COMMUNICATIONS ALLIANCE LTD

INDUSTRY GUIDELINE

G632:2012

Quality of Service parameters for networks using the Internet Protocol

G632:2012 Quality of Service parameters for networks using the Internet Protocol Industry Guideline

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Communications Alliance Ltd was formed in 2006 to provide a unified voice for the Australian communications industry and to lead it into the next generation of converging networks, technologies and services. ACIF is a division of Communications Alliance.

EXPLANATORY STATEMENT

This Explanatory Statement is to be read in conjunction with the G632:2012 ***Quality of Service parameters for networks using the Internet Protocol*** Industry Guideline.

This Explanatory Statement outlines the purpose of this Industry Guideline (the Guideline) and the factors that have been taken into account in its development.

Background

ACIF Voice over IP (VoIP) Forums held in 2004 and 2005 identified a number of concerns relating to VoIP provider inter-connectivity, such as treatment or support for IP Quality of Service (QoS) and consistency in prioritizing IP packets carrying telephony services.

In March 2006 ACIF released a discussion paper titled *QoS-Based VoIP Service Interconnectivity* covering a wide range of possible network architectures and resulting technical issues, service issues and community concerns, canvassing industry and community views. Expressed in the majority of responses was a clear desire for an 'implementation guideline' to leverage international standards and best-practices for IP packet QoS marking and handling while establishing consistency of marking and handling schemes.

A Working Committee developed the original version of this IP Network QoS framework Guideline in 2007. In parallel, a separate Working Committee developed a guideline on QoS aspects relating to VoIP services. The 2012 revision of this Guideline has defined additional IP Network QoS Classes to accommodate the growth in demand for additional IP based services that could benefit from QoS.

Increasing access bandwidths have led to increasing demands to deliver video content over IP networks, in both unicast and multicast modes.

It is expected that during the lifetime of the 2012 update to G632, that IPv6 will become more widely used across CSP networks.

In the years leading up to the 2012 revision, the National Broadband Network (NBN) was initiated, as an Australia-wide wholesale layer 2 Ethernet Access network, delivered over a number of media including satellite. The 2012 update includes guidelines for interfacing IP core networks to the NBN layer 2 Access network, for the purpose of delivering QoS-enabled, end-to-end applications.

The Objective of this Guideline

This Guideline is intended as a planning guide to help operators meet QoS performance objectives. It provides a basis for bi-lateral discussions but it does not attempt to describe the details of how service providers and network operators provide a service to their customers with a prescribed QoS.

The Guideline defines a default set of IP Network QoS Classes based on ITU-T Rec. Y.1541 which are recommended for adoption by IP network service providers. Each class has a set of end-to-end performance expectations for the three key network performance parameters, namely delay (or latency), delay variation (or jitter), and packet loss. The Guideline also recommends a set of packet marking parameters to indicate the desired IP Network QoS Class of each packet as it is passed across Network Boundaries.

Consistent adoption of these IP Network QoS Classes will enable applications and services that require 'better than best effort' packet handling to receive consistent and appropriate end-to-end network performance, even when the traffic traverses multiple provider networks between source and destination.

Anticipated Benefits to Subscribers

Subscribers will benefit from improved reliability and performance of applications that require enhanced network characteristics on an end-to-end basis. It is anticipated the development of new and innovative services that require particular levels of network performance, when the providers can be assured that traffic will receive the appropriate handling by other networks they interconnect with, so the end-to-end service will operate as expected.

Subscriber choice of provider will also be enhanced, as allowing service quality commitments to be supported through provider interconnection points will remove the restriction of having to connect all end-points to the same provider's network in order to guarantee a given network performance.

The adoption of a consistent default packet marking scheme by providers will benefit subscribers through simplification of Customer Equipment (CE) provisioning when switching between providers or when connected to multiple providers. Further simplification may occur in the longer term if vendors deliver CE that is pre-set to use the default marking scheme 'out of the box'.

Anticipated Benefits to Industry

Industry will benefit from reduced time, cost and complexity to establish bilateral network interconnects, by defining a baseline for signalling and performance expectations on which they can build agreements. Service providers will be able to offer advanced services with guaranteed performance to more locations.

Anticipated Cost to Industry

Costs to providers will vary depending on the size and scale of network deployments, and on the range of products and services they choose to deliver.

Expected costs to network service providers include staff costs for provisioning and implementing appropriate QoS handling within their network equipment, establishing systems and processes for monitoring and management of performance levels, and establishing commercial agreements and procedures for the connection of services.

The majority of new network equipment supplied currently to service providers is considered to be capable of implementing the QoS marking and handling. However in some cases, the existing network architecture or topology of a service provider may require modifications in order to achieve the performance requirements and this may result in additional costs to the provider.

Other Public Interest Benefits or Considerations

Many end-user services, such as VoIP and interactive client/server databases, make stringent demands on packet-based network performance. Enhanced reliability and guaranteed end-to-end network performance are required before end-users will have the confidence to transition their services from legacy networks to Next Generation Network services that are built on IP packet network infrastructure, while maintaining 'any-to-any' reachability.

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Chairman
IP Network Quality of Service Working Committee

TABLE OF CONTENTS

1 GENERAL

1.1 Introduction

1.1.1 The development of the Guideline has been facilitated by the Communications Alliance through a Working Committee comprised of representatives from the telecommunications industry and Government regulatory agencies.

1.1.2 The Guideline should be read in the context of other relevant Codes, Guidelines and documents, including G633:2012 ***Quality of Service parameters for networks using the Internet Protocol - Test Methods***, G634:2007 ***Quality of Service parameters for Voice over Internet Protocol (VoIP)*** and documents listed in Section 6 REFERENCES.

1.1.3 Statements in boxed text are a guide to interpretation.

1.2 Future Work

1.2.1 This Guideline has considered the application of "static" Quality of Service (QoS) targets for networks (i.e. not requiring QoS negotiation between Carriage Service Providers (CSPs) on a session-by-session basis). Section 7 of ITU-T Rec. Y.1541 states further study is required to determine how to achieve the performance objectives when multiple network operators are involved.

1.2.2 Work is proceeding in international forums on "dynamic" QoS negotiation using explicit signaling mechanisms on a session-by-session basis, which requires a higher level of coordination between CSPs. This has been allocated to future work to allow time for international recommendations and standards to stabilise.

1.2.3 The assumption of growing IP bandwidth in access and core networks means that these dynamic methods may not be required for some services (e.g. voice), but may become more important for bandwidth-intensive applications (e.g. video-on-demand).

1.2.4 This Guideline has defined IP Network QoS Classes for expected applications for which there is a demonstrated need, or for which carriage is offered on NBN. Additional IP Network QoS Classes may be defined in future revisions as further products and applications are planned which require end-to-end performance guarantees across multiple networks.

1.2.5 The use of a Measurement Point (MP) that is not the Network Boundary and/or the User Network Interface (UNI) can lead to differing views on whether or not the impairments that arise between the various points should be added to, subtracted from or included as part of a target value for a performance objective. Therefore the target performance budgets when the MP, the Network Boundary and the UNI do not align are for further study.

1.2.6 Transport of Time Division Multiplexing (TDM) streams over IP (in Asynchronous Transfer Mode networks usually carried as Constant Bit Rate) may be carried as IP Network QoS Class 0, or may require a different IP Network QoS Class to be defined with a different packet marking scheme. Therefore this is for further study.

