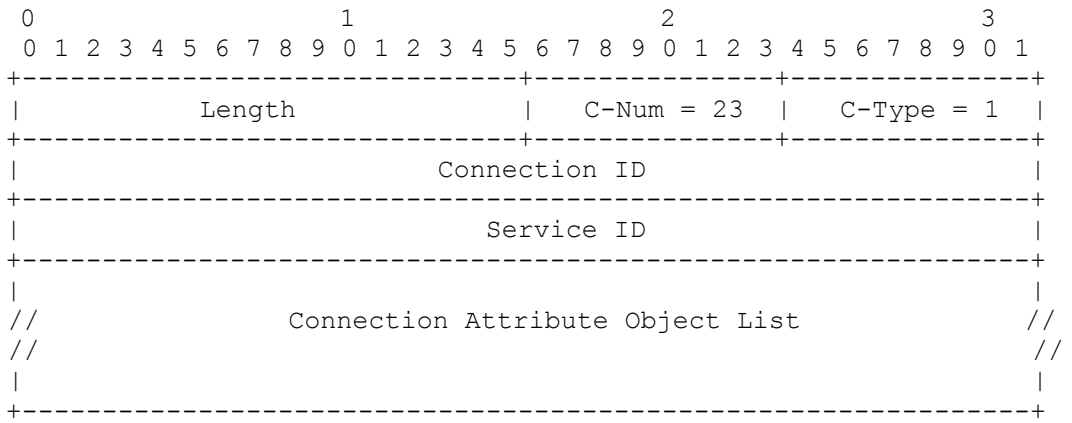

Figure 9-20 – Connection Profile Object content

C-Num = 23

C-Type = 1, Connection Profile.

The content includes Connection ID, Service ID and a list of Connection Attribute Objects. The Attribute Object is defined in clause 9.2.9.1.

The service ID is used to denote a service the connection is associated with, if it is known, otherwise this value should be set to 0x0, which represents no service is associated with this connection ID.

9.2.9.1 Connection Attribute Object

The purpose of this object is to describe the attributes associated with the transport connection. It is a sub-object of the Connection Profile Object and it can appear one or more times (with different C-Type values) in the Connection Profile Object.

Currently, the following C-Types are defined and they are described in detail in clauses 9.2.9.1.1 to 9.2.9.1.3:

C-Type =1: Bandwidth

C-Type =2: Latency

C-Type=3: Jitter

Others: unassigned

For a Service Profile Object, Bandwidth must be present. C-Type 3 and 4 are optional and depending whether the associated service has such a constraint or not.

9.2.9.1.1 Bandwidth

See Figure 9-21.

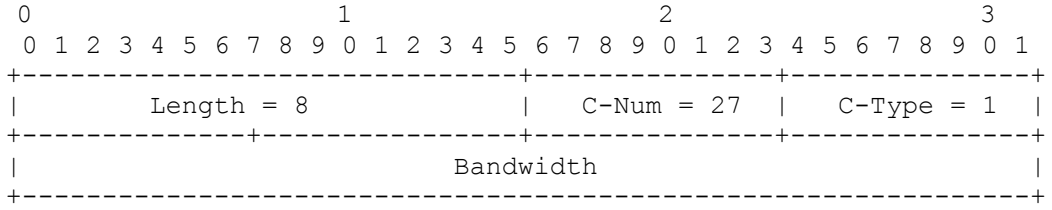

Figure 9-21 – Bandwidth content

C-Num = 27

C-Type = 1, Bandwidth

The content includes bandwidth information, encoded using IEEE floating point [IEEE 754].

9.2.9.1.2 Latency

See Figure 9-22.

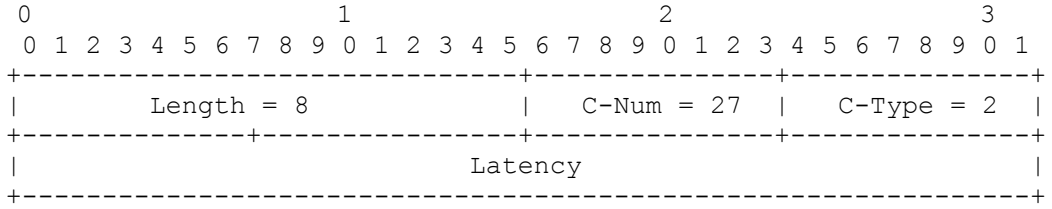

Figure 9-22 – Latency content

C-Num = 27

C-Type = 2, Latency (in seconds)

The content includes latency information associated with a connection.

