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SERIES M: TMN AND NETWORK MAINTENANCE: INTERNATIONAL TRANSMISSION SYSTEMS, TELEPHONE CIRCUITS, TELEGRAPHY, FACSIMILE AND LEASED CIRCUITS

International transport network

Performance objectives and procedures for provisioning and maintenance of IP-based networks

ITU-T Recommendation M.2301

ITU-T M-SERIES RECOMMENDATIONS

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ITU-T Recommendation M.2301

Performance objectives and procedures for provisioning and maintenance of IP-based networks

Summary

This Recommendation provides performance objectives and procedures for provisioning and maintenance of IP-based networks. It focuses attention on parameters that significantly affect the quality of service perceived by the customer, and the methods of measuring those parameters. These include those parameters that affect delay performance at the application layer. Performance limits for temporary dial-up access links, end-customer owned portions and MPLS networks are not covered by this Recommendation and are for further study. However, the performance of fixed access links, whose routing does not change, is covered.

Source

ITU-T Recommendation M.2301 was prepared by ITU-T Study Group 4 (2001-2004) and approved under the WTSA Resolution 1 procedure on 14 July 2002.

Keywords

Autonomous system, Border gateway protocol, Border gateway router, Bringing-into-service procedure, Intrusive measurements, IP operator domain, Maintenance procedure, Management information base, MIB monitoring, Non-intrusive measurements, Operator border gateway router, Performance objectives, Provisioning, Quality of service, Reference network.

FOREWORD

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

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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CONTENTS

Introduction

This Recommendation provides performance objectives and procedures for provisioning and maintenance of IP-based networks owned by different operators. This is regardless of the transport technology supporting the IP network and the higher layers to be implemented over IP. These objectives include error performance, delay performance and availability. This Recommendation defines the parameters and their associated objectives based on the principles in ITU-T Rec. Y.1540. This Recommendation uses a reference model based on the concept of IP Operator Domains (IPODs) and their interconnecting links. An IPOD consists of one or more Autonomous Systems (ASs) and their interconnecting links. The interconnecting links between IPODs involve a change in jurisdictional responsibility.

This Recommendation also provides, in an appendix, guidance on the performance objectives and limits for IP network resources (e.g. routers, subnetworks etc.), which are owned and managed by a single operator. However, the allocation of performance inside an IP network operator's domain or network portion, is the responsibility of each operator to ensure the end-to-end performance over their domain or network portion meets the limits given in this Recommendation.

ITU-T Rec. Y.1540 provides a general framework for applying these limits. Guidance on the methods and procedures for applying these limits in provisioning and maintenance are given in this Recommendation.

This Recommendation uses certain principles that are the basis of the maintenance of a digital network:

- it is desirable to do in-service, continuous measurements. In some cases, out-of-service measurements may be necessary;
- performance limits of IP flows are independent of the supporting transport, but the allocation to network sections may be dependent on the transport medium used.

ITU-T Recommendation M.2301

Performance objectives and procedures for provisioning and maintenance of IP-based networks

1 Scope

This Recommendation provides performance objectives and procedures for provisioning and maintenance of IP-based networks owned by different operators. This is regardless of the transport technology supporting the IP network and the higher layers to be implemented over IP. These objectives include error performance, delay performance and availability. This Recommendation also provides guidance, in an appendix, on the performance objectives and limits for IP network resources (e.g. routers, subnetworks etc.), which are owned and managed by a single operator. Performance limits for temporary dial-up access links, end-customer owned portions and MPLS networks are not covered by this Recommendation and are for further study. However, the performance of fixed access links, whose routing does not change, is covered.

This Recommendation provides the network QoS classes needed to support user-oriented QoS categories. Accordingly, this Recommendation is consistent with the general framework for defining quality of communication services in ITU-T Rec. G.1000 [1], and with the end-user multimedia QoS categories needed to support user applications given in ITU-T Rec. G.1010 [2].

NOTE – This Recommendation uses parameters defined in ITU-T Rec. Y.1540 [4] that can be used to characterise IP network performance provided using IPv4. Applicability or extension to other protocols (e.g. IPv6) is for further study.