1.3 Scope

1.3.1 This Guideline applies to CSPs providing IP transport services within Australia for IP applications that require packet handling different from "best efforts" to operate effectively or reliably.

1.3.2 The Guideline recommends performance objectives of networks for IP packets accepted across a UNI into each defined IP Network QoS Class, addressing "end-to-end network" or bearer QoS.

1.3.3 The Guideline recommends layer 3 packet marking mechanisms for indicating the expected IP Network QoS class that a given IP packet should be treated as belonging to by the receiving network.

1.3.4 It also recommends equivalent layer 2 frame marking mechanisms for scenarios where these layer 3 packets are transported over a sub-network which only provides layer 2 based QoS/traffic management.

NOTE: The packet marking aspects may also be applicable to end-user networks and CE that originate IP packets for such applications for transport across CSP networks, however performance aspects relating to end-user networks and CE are out of scope.

1.3.5 The Guideline does not address processes for the measurement of QoS performance.

NOTE: Refer to G633 for information on the measurement of QoS performance.

1.3.6 The Guideline does not address the performance requirements of any specific application or service that relies on a network using IP (e.g. VoIP services).

NOTE: Refer to G634 for information on the QoS performance for voice services that rely on a network using IP.

1.4 Objectives

The objectives of the Guideline are to facilitate consistent and predictable QoS-enabled handling for packets that cross multiple networks, by:

(a) defining a default set of IP Network QoS Classes for IP transport services for use across Australian networks based on IP;

(b) addressing packet delay, packet delay variation and packet loss as primary network requirements; and

(c) including definition of multiple performance levels for each of these primary network requirements.

1.5 Guideline review

Review of the Guideline will be conducted within five years of publication.

2 ACRONYMS, DEFINITIONS AND INTERPRETATIONS

2.1 Acronyms

For the purposes of the Guideline:

3G

means 3rd Generation of mobile phone technologies

3GPP

means 3rd Generation Partnership Project

ACIF

means Australian Communications Industry Forum

CE

means Customer Equipment

CSP

means Carriage Service Provider

DSCP

means DiffServ Code Point

DSL

means Digital Subscriber Line

GW

means Gateway Router

ICMP

means Internet Control Message Protocol

IEEE

means Institute of Electrical and Electronic Engineers

IETF

means Internet Engineering Task Force

IP

means Internet Protocol

IPDV

means IP packet Delay Variation

IPLR

means IP packet Loss Ratio

IPTD

means IP packet Transfer Delay

ITU-T

means International Telecommunications Union – Telecommunications Standardization sector

MP

means Measurement Point

NB

means Network Boundary

NBN

means National Broadband Network

NNI

means Network-to-Network Interface

QoS

means Quality of Service

RFC

means Request For Comment

TC

means Traffic Class

TCP

means Transmission Control Protocol

TDM

means Time Division Multiplexing

UMTS

means Universal Mobile Telecommunications System

UNI

means User-to-Network Interface

VoIP

means Voice over Internet Protocol

WiMAX

means Worldwide Interoperability for Microwave Access

2.2 Definitions

For the purposes of the Guideline, the following definitions apply:

Act

means the Telecommunications Act 1997.

Carriage Service Provider (CSP)

has the meaning given by section 87 of the Act.

Carrier

has the meaning given by section 7 of the Act.

Customer Equipment (CE)

has the meaning given by section 21 of the Act.

Internet Protocol (IP)

means the IPv4 protocol defined in the Internet Engineering Task Force (IETF) Request For Comment (RFC) 791, or the IPv6 protocol defined in RFC 2460.

IP packet Delay Variation (IPDV)

means the difference between the actual IPTD of a packet and a reference IPTD for a packet population of interest. The reference IPTD of a population of packets is the minimum IPTD for the packets within the population of interest.

IPDV is a statistical sample, measured over a packet population of interest. Unless otherwise stated, the default quantile is the 10^{-3} quantile – that is, 99.9% of packets should be received within the performance objective.

> *NOTE: IPDV is also referred to as "jitter", and is usually reported in milliseconds.*

IP packet Loss Ratio (IPLR)

means the ratio of total lost IP packets to total transmitted packets in a population of interest. Total lost packets includes any delivered with errors or IPTD greater than 3 seconds.

> *NOTES:*
>
> *1. IPLR is usually reported as a percentage.*
>
> *2. The upper limit value of 3 seconds for IPTD is based on the provisional value for the time limit for a successful packet outcome (refer to ITU-T Rec. Y.1540 clause 5.5.4).*

IP packet Transfer Delay (IPTD)

means the one-way time interval between the moment the first bit of a IP packet crosses an entry point of a network and the moment the last bit of the same packet crosses an exit point of the network.

> *NOTE: IPTD is also referred to as "delay" or "latency", and is usually reported in milliseconds.*

IP Network QoS Class

means a combination of bounds on the performance objectives for IP network parameters between a source UNI and destination UNI.

Layer 2

means Layer 2 in an OSI protocol stack (e.g. Ethernet).

Layer 3

means Layer 3 in a protocol stack (e.g. IP).

Mean IPTD

means the arithmetic average of IP packet transfer delays for a population of interest (ITU-T Rec. Y.1540, Clause 6.2.1).

Measurement Point (MP)

means the closest point to the end user side of the UNI which can transmit and/or receive a packet over an agreed standards based protocol.

NOTE: Refer to Appendix C for more information on the MP.

Network-Boundary (NB)

has the meaning given by section 22 of the Act.

NOTE: Refer to Appendix C for more information on the NB.

Network-to-Network Interface (NNI)

means the point where a network interconnects with another network.

Path MTU Discovery

means the technique defined in the IETF RFC 1191.

User-to-Network Interface (UNI)

means an interface used to connect CE with a CSP's network to access an IP transport service.

NOTE: Refer to Appendix C for more information on the UNI.

3 OVERVIEW

3.1 IP Application Requirements

3.1.1 Traditionally, the TCP/IP protocol suite and networks have been built to a principle that networks will operate on a "best efforts packet delivery, with no guarantees" basis. This principle assigns the responsibility for detecting and correcting transmission problems to the CE and higher-level protocols that require better network conditions. Retransmission (to correct for lost packets), sequence numbering (to correct for duplicated and out-of-order packet delivery), and buffering (to correct for IPDV) are all implemented at the end-points, permitting the networks between the end-points to function over the widest range of transmission systems with variable reliability, latency, transmission capacity and other characteristics.

3.1.2 Correcting for underlying network impairments requires extra time, and this principle suits applications that do not have particular time-sensitive requirements for packet delivery (on timescales smaller than a few seconds) such as bulk file transfer, electronic mail, and general web-browsing.

3.1.3 Increasingly, end-user applications that are more sensitive to network impairments and delays are being deployed, including streaming audio and video, VoIP, and distributed client/server databases. These applications work best across networks that can deliver "better than best-efforts" performance for various characteristics.

3.2 IP Network QoS Classes

3.2.1 There are many applications and services that require similar network performance, so it is useful to define a small number of IP Network QoS Classes into which applications can be mapped. For example, interactive applications and client/server database applications may have a similar requirement for a "low delay" network path, while a one-way video stream and a legacy application intolerant of retransmission delays might require "low packet-loss" network conditions.