9.2.9.1.3 Jitter

See Figure 9-23.

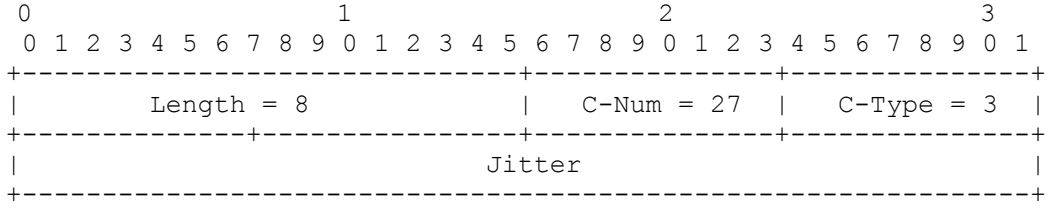

Figure 9-23 – Jitter content

C-Num = 27

C-Type = 3, Jitter

The content includes jitter information associated with this connection.

9.2.10 EventNotify

The purpose of this object is to allow the TRCM-PE to send notifications to the SRCM-PE for events that may need the SRCM-PE take appropriate action. This object can appear one or multiple times in an Event Notification (Notify) message. See Figure 9-24.

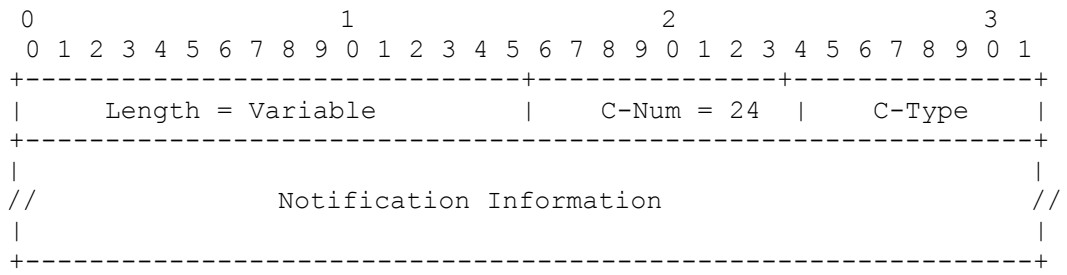

Figure 9-24 – EventNotify content

The following C-Types are defined in this Recommendation and they are defined in clauses 9.2.10.1 to 9.2.10.3.

C-Type = 1: Connection Failure

C-Type = 2: Service Recovered

C-Type = 3: Connection Re-selection Notification

Others: unassigned

9.2.10.1 Connection Failure

The purpose of this object is to notify a failure that cannot be handled by the TRCM-PE. See Figure 9-25.

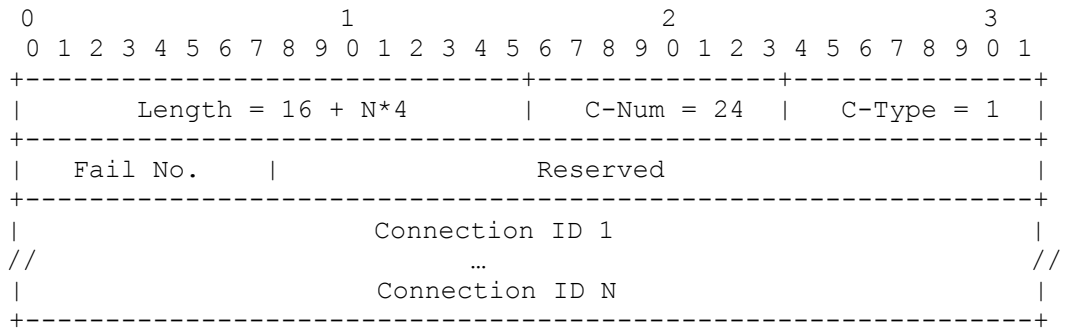

Figure 9-25 – Connection Failure content

C-Num = 24

C-Type = 1, Connection Failure

The content includes the Connection ID that cannot be recovered by the transport stratum. Upon receipt of this information, SRCM-PE can trigger service stratum recovery if there are sufficient resources and the policy allows it. For example, the SRCM-PE can choose a different data centre site for database backup purposes.

