INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2001-2004

COM 16 – LS 3 – E

English only
Original: English

Question(s):	F/16 **(WP 2/16)**	Geneva, 20-30 May 2003

LIAISON STATEMENT
(Ref : TD 63 (WP 2/16))

Source:	ITU-T SG 16
Title:	LS on Signalling Requirements for IP-QoS

LIAISON STATEMENT

To:	**Study Group 11 - Qs 7, 8, and 9/11 (for action** **Copy (for information) to: Study Group 2 - Q2/2; Study Group 9 - Q13/9; Study Group 12 - Q13/12; Study Group 13 – Qs 16, 6 & 7/13; ETSI (for 3GPP); TIA (for 3GPP2); ETSI (TIPHON & SPAN); Study Group SSG on IMT-2000 and beyond – Qs 6 & 7/SSG**
Approval:	**Approved at ITU-T SG 16 Meeting (Geneva, 20-30 May 2003)**
For:	**Action (SG 11) and information (others)**
Deadline:	**31 December 2003**

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Thank you for your reply (in TD-058/GEN) to our liaison on LS on Signalling Requirements for IP-QOS.

We strongly support the valuable work you are planning on defining signalling requirements on IP QoS and agree that the signalling schemes adopted in Annex N of H.323 should be compatible with this.

So far, the exact format of the signals in Annex N has not been defined, the approach has been purely a parametric one. This was done for flexibility but we believe this is fully compatible with the parameters used in Y.1541. It is our wish to extend this to also include class based information as defined in Y.1541 and we hope to be in a position soon to have a new draft available containing this information. Of course Y.1541 classes are end to end and there is a need for budget apportionment signalling which may involve individual parameters or could alternatively be based on an IPOD type classification as defined in M.2301. We would be very interested in collaborating with you in this respect. We include the latest draft of H.qosarch which we hope will clarify the general framework behind the more specific Annex N. We would very much welcome your comments on this document also.

We very much look forward to initiating a joint activity in this area.

Attachment: Draft H.qosarch (TD-053/WP2).

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STUDY PERIOD 2001-2004

STUDY GROUP 16

TD 53 (WP 2/16)

English only

Original: English

Question(s): F/16 Geneva, 20-30 May 2003

TEMPORARY DOCUMENT

***Source:** Editor

Title: Draft Revised Recommendation H.qos.arch

DRAFT H.QOS.ARCH
QoS Architecture

Table of Contents

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DRAFT H.QOS.ARCH

1 Introduction

End–to-end quality of service (QoS) and service priority require co-ordination of resources and quality control mechanisms at all points in a multimedia system. Procedures for achieving this entail a combination of information flows and functionality at various levels in the system. This recommendation provides a reference architecture for defining and analysing mechanisms and procedures for achieving end-to-end QoS and service priority control.

2 Scope

This Recommendation contains a reference architecture for controlling the QoS and service priority of multimedia services in ~~Next Generation Networks~~networks which are comprised of combinations of switched circuit and packet domains, wireless and wireline technologies, conventional and packet-based terminals. The reference architecture is functionally defined, however a number of physical ~~reference scenarios~~realisations are included. A domain-based approach allows issues of administrative control and security also to be considered.

3 Policy for Updating this Document

This document is managed by the ITU-T Study Group 16 Question F Rapporteur's Group. It can be revised at any recognized Q.F/16 Rapporteur's Group meeting provided the proposed revisions are unanimously accepted by the members of the group. A revision history cataloguing the evolution of this document is included.

3.1 Defect Resolution Process

Upon discovering technical defects with any components of the H.QOS Recommendations series, please provide a written description directly to the Q.F/16 Rapporteur.

4 References

4.1 Normative References

This document refers to the following H-series Recommendations:

H.mmclass

H.priority

H.trans.control

4.2 Informative References

This document refers to the following H-series Recommendations:

H.mmcp

H.trans.control

H.qos.m

H.policy

H.resilience

5 Definitions & Acronyms

This recommendation defines the following terms:

Application Service: A network based service involving the transmission and/or processing of multimedia information.

Application Service Provider (ASP): A Service Provider providing Application Services. Note: The same business entity may act as both Network Operator and Application Service Provider.

End User Domain (EUD): A collection of physical or functional entities, including terminal equipment and network resources under the control of an End User.

End User: An entity employing Application Services.

IP Telephony Service Provider (ITSP): A Service Provider providing IP Telephony Services. Note: The same business entity may act as both a ~~Transport~~ Network Operator and an IP Telephony Service Provider.

Interconnect Function (ICF) A functional entity that interconnects ~~Transport~~ Network Operator Domains. It provides a policy and/or administrative boundary and may police authorised media flows between two ~~Transport~~ Network Operator Domains to ensure they are consistent with the QoS polic~~y specified by the relevant Transport Resource Manager~~ies of the Network Operator of that domain .

Quality of Service Manager (QoSM): A functional entity residing in a Service Domain that mediates requests for end-to-end QoS in accordance with polic~~y determined by the QoSPE~~ies of the Application Service Provider controlling the Service Domain. It communicates with, other QoSMs and with TRMs to determine, establish and control ~~the offered~~ QoS.

Quality of Service Policy Element (QoSPE): A functional entity residing in a Service Domain that manages ~~multimedia~~ the QoS policies of the Application Service Provider controlling the Service Domain.~~and~~ It provides authorisation of permitted and default QoS levels. It receives requests from and issues responses to QoSMs to establish the authorised end-to-end QoS levels.

Service Domain (SD): A collection of physical or functional entities offering ~~IP telephony~~Application ~~services~~ Services under the control of an ~~IP Telephony~~Application Service Provider which share a consistent set of policies and common technologies.

~~Transport~~ Network Operator Domain (~~TD~~NOD): A collection of ~~transport~~ network resources sharing a common set of policies, QoS mechanisms and ~~transport~~ technologies under the control of a ~~Transport~~ Network Operator.

~~**Transport Network:** A collection of transport resources which provide transport functionality.~~

~~**Transport**~~ **Network Operator:** An ~~business~~ administrative entity operating a ~~Transport~~ Network.

~~**Transport**~~ **Network Policy Entity (N~~T~~PE):** A functional entity residing in a Network Operator Domain that maintains the policies of the ~~a Transport~~ Network Operator~~Domain~~.

~~**Transport**~~ **Resource Manager (~~T~~RM):** A functional entity residing in a Network Operator Domain that applies a set of policies and mechanisms to ~~a set of~~ transport resources within the domain to ~~ensure that those resources are allocated such that they are sufficient to~~ enable specified QoS ~~guarantees~~ levels to be achieved ~~across~~ within the domain. ~~of control of the TRM~~.

Transport Functionality (TF): A functional entity representing the collection of transport resources within a ~~Transport~~ Network Operator Domain. ~~which are capable of control by a Transport Resource Manager~~

User Equipment (UE): Equipment under the control of an End -User

The following acronyms are used within this recommendation:

ASP	Application Service Provider
EUD	End User Domain
MM	Multi Media
ICF	Interconnect Function
ITSP	IP Telephony Service Provider
QoS	Quality of Service
QoSM	Quality of Service Manager
QoSPE	Quality of Service Policy Element
QST	QoS Signalling Type
SD	Service Domain
NOD	Network Operator Domain
NPE	Network Policy Entity
RM	Resource Manager
~~TD~~	~~Transport Domain~~
TF	Transport Functionality
~~TRM~~	~~Transport Resource Manager~~
~~TPE~~	~~Transport Policy Entity~~
UE	User Equipment

6 Conventions

In this recommendation, "shall" refers to a mandatory requirement, while "should" refers to a suggested but optional feature or procedure. The term "may" refers to an optional course of action without expressing a preference.

7 Generic ~~IP~~ QoS Architecture

7.1 Application and Transport Planes

To achieve end-to-end QoS control in IP-based systems, the QoS mechanisms operating at multi-media application level must operate together with the QoS mechanisms operating in the transport network (e.g., RSVP, DiffServ etc.) which are independent of the application. Furthermore, network management mechanisms may also be involved in controlling and managing QoS. Figure 1 illustrates the relationship between the Application Plane, Transport Plane, and Management Plane for the general case where the end-to-end system is made up either packet-based or circuit-switched network.

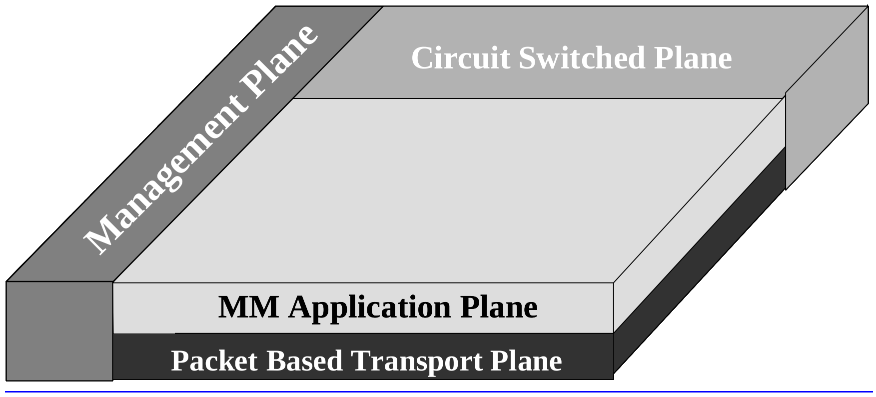


Figure 1 - Relationship between MM Application, Packet-Based Transport, Management, and Circuit Switched Planes

7.1.1 Multi-Media Application Plane

Within this plane, QoS parameters specific to the Multi-Media (MM) application (e.g., QoS service class~~, maximum end-to-end delay, mean delay variation, packet-loss statistics.~~) are requested, authorised, signalled, monitored, and controlled.

7.1.2 Packet Based Transport Plane

Within this plane, general non-application specific traffic parameters effecting QoS (e.g., end-to-end delay, delay jitter, packet loss and bandwidth) must be controlled and accounted to achieve the QoS requirements requested by the MM application.