3.2.2 This Guideline defines a number of IP Network QoS Classes, including performance expectations for each class, and methods of 'marking' packets to signal to a receiving network which IP Network QoS Class is expected to be applied to the packet as it travels through the network.

3.3 International Precedents

3.3.1 This Guideline is based on a number of international standards and recommendations.

3.3.2 ITU-T Rec. G.1010 defines a set of eight general end-user application classes by considering a two dimensional matrix of "error tolerance" and "delay tolerance", and indicates performance requirements for some 18 end-user applications mapped into these eight general classes. This work is not specifically aimed at IP networks, but rather general end-user applications that might need to operate over several forms of generalized packet-based or circuit-based networks.

3.3.3 ITU-T Rec. Y.1541 defines a set of eight IP network QoS Classes (see Appendix A for a summary) with performance requirements that are intended to be applied across potentially multiple networks from User-to-Network Interface (UNI) to UNI. There is currently no standard method for allocation of impairments amongst individual network segments. As per section 7 of ITU-T Rec. Y.1541, further study is required to determine how to achieve these performance objectives when multiple network operators are involved.

3.3.4 IETF RFC 4594 (see Appendix B for a summary) defines 12 service classes, differentiated by the tolerance of the traffic to variation in three parameters – packet loss, delay, and jitter. In contrast to the ITU-T approach, RFC 4594 does not define performance targets – rather, it suggests different 'per hop' packet processing behaviours for each class which, if implemented end-to-end, should allow the traffic to be transported to the destination without experiencing adverse conditions for the parameters that are important for that service class.

4 REFERENCE ARCHITECTURE

The performance objectives in this Guideline are statistical in nature, and are expected to be measured over packets in a population of interest that enter a network at a source UNI, travel along a path through one or more concatenated IP network sections, and exit through a destination UNI, possibly connected to a different network. This is shown diagrammatically in Figure 1.

NOTE: This Guideline addresses the "end-to-end network" or bearer QoS. It does not address "user-to-user connection" or teleservice QoS. Performance aspects relating to end-user networks and CE themselves are out of scope of this Guideline.

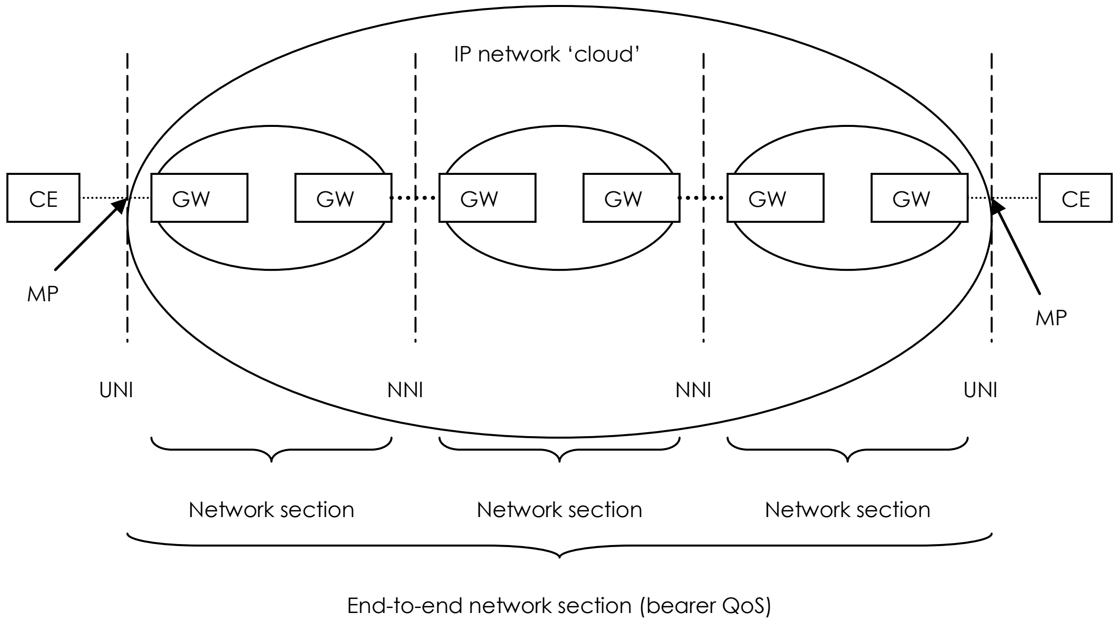

Figure 1
Reference Architecture for IP Network QoS Class Performance

5 GUIDELINES

5.1 Capacity

5.1.1 Transfer capacity is a fundamental QoS parameter, as it has a major impact on the performance of a service.

NOTE: This description is based on section 4 of Y.1541.

5.1.2 This document assumes that a maximum capacity for each Traffic Class has been agreed between the interconnecting parties (e.g. end user-CSP, CSP-CSP). Exceeding this capacity may result in dropped frames, or increased jitter and latency.

5.1.3 The performance parameters below do not apply in periods where packets are delivered in excess of the agreed maximum; for example, discarded or delayed excess packets must not be included in the IPLR or delay measurements.

5.1.4 A CSP may offer relaxed performance objectives when excess traffic is offered.

5.2 Performance Parameters

The parameters that define an IP Network QoS Class in a network are:

(a) IPTD;

(b) IPDV; and

(c) IPLR.

5.3 IP Network QoS Classes and Performance Objectives for Networks

5.3.1 Table 1 defines a set of IP Network QoS Classes and related performance objectives recommended for use in Australian terrestrial networks. These classes are based on ITU-T Rec. Y.1541.

IP Network QoS Class	Description	UNI to UNI Performance Objectives			Typical Applications
		Mean IPTD [4]	IPDV	IPLR	
0	Jitter-sensitive	≤100ms	≤50ms	≤10^{-3}	Voice telephony, real-time telephony signalling, Videoconference
2	Highly interactive, transaction data	≤100ms	-	≤10^{-3}	Multimedia streaming, interactive data
5	Best Efforts	-	-	-	Web browsing, Email
6	Ultra low loss, high capacity	≤100ms	≤50ms @.001%	≤10^{-5}	High quality video delivery

Table 1

IP Network QoS Classes and UNI to UNI performance objectives

NOTES:

1. Methods of evaluating networks against these performance objectives are found in G633.

2. This is a default set of classes. Additional classes may be defined in future as applications emerge which have different network requirements.

3. IPDV for Class 6 is measured at the 10^{-5} percentile, to align with the IPLR.

4. Networks including geostationary satellites incur additional IPTD. In such cases, an additional IPTD allowance of 300ms is recommended.

5. Class 6 is Provisional.

6. Some applications may have tighter packet loss specifications than what is offered by Class 6 (e.g. some implementations of High Definition Video). An option is to employ loss mitigation techniques (e.g. Forward Error Correction) to allow the application to work within that Class.

5.3.2 It is not necessary for a network to provide all IP Network QoS Classes from Table 1.

5.3.3 CSPs may provide other IP Network QoS Classes within their networks.

5.3.4 IPTD targets may not be achievable on some network paths e.g. satellite networks. The overriding principle is that traffic for IP Network QoS Classes where low IPTD is a requirement should be allocated to network paths with the lowest transmission delay.

5.3.5 Paths involving a satellite link, and some terrestrial wireless networks, will not be able to achieve Class 0, Class 2 or Class 6 performance. In these cases, it is recommended that a CSP state the performance objectives its network(s) can achieve for the parameters in clause 5.2.1.