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.

[1] ITU-T Recommendation G.1000 (2001), *Communications Quality of Service: A Framework and Definitions*.

[2] ITU-T Recommendation G.1010 (2001), *End-user multimedia QoS categories*.

[3] ITU-T Recommendation M.60 (1993), *Maintenance terminology and definitions*.

[4] ITU-T Recommendation Y.1540 (1999), *Internet protocol data communication service – IP packet transfer and availability performance parameters*.

[5] ITU-T Recommendation Y.1541 (2002), *Network performance objectives of IP-based services*.

[6] IETF RFC 1213 (1991), *Management Information Base for Network Management of TCP/IP–based internets: MIB-II*.

[7] IETF RFC 1267 (1991), *A Border Gateway Protocol 3 (BGP-3)*.

[8] IETF RFC 2011 (1996), *SNMPv2 Management Information Base for the Internet Protocol using SMIv2*.

[9] IETF RFC 2012 (1996), *SNMPv2 Management Information Base for the Transmission Control Protocol using SMIv2*.

[10] IETF RFC 2013 (1996), *SNMPv2 Management Information Base for the User Datagram Protocol using SMIv2*.

3 Terms and definitions

General terms and definitions related to maintenance are provided in ITU-T Rec. M.60 [3] and for IP performance are given in ITU-T Rec. Y.1540 [4]. This Recommendation defines the following terms:

3.1 Access Gateway (AG): The IP network equipment that provides access to the AS and terminates the access protocol from the user.

3.2 Autonomous System (AS): An IP network controlled and managed by a single authority and identified by a specific AS number in the whole Internet. An IP network operator may own and manage one or more ASs.

3.3 Border Gateway Protocol (BGP): The Inter-Autonomous System routing protocol defined in RFC 1267 [7] that allows an AS to exchange routing information with other ASs.

3.4 Border Gateway Router (BGR): A router, belonging to an AS, that exchanges network reachability information with the neighboured ASs.

3.5 connectivity: The ability of an AS to provide a number of routes to its customers' traffic. An AS achieves whole Internet connectivity from its interconnection with other ASs.

3.6 Customer Premises Equipment (CPE): Any network equipment sited on the customer's premises used to connect with an AS. This may include simple modems e.g. DSL, multiplexers, routers, switches or complete customer local area networks.

3.7 IP Operator Domain (IPOD): Any connected subset of ASs together with all the links that interconnect them, which are under a single jurisdiction. The term IPOD can be used to refer to a single AS or any number of ASs and their interconnecting links. It can also be used to represent an entire single operator IP network and is defined between two OBGRs.

3.8 Management Information Base (MIB): The database in a network element that contains configuration, event and performance data that is accessible by a management system.

3.9 Measurement Point (MP): The physical or logical point at which measurements can be made and to which the data obtained is related. In the context of this Recommendation, this is typically at an OBGR.

3.10 Network Interface (NI): The interface between the access network and the customer installation.

3.11 Operator Border Gateway Router (OBGR): A router, belonging to an IPOD, that exchanges network reachability information with the neighboured IPOD. It is situated at the edge of an IPOD.

3.12 provisioning: The installation, assignment and commissioning (including bringing-into-service testing) of network resources.

4 Abbreviations

This Recommendation uses the following abbreviations:

AG Access Gateway

AL Access Line

AS Autonomous System

BGP Border Gateway Protocol

BGR	Border Gateway Router
CPE	Customer Premises Equipment
DSL	Digital Subscriber Line
EGP	Edge Gateway Protocol
GbE	Gigabit Ethernet
ICMP	Internet Control Management Protocol
IP	Internet Protocol
IPDR	IP Packet Discard Rate
IPDV	IP Packet Delay Variation
IPER	IP Packet Error Ratio
IPLR	IP Packet Loss Ratio
IPOD	IP Operator Domain
IPTD	IP Packet Transfer Delay
MIB	Management Information Base
MP	Measurement Point
MPEG	Motion Picture Experts Group
MPLS	Multi-Protocol Label Switching
NI	Network Interface
OBGR	Operator Border Gateway Router
OC	Optical Channel
PO	Performance Objective
QoS	Quality of Service
R	Router
RFC	Request For Comment
SNMP	Simple Network Management Protocol
STM	Synchronous Transport Module
STS	Synchronous Transport Signal
TCP	Transmission Control Protocol
TMN	Telecommunication Management Network
VPN	Virtual Private Network