7.1.3 Circuit Switched Plane

Within this plane, every call receives the same level of quality. Circuit switched networks only provide a choice of call acceptance or non-acceptance depending upon the requested and available capacities. Once a call has been accepted, the capacity allocated is constant throughout the connection duration.. Circuit switched networks are engineered to provide acceptable quality levels for interactive communications. Transmission planning guidelines will determine the levels of quality achievable in circuit switched environments.

7.1.4 Management Plane

7.2Within this plane, QoS signalling requests and responses are exchanged with the Applications Plane and Transport Plane. This signalling will include call statistics, network utilization information, network configuration, performance monitoring, and network resource allocation.

7.2 Decomposition of MM Systems into Administrative Domains

An MM system will in the general case be made up of a number of separate Service Administrative Domains, each representing the domain of control of an MM End-User, or MMApplication Service Provider or Transport Operator. The Service Domains reside within the Application Plane depicted in Figure 1.

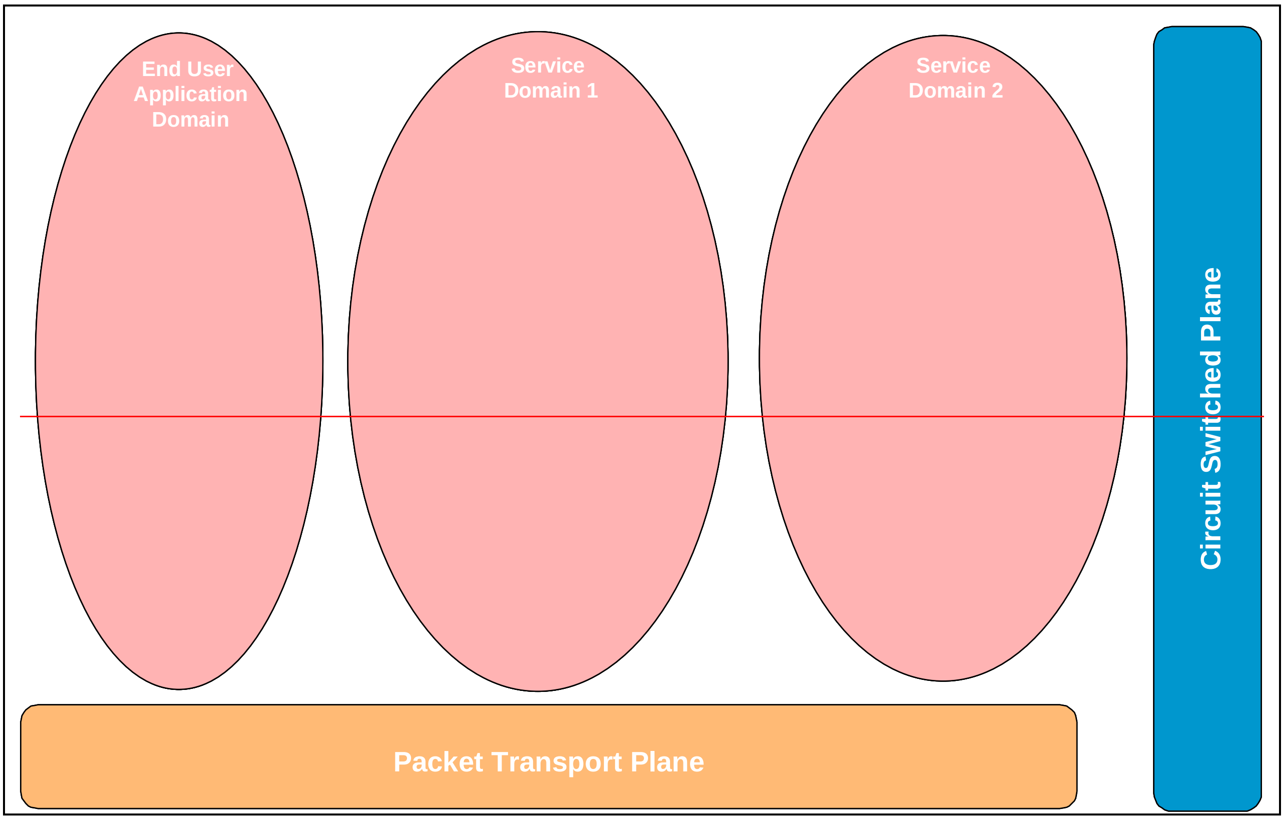
An MM system will, in general, be made up of a number of separate Transport Domains. Transport Domains consist solely of transport-related functionality; this includes IP routers, ATM/MPLS switches, NATs, firewalls, etc. Each Transport Domain may have its own QoS policies and/or differ from other domains in terms of administrative control (e.g., Network Operator), QoS mechanisms (RSVP/IntServ, DiffServ, MPLS), access, metering, addressing schemes (global, local), network protocol (IPv4 or IPv6), etc.

7.2.1 End User Domains

An End User Domain is a collection of physical or functional entities, including terminal equipment and network resources under the control of an End User. The End User may be an individual or administrative entity employing Application Services.

7.2.17.2.1 MM Application Plane Decomposition Service Domains

A Service Domain is a collection of physical or functional entities offering Application Services under the control of an Application Service Provider which share a consistent set of policies and common technologies.
The MM Application Plane in aAn MM System will in the general case be made up of a number of separate Service Domains, each representing the domain of control of an MM End-User or MM Service Provider. . As an example, Figure 3 depicts the decomposition of the MM Application Plane into three distinct domains: the End User Application Domain, Service Domain 1, and Service Domain 2.

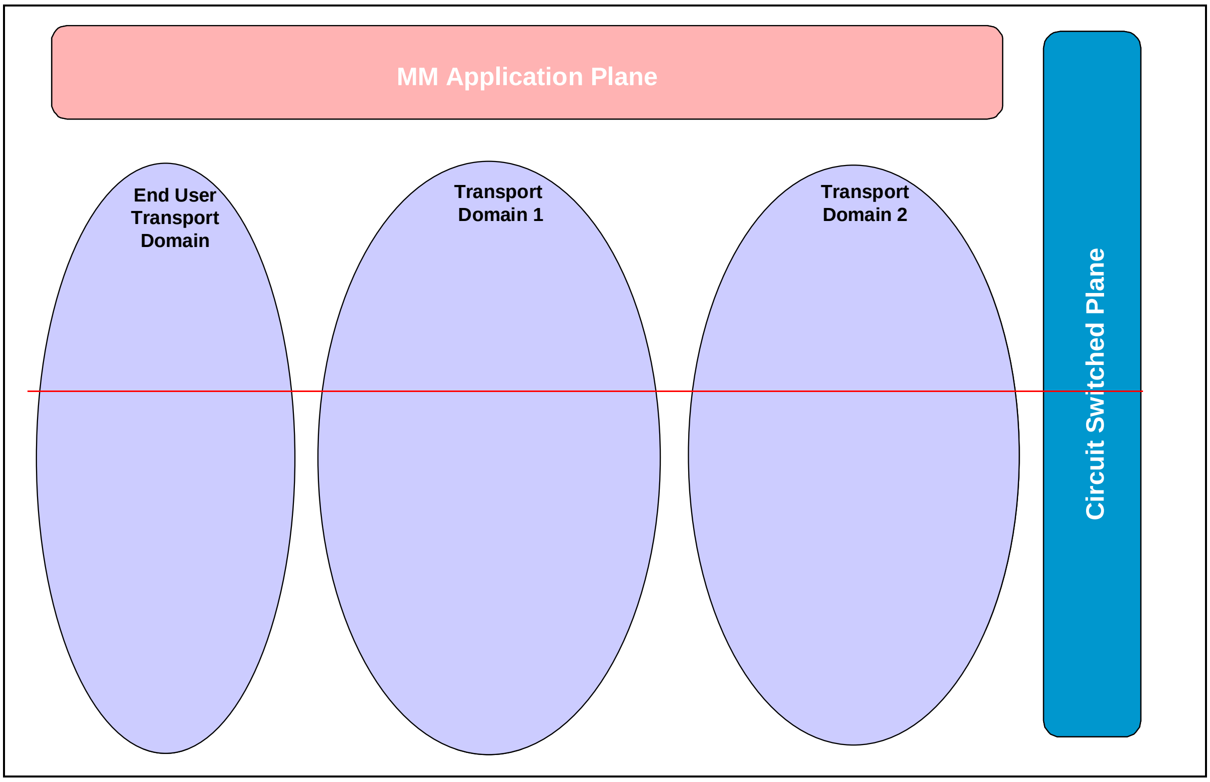


~~**Figure 3 - Decomposition of the MM Application Plane**~~

~~**7.2.2**~~

~~7.2.2~~7.2.2 ~~Packet Based Transport Plane Decomposition~~Network Operator Domains