5.4 Packet marking.

5.4.1 A single Network-to-Network Interface (NNI) or UNI may carry traffic from several applications, intended for multiple IP Network QoS Classes. In order for the receiving network to apply the appropriate treatment to each packet in accordance with the desired IP Network QoS Class, they may need to be marked in an appropriate way by the sender.

5.4.2 Recommendations for marking packets using various layer 2 and layer 3 protocols for Table 1 IP Network QoS Classes are in Table 2 below.

IP Network QoS Class	Description	Diffserv Code Point (Note 1)	Layer 2 Packet Marking	Typical applications
			Ethernet p-bits (Note 2,3)	
0	Jitter-sensitive	EF, CS5	5	Voice telephony, real-time telephony signalling
		AF4x	4	Videoconference
2	Highly interactive, transaction data	AF3x, CS3	3	Multimedia streaming, interactive data
5	Best Efforts	AF1x, DF	0	Web browsing, Email
6	Ultra low loss, high capacity	CS4	4	High quality video delivery

Table 2
Recommended packet marking parameters

NOTES:

1. DSCP (Diffserv Code Point) recommendations are sourced from RFC 4594, and are applicable to both IPv4 and IPv6.

2. There are no agreed standards for layer 2 markings. IEEE 802.1D includes some suggestions for Ethernet p-bit markings in an informational appendix. In the absence of clear industry guidance, the recommendations given here are based on the common practice of using the first 3 bits of the DSCP as the layer 2 marking.

> *3. Currently most customer equipment sets p=5, however some set p=6 for jitter-sensitive Ethernet frames. It is suggested that customer equipment using p=6 should migrate to p=5 over time.*
>
> *5. It is recommended that telephony signalling be marked in class 0. However, it may be marked in a different class, based on the desired performance, considering any performance impact on telephony media from exceeding the subscribed capacity.*
>
> *6. P-bits 6 and 7 are normally used for critical network functions in the service provider network. Therefore it is recommended that p-bits 6 and 7 not be used for end-user applications that run over the service provider networks. If traffic marked with p-bit 6 or 7 needs to be sent, there should be agreement between the service provider(s) and customer(s) on treatment of the traffic markings.*
>
> *7. AF4, CS4, CS3 are also valid alternatives for use within Classes 0 and 6, however CSPs should strive to align with the recommended markings in Table 2 in order ensure end-to-end compatibility.*
>
> *8. Voice and video appear as applications in the same QoS Class as they have similar performance requirements. In practise, they may need to be handled differently (including marking) as they have very different traffic characteristics (i.e. one has constant interval short packets, while the other has long bursty packets).*

5.4.3 It is recommended that layer 3 DSCP marking should be used to indicate the desired IP Network QoS Class on UNI links between IP routers. Across a NNI, the traffic classification may be based on layer 2 or layer 3 markings, or other mechanism, as mutually agreed.

5.4.4 IP routers should map layer 3 markings to layer 2 markings to indicate the desired layer 2 Network QoS Class when transported over a sub-network which only provides layer 2 based QoS / traffic management.

5.5 Packet handling

5.5.1 When a packet is received for a supported IP Network QoS Class, the receiving CSP will transport it according to the service agreement it has established with the sender.

> *NOTE: Some of the issues which should be considered in establishing performance parameters for such service agreements are discussed in Appendix B.*

5.5.2 If a packet exceeds the capacity contract for a traffic class, the receiving CSP may take any of the following actions:

(a) Drop the packet;

(b) Carry the packet in another traffic class but with the sender's DSCP marking preserved; or

(c) Carry the packet with relaxed performance objectives.

5.5.3 A receiving CSP should document its policies for modifying packets, including received traffic that exceeds the capacity contract.

5.5.4 When a packet is received, that is marked for an IP Network QoS Class that is not supported within the sender's service agreement with the receiving CSP, the receiving CSP may take any of the following actions:

(a) The packet may be dropped;

(b) The packet may be carried in another class but with the sender's DSCP marking preserved; or

(c) The packet may be remarked only when received at a UNI. Packets should not be remarked when received on an NNI.

5.5.5 For the options in clause 5.5.4(b) and 5.5.4(c), the layer 2 marking may be rewritten or preserved.

5.5.6 A layer 2 network must preserve the DSCP markings of IP packets they transport.

5.5.7 If the packet is discarded by the network, it should send an Internet Control Message Protocol (ICMP) *Destination Network Unreachable* message to the traffic source as appropriate for the IP version, namely:

(a) for IPv4, ICMPv4 Type 3 Code 11 '*Destination Unreachable for Type of Service*'; or

(b) for IPv6, ICMPv6 Type 1 Code 5 '*Destination Unreachable - failed ingress/egress policy*'.

NOTES:

1. For more information refer to RFC 792, RFC 1122 or RFC 4443.

2. Layer 2 networks and links do not generate layer 3 ICMP messages. Conditions which would cause packet discard in a layer 2 network, such as an unsupported layer 2 traffic class or packet too big, should be detected by IP routers, which generate the relevant ICMP messages.

5.5.8 To avoid packet re-ordering it is recommended that packets belonging to the same flow should be allocated to the same IP Network QoS Class and given the same treatment in network queues.

6 REFERENCES

Publication	Title
Australian/ACIF Standard	
AS/ACIF S009:2006	Installation requirements for customer cabling (Wiring Rules) http://commsalliance.com.au/Documents/all/Standards/s009
ETSI Standard	
ETSI TS 123 107 / 3GPP TS 23.107 V10.2.0 (2012-01)	Digital cellular telecommunications system (Phase 2+);Universal Mobile Telecommunications System (UMTS);Quality of Service (QoS) concept and architecture (3GPP TS 23.107 version 10.2.0 Release 10) http://pda.etsi.org/exchangefolder/ts_123107v100200p.pdf
IEEE Standard	
IEEE 802.1D-2004	IEEE standard for local and metropolitan area networks—Media access control (MAC) Bridges http://standards.ieee.org/about/get/802/802.1.html
IEEE 802.16-2009	IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands http://standards.ieee.org/about/get/802/802.16.html
IETF RFC	
RFC 791	Internet Protocol http://tools.ietf.org/html/rfc791
RFC 792	Internet Control Message Protocol http://tools.ietf.org/html/rfc792
RFC 1122	Requirements for Internet Hosts -- Communication Layers http://tools.ietf.org/html/rfc1122
RFC 1191	Path MTU Discovery http://tools.ietf.org/html/rfc1191
RFC 1349	Type of Service in the Internet Protocol Suite http://tools.ietf.org/html/rfc1349
RFC 2460	Internet Protocol, Version 6 (IPv6) http://tools.ietf.org/html/rfc2460