5 Reference network and procedures

Figure 1 shows a typical flow of an IP customer's traffic, through an IP network across a number of IPODs to the distant end.

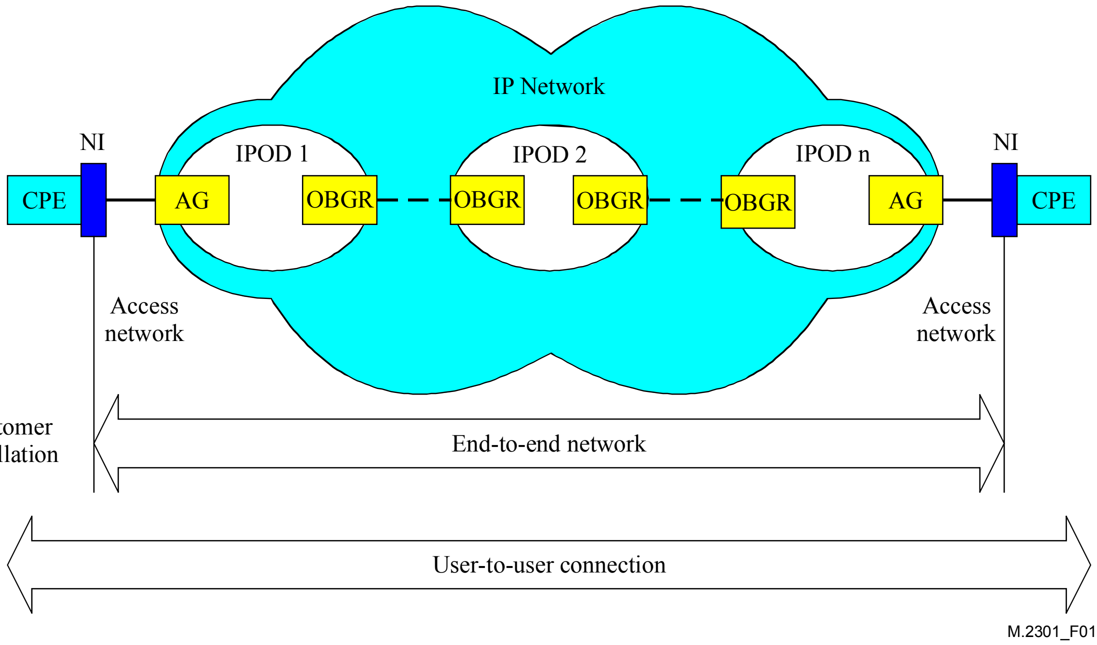

Figure 1/M.2301 – Example of an end-to-end IP flow

The CPE is connected to the operator's IP network through, for example, a leased line.

NOTE – The CPE may or may not contain a router, and the NI may be co-located with a router or not, depending on the connecting operators' agreement. Depending on the nature of the access link technology in use, the performance allocation given to this link may need to be greater than that for other links. Note that the IPOD may or may not include the access network portion.

From that point on (Access Gateway), the routing is delegated to the routing policies of the operator. The NI is normally the physical point at which the jurisdiction boundary is located. It may be difficult to perform measurements at the NI.

Figure 2 shows how an IPOD may contain more than one AS and the position of the OBGRs relative to the BGRs between ASs.