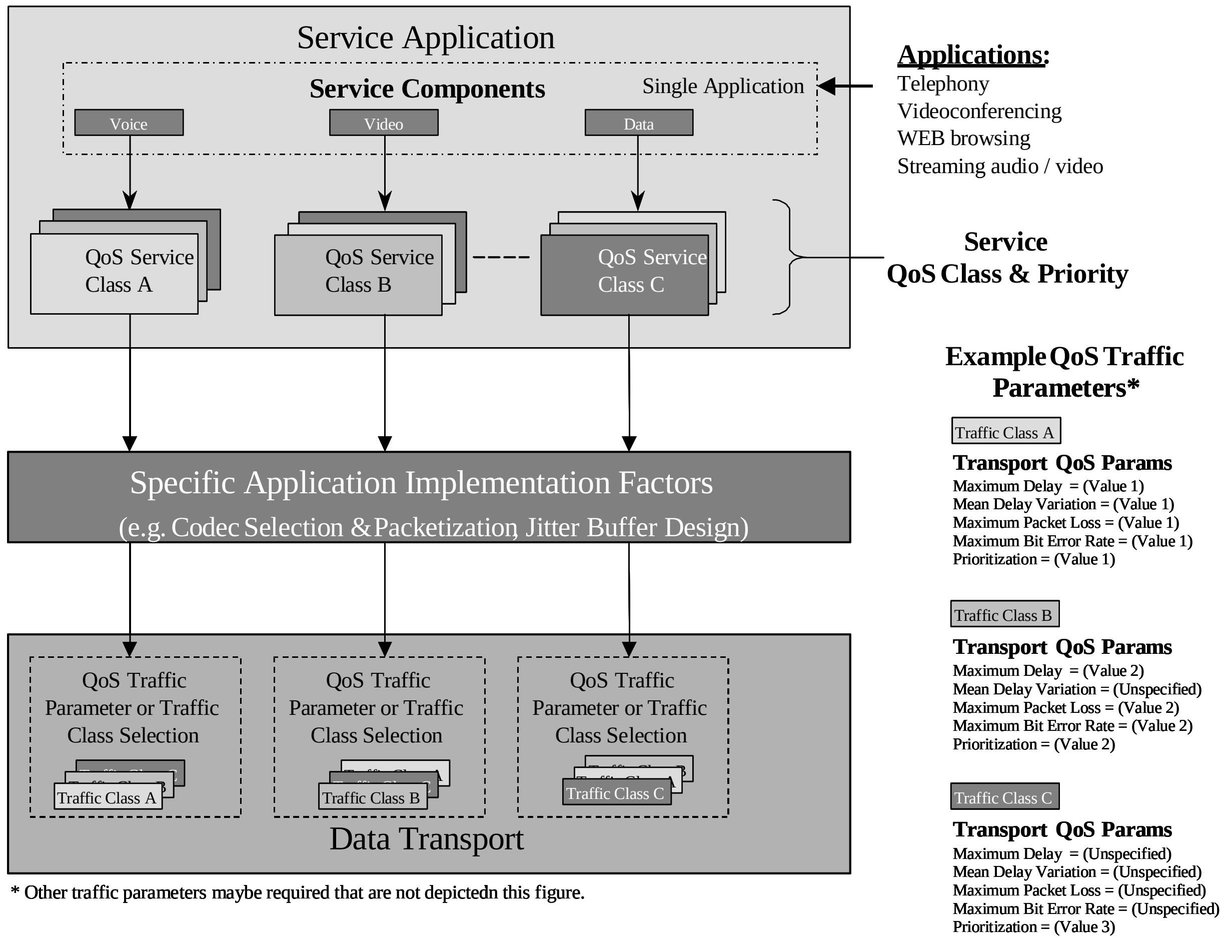
Network Operator Domain is a collection of network resources sharing a common set of policies, QoS mechanisms and technologies under the control of a Network Operator. An MM system will, in general, be made up of a number of separate ~~Transport~~ Network Operator Domains. ~~Transport~~ Network Operator Domains consist ~~solely~~ largely of transport related functionality; this includes IP routers, ATM/MPLS switches, however may contain application based elements such as NATs, firewalls, etc. Each Transport Domain may have its own QoS policies and/or differ from other domains in terms of administrative control (e.g., Network Operator), QoS mechanisms (RSVP/IntServ, DiffServ, MPLS), access, metering, addressing schemes (global, local), network protocol (IPv4 or IPv6), etc. ~~As an example, Figure 5 depicts the decomposition of the Transport Plane into three distinct domains: the End User Transport Domain, Transport Domain 1, and Transport Domain 2.~~



~~Figure 5 - Decomposition of the Packet Based Transport Plane~~

~~7.3~~7.3 QoS Classification at the Service, Application, and Transport Levels

A single application such as videoconferencing, telephony, or web browsing can be made of many unique media streams. To provide maximum flexibility and network optimisation not all media streams from one application have to be tagged with the same classifications. Each media stream of an application may be uniquely classified by a ~~Prioritisation~~ prioritisation level as well as a QoS Service Class as shown in Figure 4.



* Other traffic parameters maybe required that are not depictedn this figure.

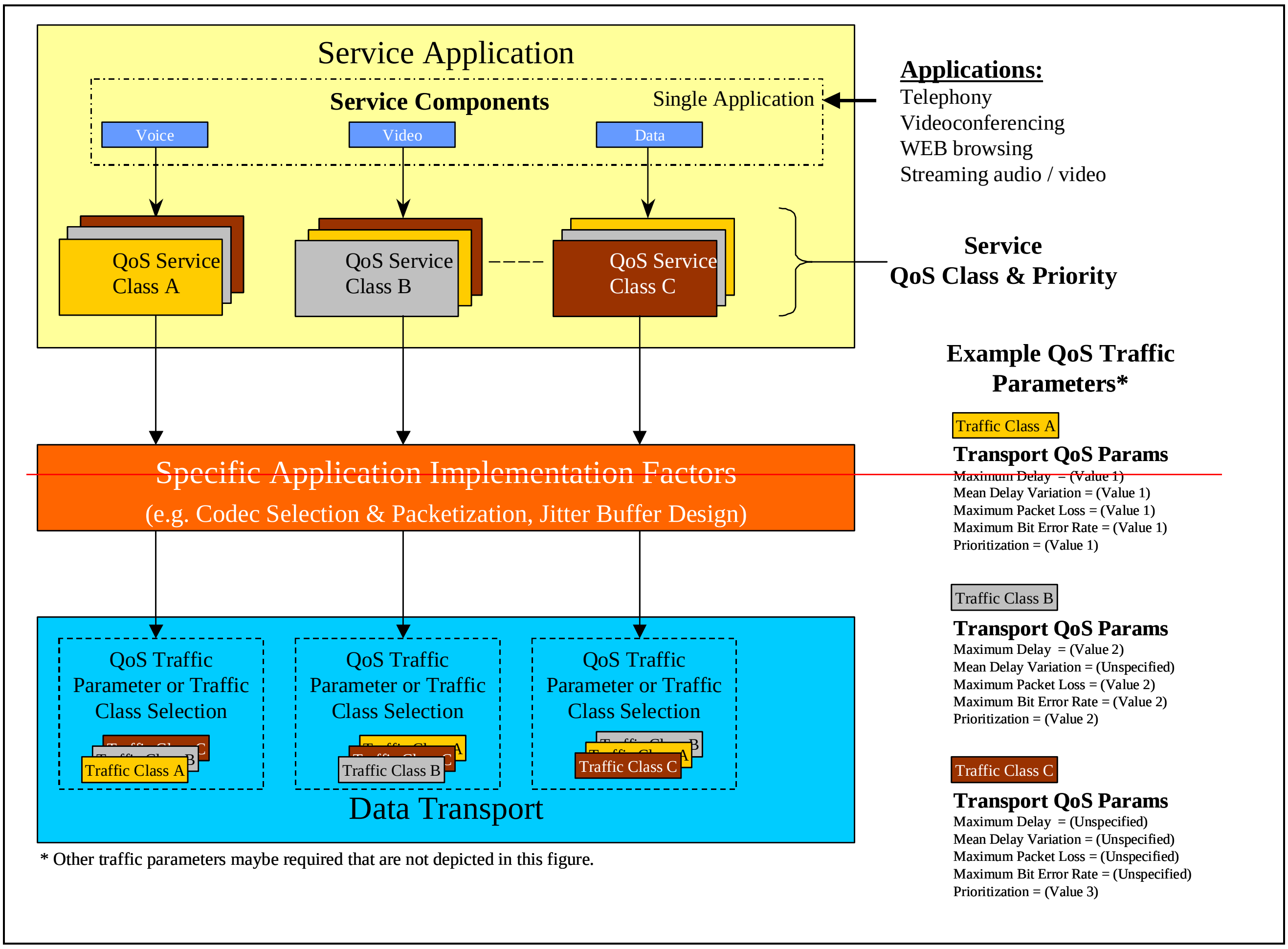


Figure 4 QoS Classification at the Service, Application, and Transport Levels

~~7.3.1~~7.3.1 Service & Application Level

Any specific application can be broken down into multiple data streams. Each data stream or service component shall be classified into a QoS Service Class.

~~7.3.1.1~~7.3.1.1 QoS Service Classes

Details of the recommended QoS service classes can be found in H.mmclass and recommendation G.1010.

~~7.3.1.2~~7.3.1.2 Priority Levels

Details of the recommended priority levels can be found in H.priority.

~~7.3.1.3~~7.3.1.3 Application Factors

There are a number of implementation factors that determine the required QoS traffic classes or parameters in the Transport Plane. These implementation factors should be chosen to optimise performance and will determine the specification of the required transport QoS classes or parameters. For example, highly interactive speech with an MOS rating of 4.0 will require use of a G.711 codec or wideband codecs and will set tight bounds on end-to-end delay, jitter, and packet loss.

7.3.27.3.2 Transport Level

Bounds must be placed on a number of transport parameters to achieve the desired QoS Service Level. These bounds must be either specified numerically on a per stream basis or maybe selected from a number of predefined QoS traffic classes. Recommendation Y.1541 specifies a number of such QoS traffic classes. Whether or not the classes defined in Y.1541 provide a sufficient basis for all MM applications requires further study.

7.3.2.17.3.2.1 QoS Traffic Classes

Details of the recommended QoS traffic classes can be found in Y.1541.