RFC 2474	Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers http://tools.ietf.org/html/rfc2474
RFC 2475	Architecture for Differentiated Services http://tools.ietf.org/html/rfc2475
RFC 4443	Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification http://tools.ietf.org/html/rfc4443
RFC 4594	Guidelines for Diffserv Service Classes http://tools.ietf.org/html/rfc4594
RFC 5127	Aggregation of Diffserv Service Classes http://tools.ietf.org/html/rfc5127
ITU-T Recommendations	
G.1010 (11/01)	End-user multimedia QoS categories http://www.itu.int/rec/T-REC-G.1010-200111-I
Y.1540 (03/11)	IP data communication service- IP packet transfer and availability performance parameters http://www.itu.int/rec/T-REC-Y.1540-201103-I
Y.1541 (12/11)	Network performance objectives for IP-based services http://www.itu.int/rec/T-REC-Y.1541-201112-I
Y.1542 (06/10)	Framework for achieving end-to-end IP performance objectives http://www.itu.int/rec/T-REC-Y.1542-201006-I
Industry Guidelines	
G633:2012	Quality of Service parameters for networks using the Internet Protocol - Test Methods http://commsalliance.com.au/Documents/all/guidelines/g633
G634:2007	Quality of Service parameters for Voice over Internet Protocol (VoIP) services http://commsalliance.com.au/Documents/all/guidelines/g634
Other	
MIT Communications Futures Program	Inter-provider Quality of Service – White Paper http://cfp.mit.edu/publications/index.shtml
NBN Co	NBN Co Fibre Access Service – Traffic Class Performance Discussion Paper http://www.nbnco.com.au/assets/documents/traffic-performance-whitepaper-dec-2011.pdf

APPENDIX A SUMMARY OF INTERNATIONAL REFERENCES

A1 ITU-T Rec. Y.1541 Network Performance Objectives for IP-based Services

Following from an earlier ITU-T recommendation (ITU-T Rec. G.1010) that divided end-user application requirements into eight QoS categories (without regard to any specific networking technology), the ITU-T has defined a set of eight IP network QoS Classes (six main classes, and a further two 'provisional classes' 6 and 7 for further study) for IP networks in ITU-T Rec. Y.1541. The classes are summarized as follows:

QoS Class	IPTD	IPDV	IPLR	Application (examples)	Comment
0	≤100ms	≤50ms (@0.1%)	$\leq 10^{-3}$	Real-time, jitter sensitive, high interaction (VoIP, VTC)	PSTN-quality VoIP
1	≤400ms	≤50ms (@0.1%)	$\leq 10^{-3}$	Real-time, jitter sensitive, interactive (VoIP, VTC).	Satellite-quality VoIP
2	≤100ms	-	$\leq 10^{-3}$	Transaction data, highly interactive (Signalling)	
3	≤400ms	-	$\leq 10^{-3}$	Transaction data, interactive	Business data
4	≤1s	-	$\leq 10^{-3}$	Low loss only (short transactions, bulk data, video streaming)	File transfers
5	-	-	-	Traditional applications of default IP networks	Best-effort
6	≤100ms	≤50ms (@.001%)	$\leq 10^{-5}$	High bit-rate streaming video, with particularly low loss	Low loss
7	≤400ms	≤50ms (@.001%)	$\leq 10^{-5}$	High bit-rate streaming video, with particularly low loss	Low loss

Table 3

ITU-T Rec. Y.1541 IP network QoS Classes & Performance Objectives (Tables 1, 2 & 3)

The end-to-end performance figures in ITU-T Rec. Y.1541 are intended to be applied from UNI to UNI.

A2 IETF RFC 4594 Guidelines for DiffServ Service Classes

QoS signalling in the IP header is accomplished through the DIFFSERV (Differential Services) mechanisms defined in RFC 2474 and RFC 2475. The original ToS (Type of Service – refer to RFC 1349) bits in the IP header are re-interpreted as a Diffserv Code Point (DSCP) value, to indicate to each router the packet passes through that it requires some form of special non-default handling.

RFC 4594 defines twelve generic IP network service classes, and describes recommended per-hop behaviours, queuing algorithms and other packet treatments for each.

The twelve service classes from Table 2 and Table 3 of RFC 4594 are summarized in Table 4 of this Guideline.

Service Class Name	Traffic Characteristics	Tolerance to			DSCP Name	DSCP Value	Application Examples
		Loss	Delay	Jitter			
Network Control	Variable size packets, mostly inelastic short messages, but traffic can also burst (BGP)	Low	Low	Yes	CS6	110000	Network routing
Telephony	Fixed-size small packets, constant emission rate, inelastic and low-rate flows	Very Low	Very Low	Very Low	EF	101110	VoIP telephony bearer
Signalling	Variable size packets, somewhat bursty short-lived flows	Low	Low	Yes	CS5	101000	VoIP telephony signalling
Multimedia Conferencing	Variable size packets, constant transmit interval, rate adaptive, reacts to loss	Low - Medium	Very Low	Low	AF41,AF42, AF43	100010, 100100, 100110	H.323/V2 video conferencing (adaptive)
Real-Time Interactive	RTP/UDP streams, inelastic, mostly variable rate	Low	Very Low	Low	CS4	100000	Video conferencing and Interactive Gaming
Multimedia Streaming	Variable size packets, elastic with variable rate	Low - Medium	Medium	Yes	AF31,AF32, AF33	011010, 011100, 011110	Streaming video and audio on demand
Broadcast Video	Constant and variable rate, inelastic, non-bursty flows	Very Low	Medium	Low	CS3	011000	Broadcast TV & live events
Low-Latency Data	Variable rate, bursty short-lived elastic flows	Low	Low - Medium	Yes	AF21,AF22, AF23	010010, 010100, 010110	Client/server transactions & Web-based ordering
OAM	Variable size packets, elastic & inelastic flows	Low	Medium	Yes	CS2	010000	OAM&P
High-Throughput Data	Variable rate, bursty long-lived elastic flows	Low	Medium	Yes	AF11,AF12, AF13	001010, 001100, 001110	Store and forward applications
Standard	A bit of everything	Not Specified			DF (CS0)	000000	Undifferentiated applications
Low-Priority Data	Non-real-time and elastic	High	High	Yes	CS1	001000	Any flow that has no BW assurance

Table 4

RFC 4594 Service Classes & Mapping of classes to DSCP values (Tables 2 & 3)

A3 3GPP QoS Classes

The 3rd Generation Partnership Project (3GPP) specifies four Universal Mobile Telecommunications System (UMTS) QOS Classes (refer to section 6.3 in ETSI TS 123 107 / 3GPP TS 23.107) for the capability of a UMTS network, namely:

(a) Conversational

(b) Streaming

(c) Interactive

(d) Background.

NOTE: Refer to Table 4 in sec 6.5.1 of ETSI TS 123 107 for a summary of the UMTS bearer service attributes for each of these QoS Classes, which are specific to 3G networks.

A4 IEEE 802.16-2009 (WiMAX) QoS Classes

IEEE 802.16-2009 (also known as WiMAX) defines five QoS Classes. Refer to Table 5 for a summary of the classes.

Service	**Abbrev-iation**	**Definition**	**Typical Applications**
Unsolicited Grant Service	UGS	Real-Time applications generating fixed-rate data	T1/E1 transport
Extended Real-Time Variable Rate Service	ERT-VR	Real-Time applications with variable bit rates requiring guaranteed data rate, delay and jitter	VoIP
Real-Time Variable Rate Service	RT-VR	Real-Time applications with variable bit rates requiring guaranteed data rate and delay	MPEG Video
Non-Real-Time Variable Rate Service	NRT-VR	Applications with variable bit rates requiring guaranteed data rate but are delay insensitive	FTP
Best Effort Service	BE	Applications with no rate or delay requirements	HTTP

Table 5
IEEE 802.16-2009 (WiMAX) QoS Classes

APPENDIX B PARTITIONING OF BEARER QOS

B1 Introduction

When a service passes through multiple interconnected networks, it is necessary for the end-to-end performance targets to be apportioned between each of the networks, in a fair way that ensures the targets are met.