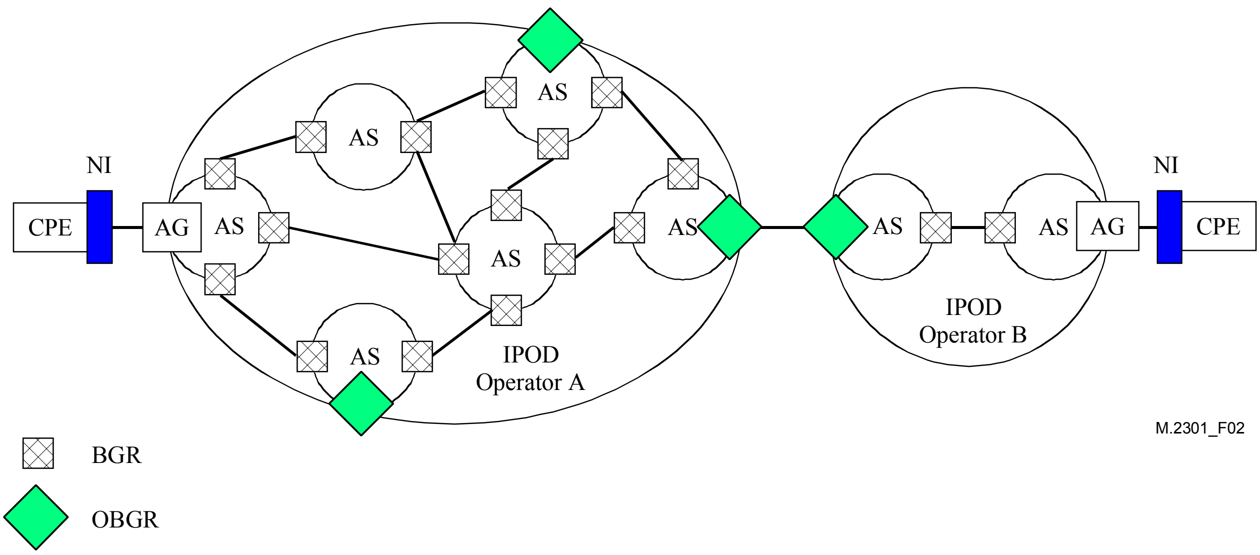

Figure 2/M.2301 – Example showing the make up of an IPOD

Figure 3 expands Figure 2 to show more detail of the reference network with indication of the network portions and Measurement Points (MPs). It shows how the neighbouring ASs connect together and each contains a number of interconnected routers and BGRs.

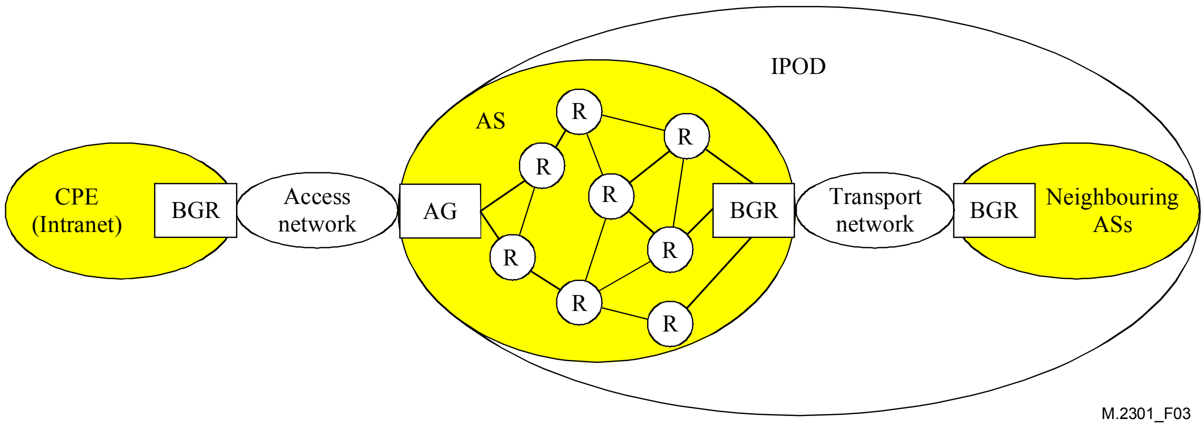

Figure 3/M.2301 – Example of a network topology for a typical IP customer

The hypothetical reference model used in this Recommendation is a network consisting of two access links and eight IPODs. For the more stringent QoS classes (QoS classes 0 and 2), the number of IPODs is reduced to three. Further details are given in clause 9.