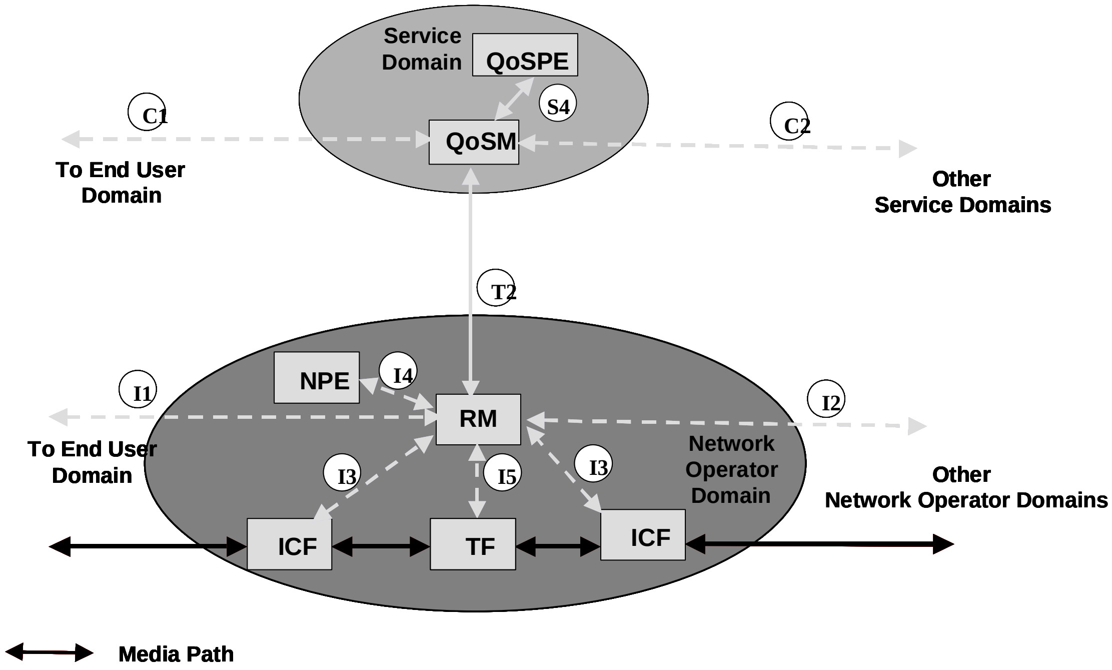
7.3.2.27.3.2.2 QoS Traffic Parameters

The primary traffic parameters that impact QoS are:

- End-to-End Delay: Echo and talker overlap are the problems that result from high end-to-end delay in a voice network. Packet based systems may incur longer delays than circuit switched networks and in general will require echo control and implement some means of echo cancellation on the access links . The ITU recommendation G.168 defines the performance requirements that are currently required for echo cancellers. Talker overlap (problem of one caller stepping on the other talker's speech) becomes significant if the one-way delay becomes greater than 250 ms. Delay can be attributed to accumulation of delay, processing delay and network delay. The choice of a fast codec takes care of the accumulation and processing. Network delay describes the average length of time a packet traverses in a network. The network delay is handled by a good network design that minimizes the number of hops encountered and by the advent of faster switching devices like Layer 3 switches, tag switching system like MPLS systems and ATM switches.
- Packet Delay Variation (Jitter): This is the variation in the inter-packet arrival time (leading to gaps, known as jitter, between packets) as introduced by the variable transmission delay over the network. Removing jitter requires collecting packets in buffers and holding them long enough to allow the slowest packets to arrive in time to be played in correct sequence. Jitter buffers cause additional delay, which is used to remove the packet delay variation as each packet transits the network.
- Packet Loss: IP networks do not guarantee delivery of packets, much less in order. Packets will be dropped under peak loads and during periods of congestion. Approaches used to compensate for packet loss include interpolation of speech by replaying the last packet, and sending of redundant information. Out of order packets are treated as lost and replayed by their predecessors. When the late packet finally arrives, it is discarded.

7.47.4 Functional Entities

A number of Functional Entities within both Service and Network Operator Domains are defined as part of the IPa generic -end-to-end QoS control mechanism within both the Service and Transport domains. The relationship between these Functional entities is shown in Figure 5.



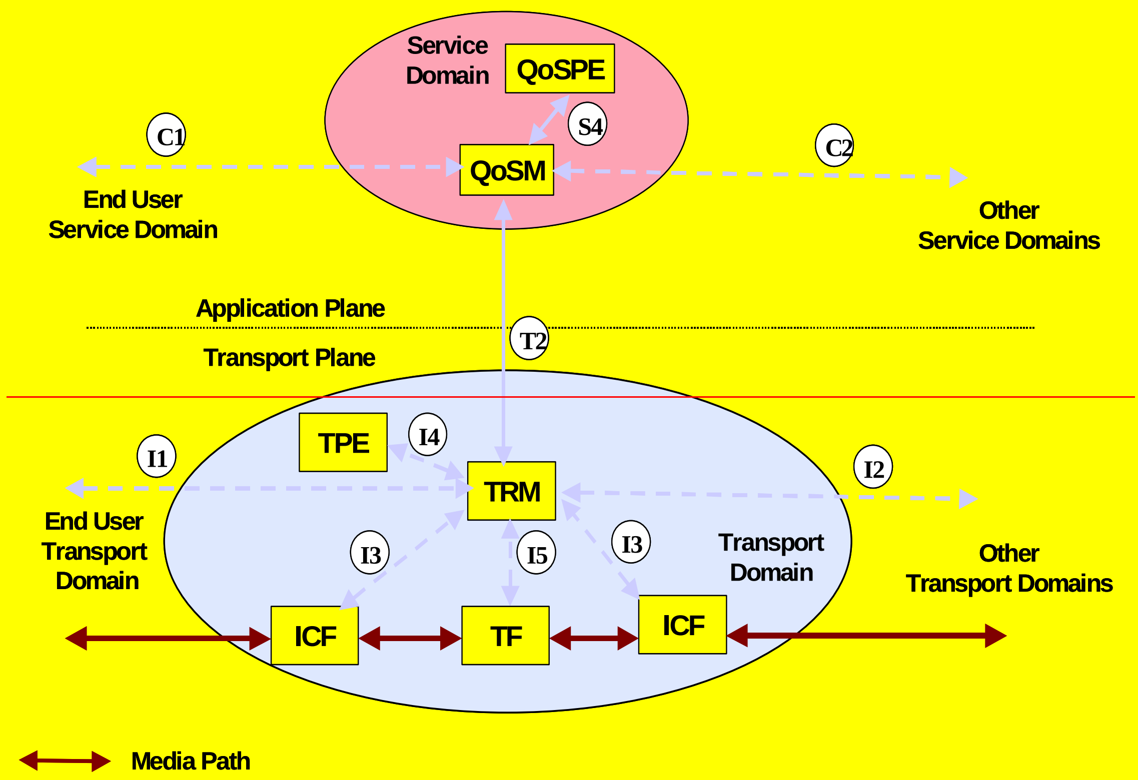


Figure 5 - Relationship between QoS Functional Entities

~~7.4.1~~7.4.1 QoS Service Manager (QoSM)

The QoSM is a functional entity that mediates requests for end-to-end QoS in accordance with policy determined by the QoSPE. It communicates with other QoSMs and with ~~T~~RMs to determine, establish and control the offered QoS.

~~7.4.2~~7.4.2 QoS Policy Entity (QoSPE)

The QoSPE is a functional entity that manages application policies and provides authorization of permitted and default QoS levels. It receives requests from and issues responses to QoSMs to establish the authorized end-to-end QoS levels.

~~7.4.3~~7.4.3 Transport Functionality (TF)

The TF is a functional entity representing the collection of transport resources within a ~~Transport~~ Network Operator Domain, which are capable of QoS control.

~~Figure 9 - Relationship between QoS Functional Entities~~

~~7.4.4Transport Policy Entity (TPE)~~

~~The TPE is a functional entity that maintains the policies of a Transport Domain.~~

~~7.4.5Transport Resource Manager (TRM)~~

~~The TRM is a functional entity that applies a set of policies and mechanisms to a set of transport resources to ensure that those resources are allocated such that they are sufficient to enable QoS guarantees across the domain of control of the TRM.~~

7.4.4 **Network Policy Entity (NPE):** A functional entity residing in a Network Operator Domain that maintains the policies of the Network Operator.

7.4.5 Resource Manager (RM): A functional entity residing in a Network Operator Domain that applies a set of policies and mechanisms to transport resources within the domain to enable specified QoS levels to be achieved within the domain..

7.4.6 Interconnect Function (ICF) A functional entity that interconnects Network Operator Domains. It provides a policy and/or administrative boundary and may police authorised media flows between two Network Operator Domains to ensure they are consistent with the QoS policies of the Network Operator of that domain .

~~7.4.6Interconnect Function (ICF)~~

~~The ICF is a functional entity that interconnects Transport Domains. It provides a policy and/or administrative boundary and may police authorised media flows between two Transport Domains to ensure they are consistent with the QoS policy specified by the relevant Transport Resource Manager.~~