9.2.10.2 Service Recovered

The purpose of this object is to notify a failure that has already been recovered by the TRCM-PE. See Figure 9-26.

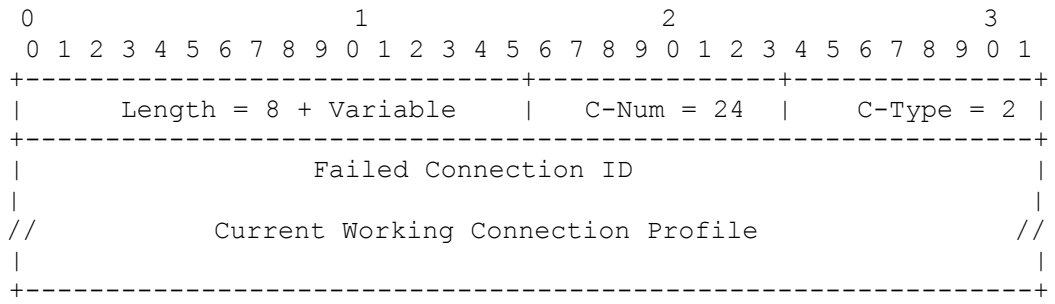

Figure 9-26 –Service Recovered content

C-Num = 24

C-Type = 2, Service Recovered

The content includes the Failed Connection ID and the associated alternative Connection profile information. The latter should also include the same service ID associated with the failed connection ID, together with the same connection attribute information provided by the failed connection ID.

9.2.10.3 Connection Re-selection Notification

The purpose of this object is to notify the SRCM-PE that a new connection resource is available for a service under schedule by the TRCM-PE so that the SRCM-PE can decide whether the new transport connection is preferred y replying with a RR message (with Flags set to 0x04). See Figure 9-27.

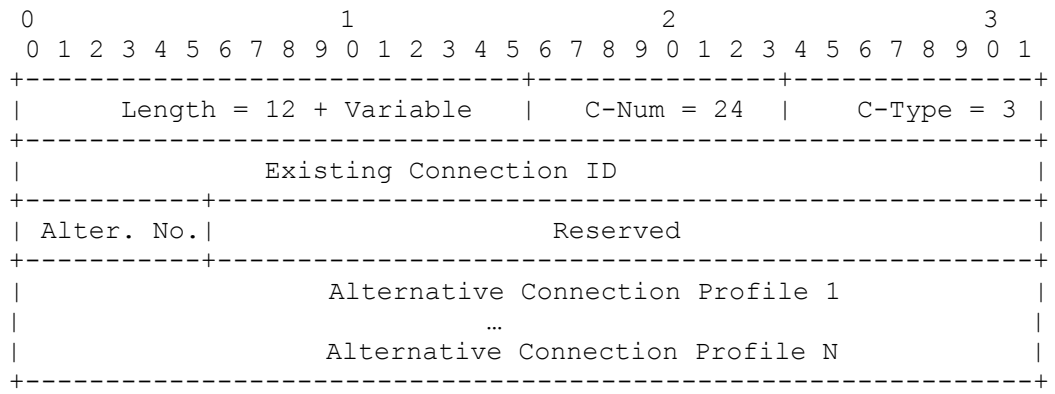

Figure 9-27 – Connection Re-selection Notification content

C-Num = 24

C-Type = 3, Connection Re-selection Notification

Alter. No. (6 bits): the number of alternative connection number.

The rest of the content includes the existing Connection ID and the associated alternative Connection profile information. The latter should set the service ID to 0x0, since it is not yet associated with any service when such a notification message is sent. However, it should include the same connection attribute information provided by the existing connection.

10 Security consideration

The CSO function based on the functional architecture defined by the VNC follows the security consideration in [ITU-T Y.3014].

The specification for CSO function based on the RCIP protocol follows the RCIP security consideration as defined in [ITU-T Q.3302.1].

Bibliography

[b-IETF RFC 2104] IETF RFC 2104 (1997), *HMAC: Keyed-Hashing for Message Authentication.*

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Printed in Switzerland
Geneva, 2016