Methods for apportioning impairments between segments of an IP network are described in ITU-T Rec. Y.1542, however it does not recommend a preferred approach. It is therefore inappropriate in this document to be prescriptive about how the partitioning should be done. The following is a provisional recommendation of how this issue can be addressed in practice, in advance of international standards being agreed.

There is also insufficient experience at present to support a recommendation of particular values for the performance targets to be met by individual networks. The example in section B2 below uses values which we believe are reasonable for many network scenarios, but which may need to be revised in the light of testing and operational experience, and to take account of the variety of real-world deployments.

This discussion refers only to the impairments within provider networks; however the approach can be extended to include the effects of end user networks and CE.

B2 Static QoS partitioning

It is assumed that an initial introduction of IP QoS in the Australian network will be done by setting static QoS targets for each of the networks involved in providing the service, since the signalling methods to negotiate QoS targets on a session-by-session basis are not yet stable.

The static allocation method involves setting performance targets for each network involved in the end-to-end service and then combining these to provide the overall expected performance. The main limitation of this approach is that a given session may have a greater or fewer number of transit providers, and consequently higher or lower performance than the class target.

B.2.1 **Recommended Method**

(a) Each provider sets target values for IPTD, IPDV and IPLR for their portion of the network.

(b) The end-to-end expectation for each of these parameters can then be calculated as follows:

  (i) IPTD: Sum the individual network values.

  (ii) IPLR: Multiply the probabilities of successful transmission. (Note that for typical values of IPLR this is equivalent to summing the individual IPLR values).

  (iii) IPDV: No practical method for calculating expected IPDV is available. The best that can be done is an estimate of the probability that IPDV exceeds a target. Refer to the MIT Communications Futures Program white paper on Inter-provider Quality of Service for more information.

(iv) There is a method outlined in ITU-T Rec. Y.1541 for obtaining an IPDV estimate when the standard deviation of delay is known. However this method is only provisionally recommended, and may change in future. In general the standard deviation of delay will not be known. Consequently the provisional method is not recommended.

B3 Example Network

Figure B.1 shows the parties involved in a hypothetical data communication path over multiple provider networks. This example takes the simple case of two core networks joined by a single inter-provider link, with each end user site connected via an access link. Much more complex topologies are likely to exist in practice.

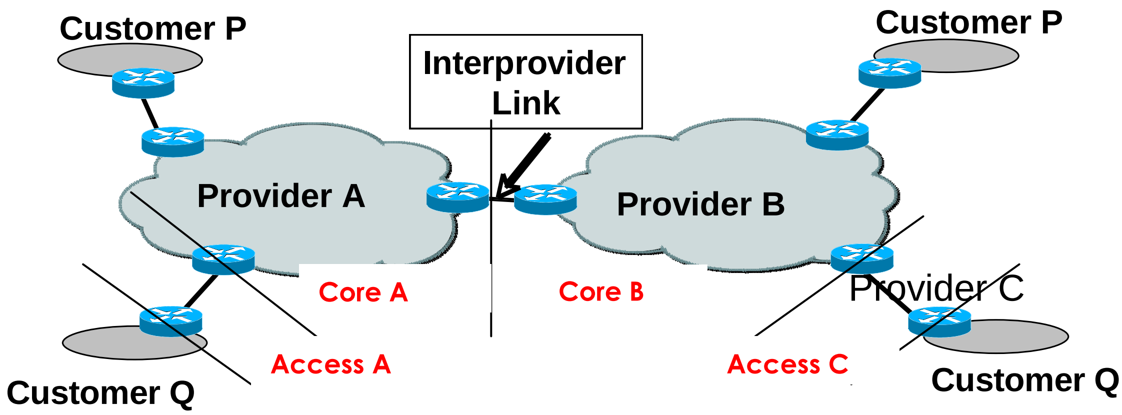

Figure B.1
Example Network for QoS Performance partitioning

NOTE: The NBN is an example of a non-IP access network, such as Provider C and Access C in Figure B.1. *Provider A claims an Access and Core budget.* *Provider B claims a Core budget only.* *Provider C (non-IP network) claims an Access budget only.*

IP routers provide conversion of layer 3 IP QoS markings into layer 2 QoS markings recognised by layer 2 links or CSPs.

IPv4 routers generate ICMP messages in case a packet cannot be forwarded across a layer 2 link, due to unsupported traffic class or frame length, etc. IPv6 networks rely on the endpoints performing Path MTU Discovery to identify when packets cannot be forwarded across a layer 2 link.

In the case where the Customer network does not contain an IP router conforming to G632, a layer 2 CSP may offer translation of L3 IP QoS Classes into layer 2 QoS Classes, for common protocols.

B.3.1 Example performance objectives per network

Table 6 contains some example performance objectives for IP Network QoS Class 0. Refer to the MIT Communication Futures Program white paper on Inter-provider Quality of Service for more information.

These objectives are based on the following considerations:

(a) IPTD values allow for the significant delays due to the finite speed of light on inter-state or international core network links.

(b) In general, the largest share of the impairment budgets should be allocated to access networks because slower link speeds and challenging transmission environments create higher levels of jitter, delay, loss and errors than are generally found in core networks.

(c) For Class 2, the end-to-end performance targets are the same as for class 0, except that there is no IPDV target. Therefore, the same objectives should be used, except that IPDV does not apply.

(d) For Class 5, there are no end-to-end performance targets, so no objectives are required.

Parameter	Access Network	Transit/Core Network
Mean IPTD	≤25ms (Notes 1, 3, 4)	Largest of: a) 15 ms; or b) 10ms + (airpath distance in km) x 1.4 x 0.005ms
99.9% IPDV (Note 2)	≤16ms	≤2ms
IPLR	$\leq 4 \times 10^{-4}$	$\leq 10^{-5}$

Table 6
Example Performance Objectives for IP Network QoS Class 0

NOTES

1. Where a single operator provides both an access and a transit segment, they may consume both allocations.

2. For reasons of measurement practicality, IPDV might be measured to the 99% level, rather than 99.9%.

3. If the distance spanned by the Access tail exceeds 100km, a distance allowance of airpath distance in km) x 1.4 x 0.005ms should be added.

4. If the network includes a geosynchronous satellite hop, add 300ms.

B.3.2 Calculating the expected end-to-end performance

Assuming the providers of the four networks involved in this example have agreed to the above targets, the expected end-to-end performance can be determined using the methods for combining individual network values described above.

IPTD: Sum the individual IPTD values:

IPTD = 25+15+15+25 = 80ms (assuming no additional distance allowance for a long-distance component)

IPLR: Multiply the probabilities of successful transmission

IPLR = 1- $(1\text{-}4\times10^{-4}) \times (1\text{-}10^{-5}) \times (1\text{-}10^{-5}) \times (1\text{-}4\times10^{-4}) = 8.2 \times 10^{-4}$

IPDV: Cannot be reliably calculated. It will lie somewhere between the value for the worst segment of the link, and the sum of all the segments,

16 ms ≤ IPDV ≤ 36 ms (i.e.16+2+2+16)

While the IPDV cannot be reliably calculated, it is possible to estimate the probability of breaching the end-to-end target value. In the case above, the target of 50ms could only be breached by all four segments simultaneously exceeding their 99.9% limit. Consequently this terrestrial network is very unlikely to breach its target under any but the most exceptional circumstances.