7.~~5~~8 ~~QoS Signaling Methods~~QoS Control Procedures

8.1 General Framework

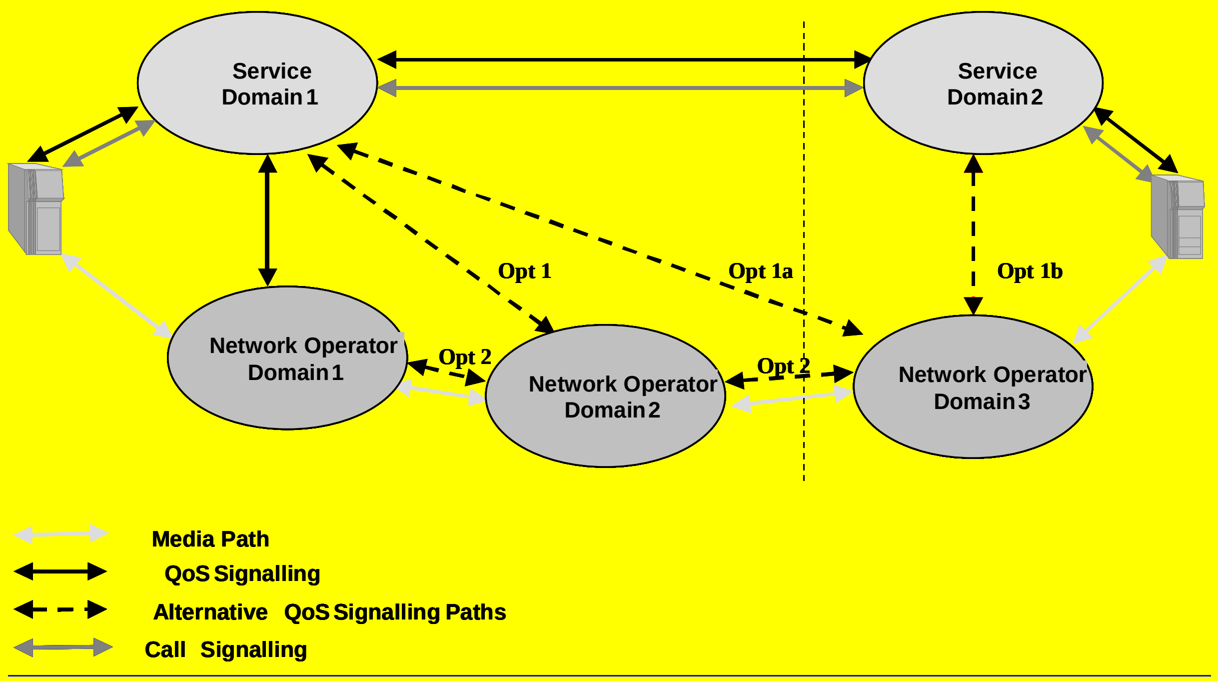
End-to-end QoS control is required to ensure that the desired QoS Service Class and Priority is achieved during a MM session. Each flow during a session may potentially have associated with it a different Qos Service Class and Priority so the mechanisms used must support this possibility. Furthermore, QoS control must be supported throughout the entire path the media stream(s) traverses in order to achieve an end-to-end result.

The general case is illustrated in In Figure 7. -Ceall control information flows, QoS ~~information flows~~control flows, and media flows are shown separately. There are two primary options for end to end QoS ~~information flows~~control,

- Option 1. Application Service Provider Controlled routing involving QoS signalling between ~~different~~ QoSM functions and between QoSM functions and RMs. ~~Service & Transport Domains: across the Application Plane via the QoSM Function~~ or

- Option 2. Network Operator Controlled Routing involving ~~within the Transport Plane via Transport~~ QoS Signalling between RMs.

The signalling protocols used are outside the scope of this recommendation.



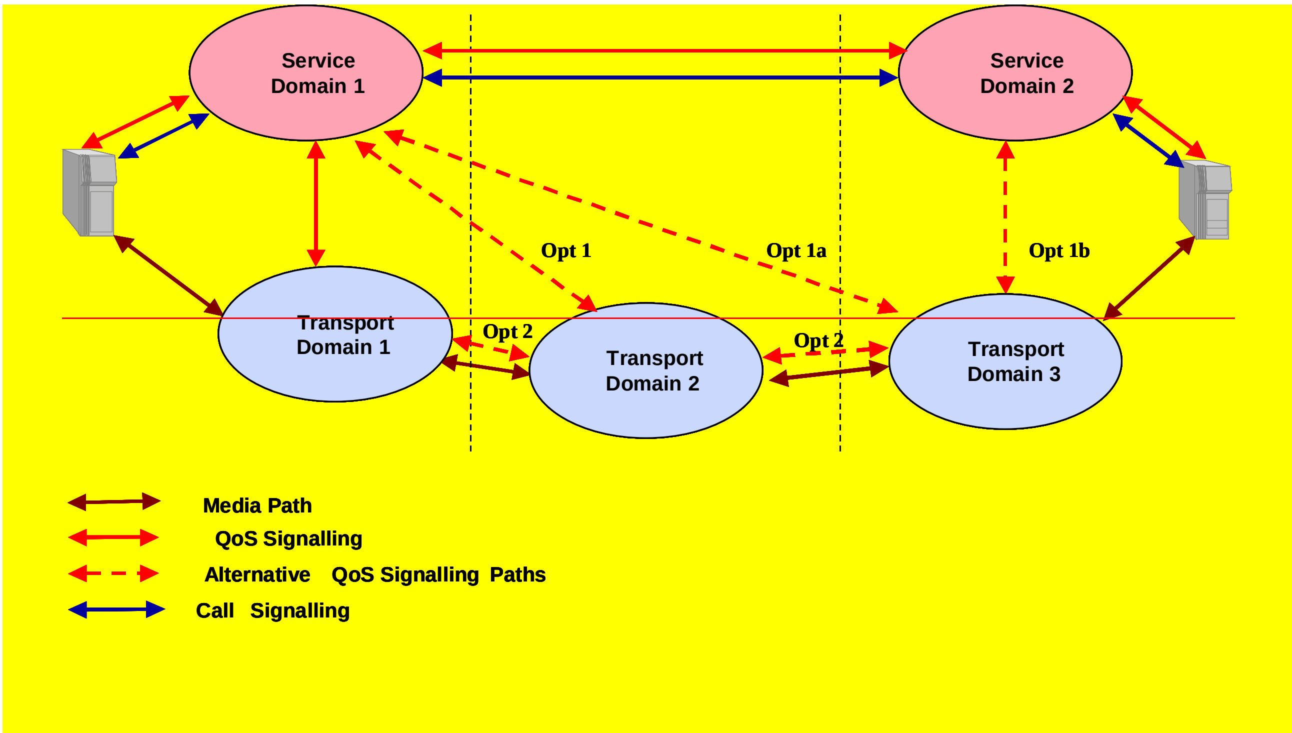


Figure 7 - Call involving multiple ~~transport~~ Network Operator and ~~S~~service ~~D~~domains

~~A primary function of end-to-end QoS signalling is used during MM session establishment to ensure the required QoS Service Class and Priority can be supported throughout the entire path the media stream(s) traverses. In addition, the QoS signalling is also used during the MM session to monitor or modify QoS performance to ensure that QoS guarantees are being achieved throughout the duration of the MM session.~~

~~7.5.1~~8.1.1 ~~Service Domain QoS Signalling:~~ Option 1: ASP Controlled Routing

ASP Controlled Routing allows for the ASP initiating the call, possibly in conjunction with other ASPs, to select the sequence of Network Operators that will be involved in carrying the media flow. This arrangement permits the most flexible business model involving multiple ASPs and multiple Network Operators. This option ~~Option 1 describes where the~~ involves end-to-end QoS control signalling takes place between Service Domain's QoSMs and between QoSMs and Network Operator Domain ~~Transport Doamin's T~~RMs. ~~The signalling protocol used between the two QoSMs is not within the scope of this recommendation.~~ QoS Signalling to End User domains, is the responsibility of the initiating and terminating ASP.

8.1.1.1 ASP Control: Option 1a

In Option 1a, the entire end-to-end QoS control is with the initiating ASP. QoS control signalling takes place between the initiating ASPs QoSM and the relevant ~~T~~RMs.

8.1.1.2 ~~Service Domain QoS Signalling~~ASP Control: Option 1b~~a~~

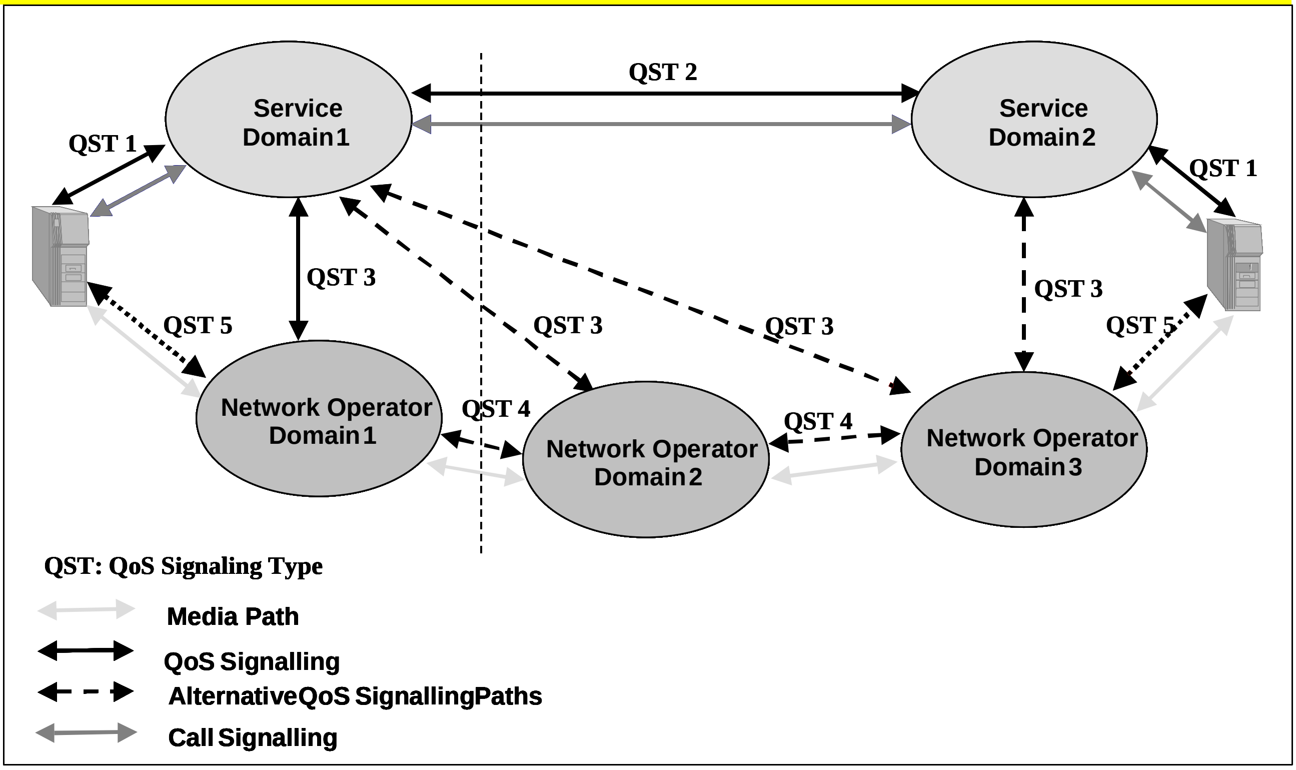
~~Option 1a is a variant of option 1 where~~In Option 1b the end-to-end QoS control is shared between the initiating ASP and other ASPs. QoS control signalling takes place between ~~the initiating~~ the QoSM~~s~~ of the ASPs involved and the relevant ~~T~~RMs. ~~The signalling protocol used between the QoSMs and TRMs is not within the scope of this recommendation.~~

7.5.28.1.2 Transport Domain QoS Signalling: Option 2: Network Operator cControlled Rrouting

With Network Operator Controlled Routing, selection of the sequence of Network Operators that will be involved in carrying the media flow lies with the Network Operators. This arrangement is the model most commonly used for circuit-switched networks. This option involves end-to-end QoS control signalling takes place only between the initiating ASP and the first Network Operator Signalling then takes place between Network Operator Domain RMs to establish end to end control. QoS Signalling to End User domains, in general, will remain the responsibility of the initiating and terminating ASP.

Option 2 describes where the end-to-end QoS control signalling takes place within the Transport domain. In this scenario the transport and QoS mechanisms and policies are homogeneous throughout all Transport Domains or the ICFs between the transport domains can interpret and convert between the different QoS mechanisms.

7.5.38.2 Classification of QoS Signalling Types



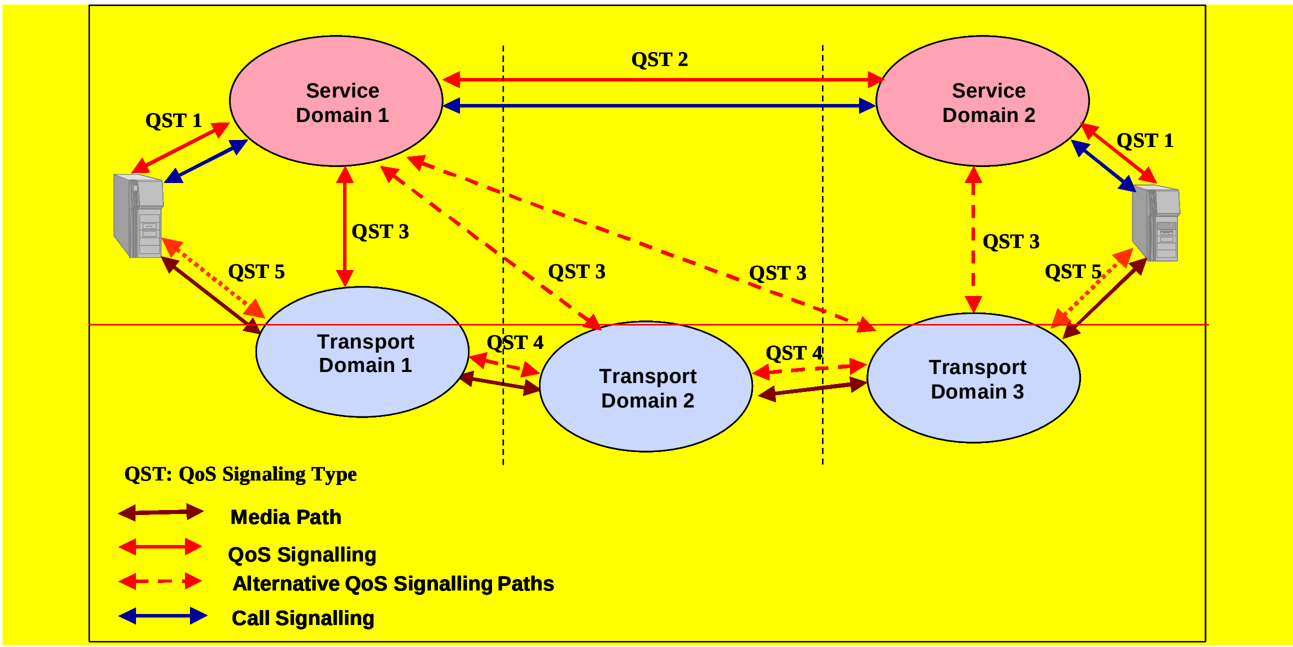


Figure 8 – QoS Signalling Types for calls involving multiple ~~transport~~ Network Operator and S~~s~~ervice D~~d~~omains

QoS signalling can be classified into ~~further specified by defining~~ several QoS signalling types (QSTs) as shown in Figure 7.

~~7.5.3.1~~8.2.1 QoS Signalling Type 1 (QST 1)

QST 1 describes QoS signalling between ~~the~~ an E~~e~~nd U~~u~~ser~~'s QoSM~~ and an ASP~~a service domain's QoSM~~. ~~This signalling takes place in the MM Application Plane.~~

~~7.5.3.2~~8.2.2 QoS Signalling Type 2 (QST 2)

QST 2 describes QoS signalling between two ASPs. ~~the QoSMs in different service domains. This signalling takes place in the MM Application Plane.~~

~~7.5.3.3~~8.2.3 QoS Signalling Type 3 (QST 3)

QST 3 describes QoS signalling between an ASP and a Network Operator. ~~a QoSM in a service domain and a TRM in a transport domain. This signalling takes place between the MM Application Plane and the Packet Based Transport Plane.~~

~~7.5.3.4~~8.2.4 QoS Signalling Type 4 (QST 4)

QST 4 describes QoS signalling between two Network Operators. ~~the TRMs in different transport domains. This signalling takes place in the Packet Based Transport Plane.~~

7.5.3.58.2.5 QoS Signalling Type 5 (QST 5)

QST 5 describes QoS signalling between an End User and a Network Operator. the TRM in the end user's transport domain and the TRM in another transport domain. This signalling takes place in the Packet Based Transport Plane.

7.5.3.68.3 A QoS Signalling ExampleProcedures

Figures 8 – 10 illustrates an example ofthe procedures for QoS signalling for establishing end–to-end a QoS control for a MM application. The QoS signalling may independent of call or media stream establishment or control signalling or be combined with either of these. In the figures, each arrow indicates when each QST signalling is initiated over the entire session period.