	Access			**Core**		
Class	**Mean IPTD (ms)**	**IPDV (ms)**	**IPLR**	**Mean IPTD (ms)**	**IPDV (ms)**	**IPLR**
0	≤25	≤16	$\leq4\times10^{-4}$	Largest of: a) 15 ms; or b) 10ms + (airpath distance in km) x 1.4 x 0.005ms	≤2	$\leq10^{-5}$
2	≤25	-	$\leq4\times10^{-4}$		-	$\leq10^{-5}$
6	≤25	≤16 @0.001%	$\leq4\times10^{-6}$		≤2 @0.001%	$\leq10^{-7}$
5	-	-	-	-	-	-

Table 7

Example Performance Objectives for IP Network Supporting multiple QoS Classes

NOTES

1. Use of a geostationary satellite link adds 300ms IPTD – refer to traffic classes 1, 3 or 7 in Table 3.

B4 Worked Example – International Network

This example network demonstrates the calculations of end-to-end performance and partitioning of performance impairments across multiple network segments in a hypothetical international situation.

Figure B.2 shows a hypothetical network path, where an Antarctic scientific research agency has asked a network integrator to establish an IP Network QoS Class 2 network link between laboratories in Hobart and Dunedin.

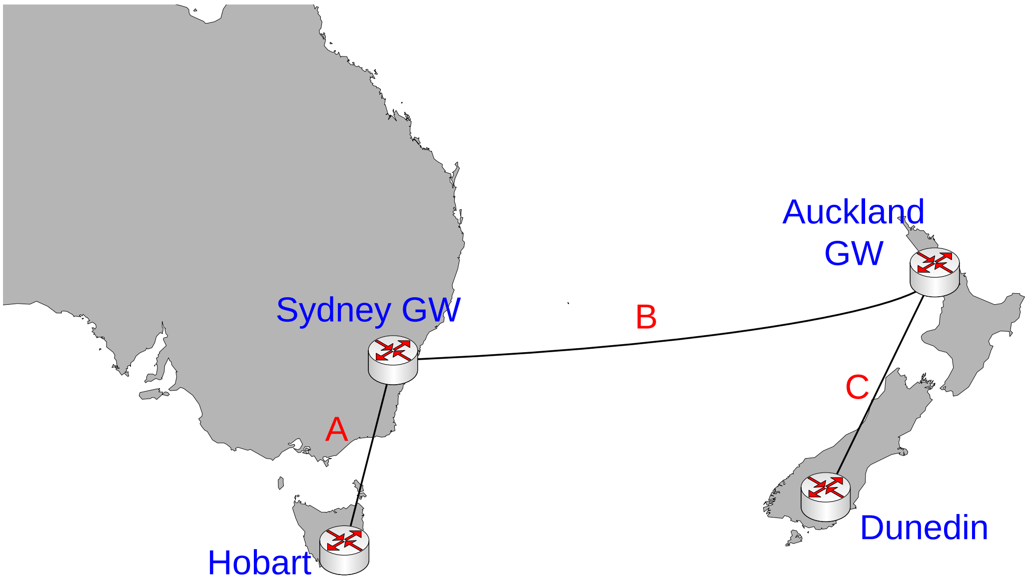

Figure B.2
Worked Example for QoS Performance partitioning

The network integrator contracts one provider to provide link A between the Sydney international gateway and Hobart, a different provider to provide link C between the Auckland international gateway and Dunedin, and a third provider to provide the subsea link B between the international gateways in Sydney and Auckland.

Each provider confirms that its network will apply appropriate prioritization to achieve IP Network QoS Class 2 performance to each packet marked with DSCP value of CS3.

Assume each provider provides its own Service Level Agreement for IP traffic marked with DSCP value of CS3 as follows:

Segment	IPTD SLA (ms)	IPDV SLA (ms)	IPLR SLA	Notes
Provider A	30	2	0.03%	Australian segment
Provider B	20	2	0.01%	International Segment
Provider C	25	10	0.05%	NZ segment

Table 8
Example Service Level Limits for service providers

Combining the separate commitments according to the processes described in B.3.2 gives:

IPTD commitment by summing (30+20+25) = 75 ms IPTD end-to-end

IPLR commitment by multiplication of probabilities = 0.09%

IPDV commitment by sum-of-squares = 10.4ms up to 14ms

Referring to Table 1, the end-to-end path should comply with IP Network QoS Class 2 for IPTD and IPLR. (a limit on IPDV is not specified for IP Network QoS Class 2), so the network integrator can offer these performance commitments to the customer research agency.

> *NOTES:*
>
> *1. International networks are for future study as this Guideline has been primarily developed for CSPs providing IP transport services within Australia (refer Clause 1.3.1).*
>
> *2. Some paths (Australian plus international) may be too long for the IPTD targets in Table 1 to be achievable (refer Clauses 5.3.4 and 5.3.5).*

B5 Worked Example – Australian Domestic Network

This example network demonstrates the calculations of end-to-end performance and partitioning of performance impairments across multiple network segments in a hypothetical Australian situation, including a third-party FTTP access network segment.

Figure B.3 shows a hypothetical network path where a provider wishes to supply its customer with a point-to-point IP link between a headquarter location in Brisbane and a branch office located in Perth. The provider maintains an intercapital transmission network with provider PoPs in Brisbane and Perth. The provider proposes to establish the 'Access A' link as a gigabit Ethernet link on point-to-point optical fibre (assume ~10km length). The provider proposes to use a FTTP access network segment from a separate wholesale provider for the 'Access B' link to the branch office premises.

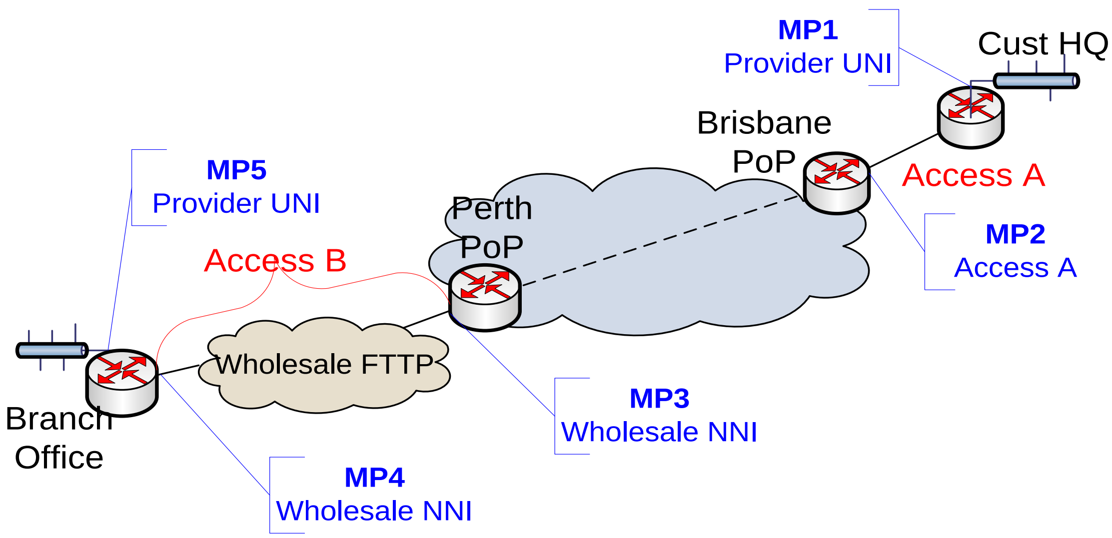

Figure B.3
Worked Example for QoS Performance partitioning

The customer has requested that bidirectional capacity be provisioned with end-to-end performance within IP Network QoS Class 0 performance specifications, guaranteed by the provider in a Service Level Agreement.