- Option 1a

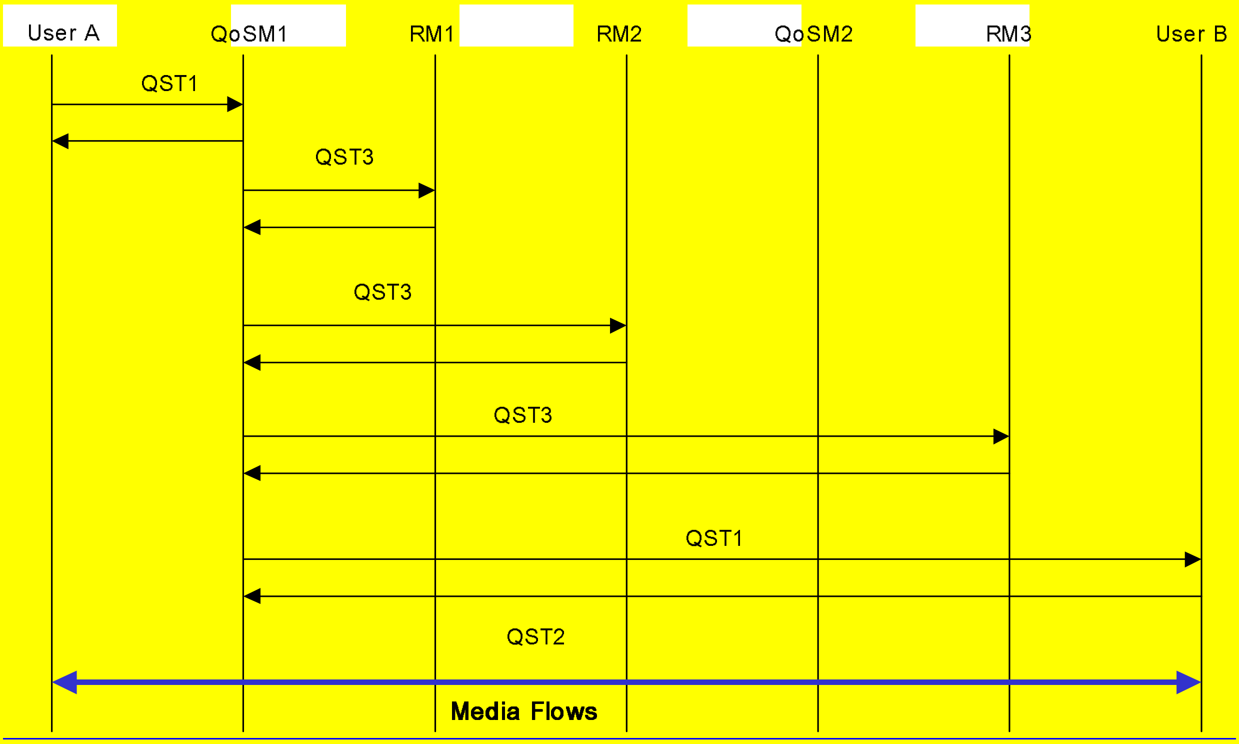


Figure 9 –QoS Signalling Option 1a

- Option 1b~~.~~

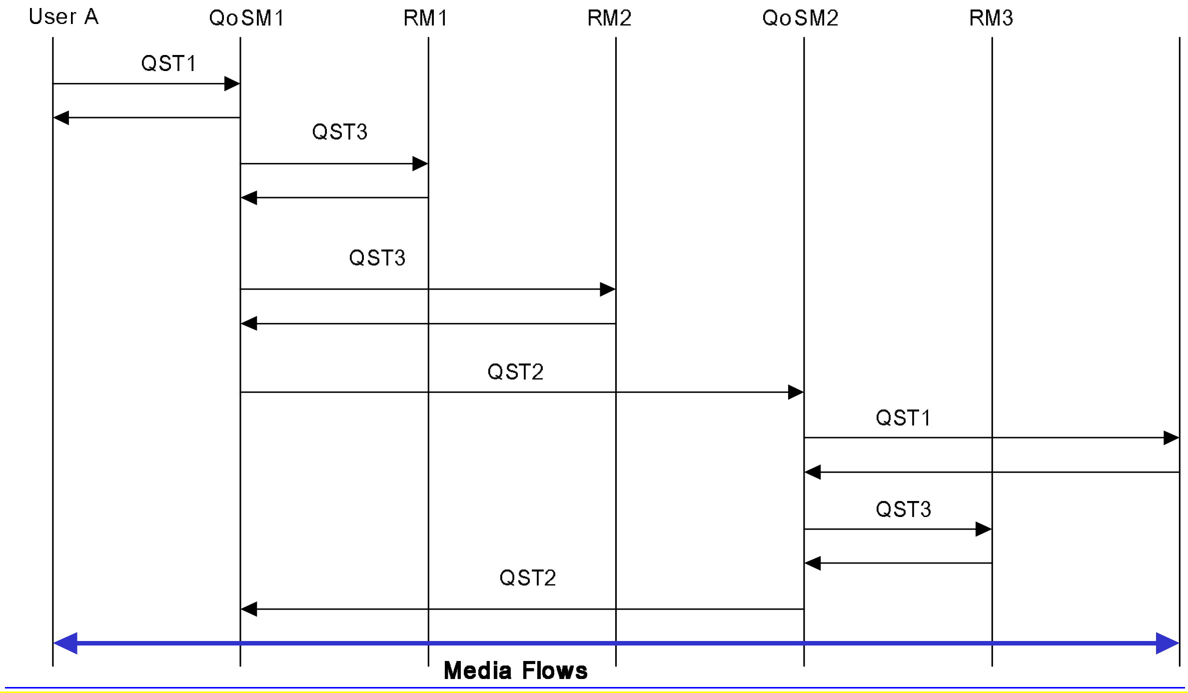


Figure 10 – ~~A~~ QoS Signalling ~~Example 1~~Option 1b

- Option 2

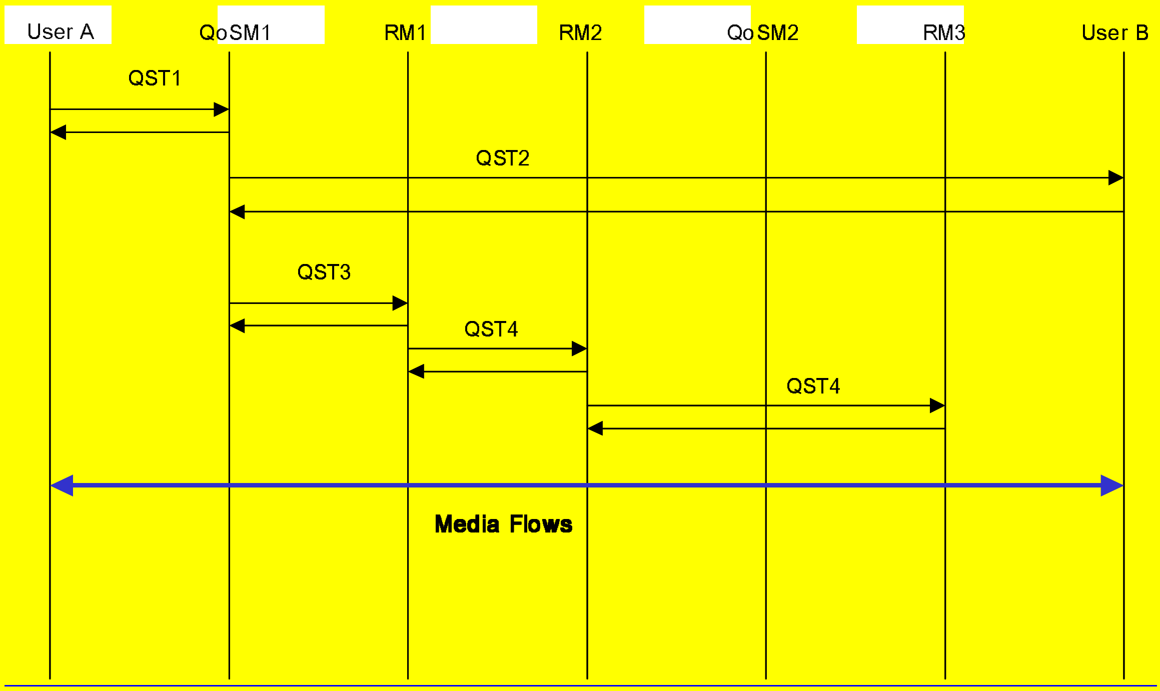
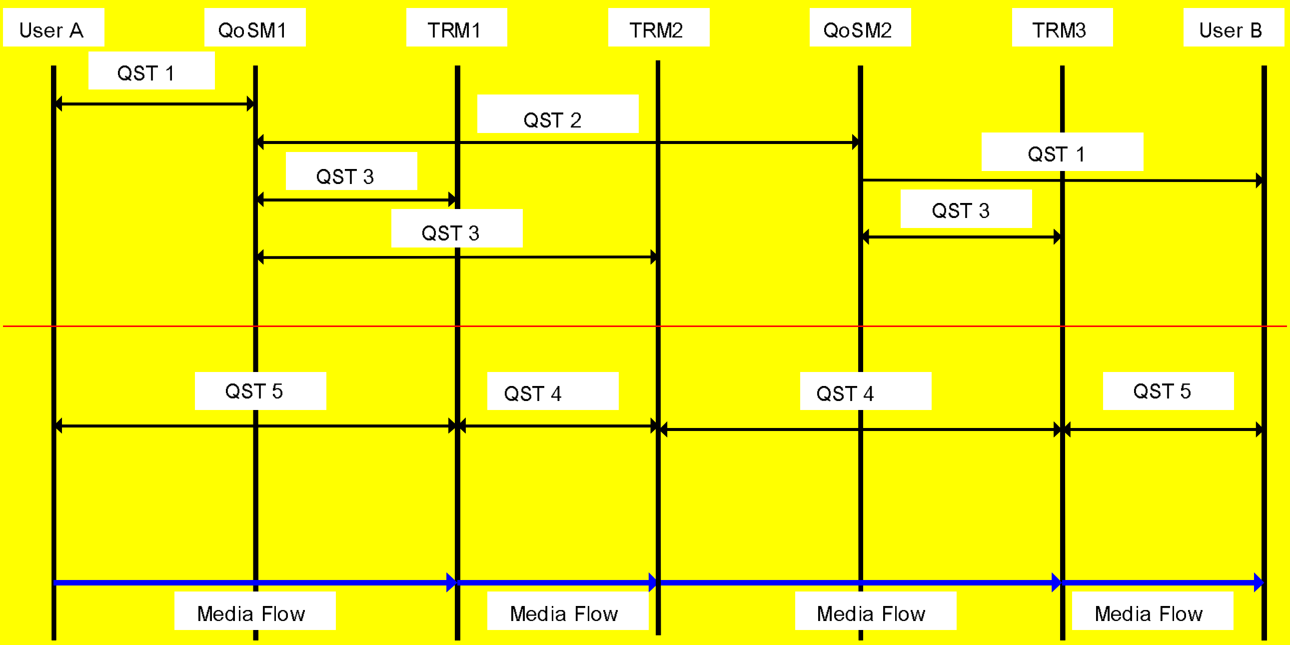


Figure 11 – A QoS Signalling ~~Example 2~~Option 2



~~Figure 1117 – An Example of QoS Signalling~~

~~7.6~~8.4 ~~Generic End-to-End IP QoS Architecture~~Relationship between Signalling Entities

~~7.6.1Applying QoS in an End-to-End Fashion~~

8.4.1 Functional Relationships between End User, Access Network Operator Domain and Initiating Service Domain (QST1)~~.~~

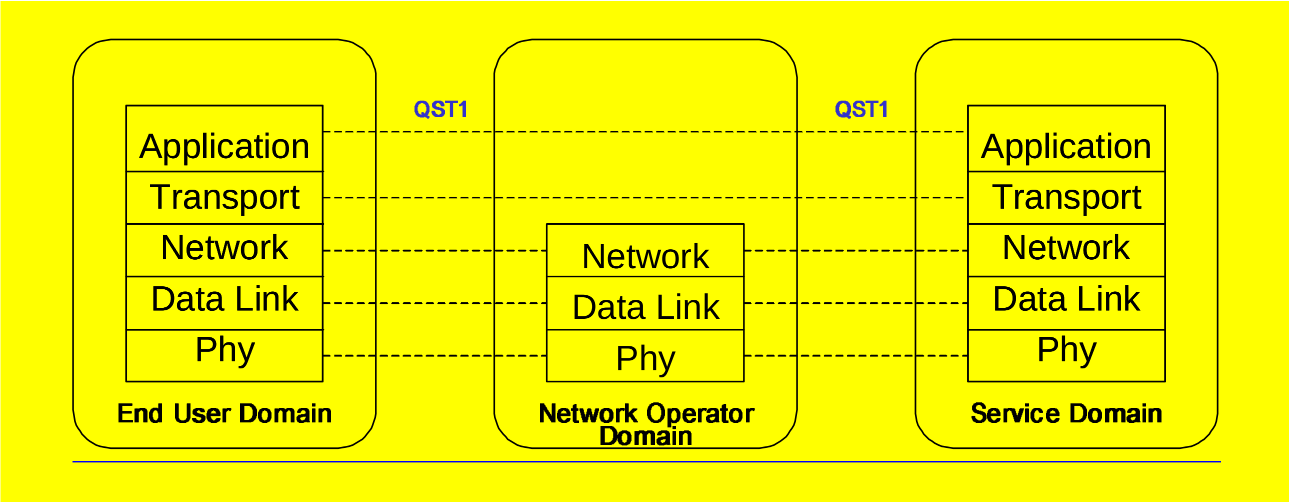


Figure 11 – Interactions between End User and Service Domain via Network Operator Domain