The end-to-end path for this Service Level Agreement is between the two Provider UNI ports corresponding to MP1 and MP5.

Examining the budget and expected maximum impairments for each segment in turn:

END-To-END IPTD:

Segment	Budget IPTD	Expected IPTD	Note
MP1-MP2 (Access A)	≤25 ms	≤ 6 ms (measured)	10km dark fibre as gigabit Ethernet, plus PE router
MP2-MP3 (intercapital core)	35.2 ms	34 ms (measured)	Airpath 3605 km
MP3-MP4 (Access B)	≤25 ms	≤25 ms (wholesale provider specified)	Assumes the use of an access network consistent with Table 6.
MP4-MP5 (PE router)		≤4 ms	Typical Specification of typical routers
TOTAL	75 ms	≤69 ms	

Table 9

Worked Example IPTD Performance Design for IP Network QoS Class 0

As the expected end-to-end IPTD of less than 69ms is less than the IP Qos Class 0 IPTD specification of 100ms, this service will comply with the expected SLA.

END-To-END IPLR:

Segment	Budget IPLR	Expected IPLR	Note
MP1-MP2 (Access A)	$\leq 4\times10^{-4}$	$\leq 10^{-5}$	10km dark fibre as gigabit Ethernet, plus PE router
MP2-MP3 (intercapital core)	$\leq 10^{-5}$	$\leq 10^{-5}$	
MP3-MP4 (Access B)	$\leq 4\times10^{-4}$	$\leq 4\times10^{-4}$	Assumes an access network consistent with Table 6
MP4-MP5 (PE router)		$\leq 10^{-6}$	Typical specification of typical router
TOTAL	$\leq 8.1\times10^{-4}$	$\leq 4.21\times10^{-4}$	See B.3.2 above

Table 10

Worked Example IPLR Performance Design for IP Network QoS Class 0

As the expected end-to-end IPLR of better than 4.21×10^{-4} is better than the IP Qos Class 0 IPLR specification of $\leq 10^{-3}$, this service will comply with the expected SLA.

END-To-END IPDV:

Segment	Budget IPDV	Expected IPDV	Note
MP1-MP2 (Access A)	≤16ms	≤ 2 ms	10km dark fibre as gigabit Ethernet, plus PE router
MP2-MP3 (intercapital core)	≤2ms	≤2ms	
MP3-MP4 (Access B)	≤16ms	≤16ms	Assumes an access network consistent with Table 6
MP4-MP5 (PE router)		≤2ms	Typical specification of typical router
TOTAL	16ms ≤ IPDV ≤ 34 ms	16ms ≤ IPDV ≤ 22 ms	See B.3.2 above

Table 11

Worked Example IPDV Performance Design for IP Network QoS Class 0

As the expected end-to-end 99.9% IPDV is less than 22ms, , and this is better than the IP Qos Class 0 IPDV limit of 50ms , this service will comply with the expected SLA.

Combining these to summarise the design goal performance:

QoS Criteria	Class 0 Limit	Expected path performance	Margin	Note
IPTD	≤100ms	≤ 69ms	31ms	Complies
IPLR	$\le 10^{-3}$	$\le 4.2x10^{-4}$	2.3 x	Complies
IPDV	≤50ms	≤22ms	28ms	Complies

Table 12

Worked Example IPDV Performance Design for IP Network QoS Class 0

The service provider can be satisfied that under normal conditions the end-to-end service will remain comfortably within the performance commitment for IP Network QoS Class 0.

APPENDIX C – SUPPLEMENTARY INFORMATION

C1 The Measurement Point, The Network Boundary And The User Network Interface

C.1.1 This Appendix provides supplementary information on the related roles of the Measurement Point (MP), the Network Boundary (NB) and the UNI in this Guideline.

> *NOTE: Refer to Appendix J of AS/ACIF S009:2006 for more information on the NB, including multiple examples of the NB for a variety of access network types.*

C.1.2 Some guiding principles in understanding the relative roles of the MP, the NB and the UNI are:

(a) a CSP is responsible for UNI-UNI or UNI-NNI impairments within its network(s);

(b) a CSP is not responsible for rectifying impairments arising from outside its network(s);

(c) if the MP, the NB and the UNI are the same point (for an example, refer to clause C.1.3, Note 4(a) below) then the NB and the UNI are likely to be appropriate as the MP for measuring performance against the objectives in Table 1;

(d) If the NB and/or UNI are inappropriate as the MP (e.g. one is unable to measure an IP packet at the NB and/or the UNI), then the MP, the NB and the UNI do not align, and it requires the definition of an alternate MP

C.1.3 The use of a MP that is not the NB and/or the UNI can lead to differing views on whether or not the impairments that arise between the various points should be added to, subtracted from or included as part of a target value for a performance objective. Therefore the target performance budgets when the MP, the NB and the UNI do not align are for further study.

> *NOTES*
>
> *1. Impairments (e.g. delay) can arise in the processing of IP packets by measuring equipment (e.g. encapsulation by test equipment of IP packets into a lower layer protocol for transmission or reception).*
>
> *2. If such impairments are not included in the overall performance objective for the given IP Network QoS Class then it can be helpful to identify those impairments and share information on why it may be inappropriate to include them. This can help ensure there is a common understanding among relevant stakeholders (e.g. end users, network operators) in assessing performance.*

3. Target performance budgets should take into account a number of factors including:

(a) the appropriate apportionment of impairments;

(b) the minimum multiplexing and/or framing requirements (e.g. by an end user);

(c) the applicable performance targets; and

(d) the type of equipment e.g. use of typical, commercially available CE.

4. Three examples of different network types follow to help illustrate variations in the MP location that can arise.

(a) For an optical fibre based IP transport service:
(i) the NB is a network terminating unit/device;
(ii) the UNI is also the NB; and
(iii) the MP is likely to be the NB and UNI.

(b) For a wired, DSL based, IP transport service:
(i) the NB might be the first wall socket or main distribution frame on the end user premises;
(ii) the UNI might be the same as the NB; but
(iii) the MP might be the port on the end user side of a reference DSL modem.

(c) For a wireless, 3G based, IP transport service:
(i) the NB might be the CSP's receive and/or transmit antenna at the 3G base station,
(ii) the UNI might be the NB, but
(iii) the MP might be the output of a reference data card used to access the IP transport service.

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ACMA	Non-voting	Chris Wong
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Alcatel-Lucent	Non-voting	Mickey Vucic
Internet Society of Australia	Voting	Paul Brooks
NBN Co	Voting	Rod Ferguson
SingTel Optus	Voting	Krishna Ramalingam
SingTel Optus	Non-voting	Sam Mangar
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This Working Committee was chaired by Paul Brooks.

James Duck of Communications Alliance provided project management support.

Communications Alliance was formed in 2006 to provide a unified voice for the Australian communications industry and to lead it into the next generation of converging networks, technologies and services.

In pursuing its goals, Communications Alliance offers a forum for the industry to make coherent and constructive contributions to policy development and debate.

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