8.4.2 Functional Relationships between two Service Domains and interconnecting, Network Operator Domain(s) (QST2)

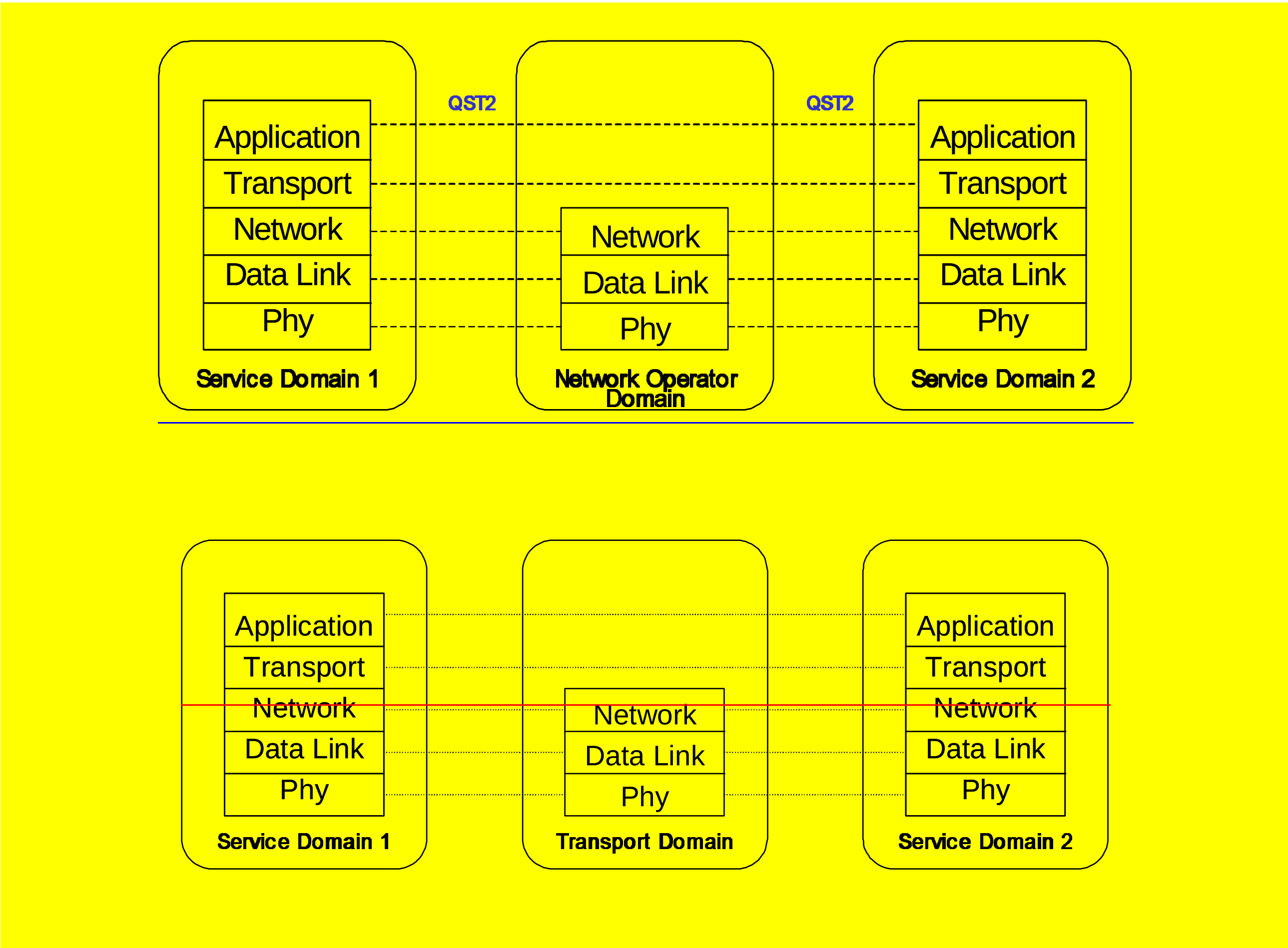


Figure 12 – Interactions between Service Domains via Network Operator Domain

8.4.3 Functional Relationships between two Network Operator Domains (QST4)

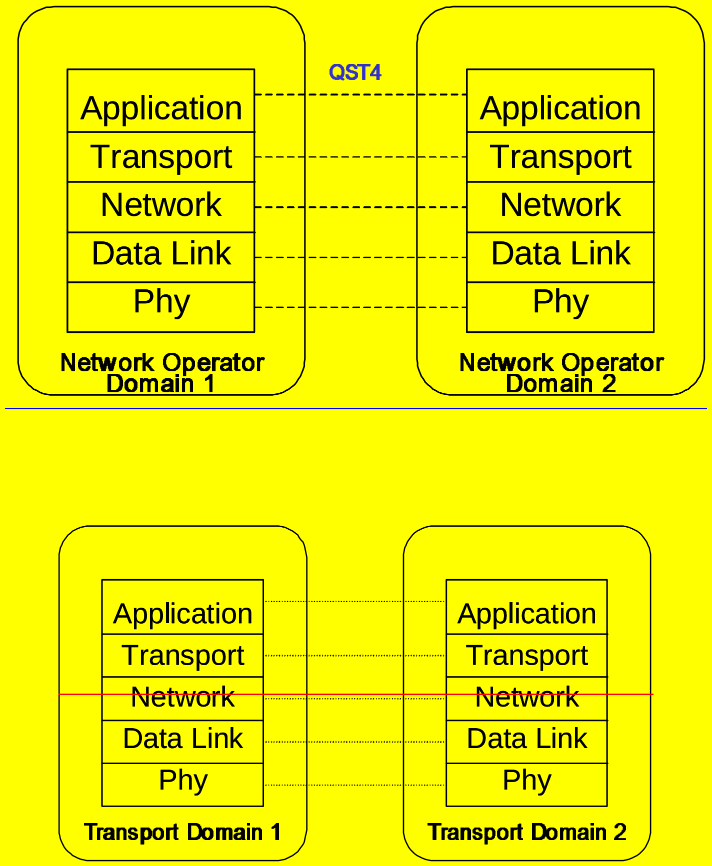


Figure 13 – Interactions between Network Operator Domains

8.4.4 Functional Relationships between a Service Domain and a Network Operator Domain (QST3)

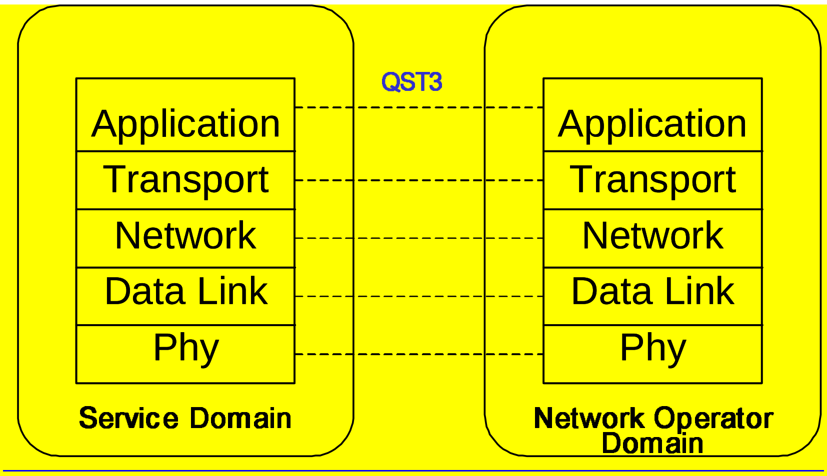


Figure 13 – Interactions between Network Operator Domain and Service Domain

8.4.5 Functional Relationships between two End User Domains via interconnecting Network Operator Domains

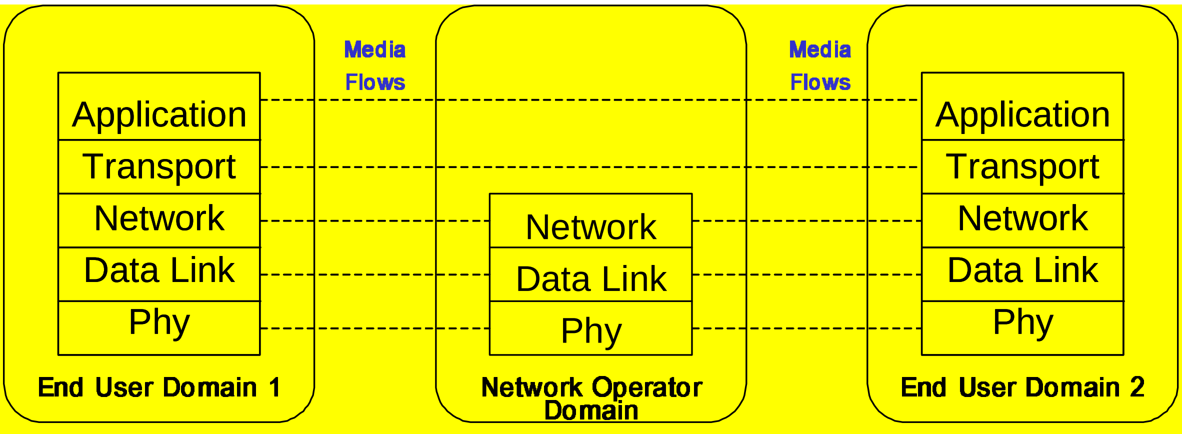


Figure 13 – Interactions between End User Domains via Network Operator Domain(s)

~~8Types of Communications in Transport Domains~~

~~Types of communications in Transport Domains could be divided into packet-based and packet & circuit switched communications. Examples of all packet-based communications are the Internet, ATM, Frame Relay, 3GPP, Wireless LAN(802.11b), SatCom, Cable Network, etc. Examples of packet & circuit switched communication are IP-PSTN, GSM, etc.~~