5.1 Definitions of availability

The measurements defined in this Recommendation should only be performed on a network, or part of a network, during periods of availability. The definition and criteria of availability are under study and may depend on the application being supported by the IP network. For further information, see ITU-T Rec. Y.1540 [4].

In the case when test traffic is needed to check availability, the traffic generated specifically to test the availability state should be limited so that it does not cause congestion. This congestion could affect other traffic and/or could significantly increase the probability that the outage criteria will be exceeded. However, it should be noted that this test may not indicate the true availability for higher volumes of customers' traffic. The specification of the test packet stream is under study.

5.2 Virtual private networks

Each of the IPODs that support a Virtual Private Network (VPN) shall have been tested and be compliant with the figures in Table 3. End-to-end tests carried out on the VPN shall comply with the figures in Table 2. Performance limits for VPNs may be different (e.g. more stringent) dependent on Service Level Agreements between Service Provider and Customer.

5.3 Bringing-into-service procedure

When a new AS or new network resources are brought into service, the following procedure shall be adopted in order to check that the performance across an IPOD still meets the limits in this Recommendation.

End-to-end flow tests should be carried out as described in clause 7 between each pair combination of OBGRs. Each test pair should meet the performance objectives of Table 3. Upon successful completion of this test the AS or network resources can be brought into service.

The tests described in clause 7 should be repeated 24 hours after the AS or network resources have been brought into service in order to check that the introduction of them has not impaired the end-to-end performance.

If either the initial test or the repeat test fails, appropriate fault management procedures should be initiated.

Similarly, when a new link between two IPODs (pairs of OBGRs) is brought into service, the same procedure should apply and the limits in Table 4 should be met. Access links should meet the limits in Table 5.

5.4 Maintenance procedure

It is desirable that performance monitoring of an IPOD and links between IPODs is performed on a regular basis to check that performance is not degraded, and to indicate possible congestion or fault conditions. The overall set of measurements specified in clauses 7 and 8, or a subset of them, can be used for this purpose. This procedure may include the application of maintenance thresholds to one or more performance parameters. If these are exceeded, corrective maintenance actions should be initiated. The limits given in Tables 3, 4 and 5 should also be used for maintenance.

After maintenance work on an AS, the network resources that have been repaired (routers or transmission links) should be tested to ensure the end-to-end performance can still be met. Further guidance on testing of individual routers and links is given in Appendix I.

6 Measurement methods

There are two basic approaches to performance measurement defined in this Recommendation. These are "intrusive" and "non-intrusive" which equate to the terms "active" and "passive" used by the IETF. Some performance parameters can be measured only intrusively, others only non-intrusively, and some both intrusively and non-intrusively as illustrated, for example using MIB monitoring[1], in Table 1.

Table 1/M.2301 – Intrusive and non-intrusive measurement of performance parameters

Parameter	Intrusive	Non-intrusive
IPTD	√	
IPDV	√	
IPER	√	√
IPLR	√	√
IPDR		√

6.1 Intrusive performance measurement (using test packets)

Intrusive performance measurements are made by inserting test packets interleaved with the normal traffic flows between two MPs. This kind of measurement allows more detailed investigation of specific performance parameters e.g. one-way delay using time stamped packets, effect of packet size and number of packets on performance.

It should be noted that intrusive performance measurement causes additional traffic through the network so care must be taken to ensure that the use of this test does not cause congestion and the subsequent loss of customer's packets. It is also important that the test is not carried out when customer traffic is so low that the results of the test are invalid.

[1] Note that other methods of non-intrusive measurement are possible.

The test packet stream and the measurement period should be appropriate to the application service to be supported. The packet length and characteristics, and the intervals between measurement periods are for further study.

6.2 Non-intrusive performance measurement (using MIB monitoring)

The performance can be assessed by interrogating all the routers for performance statistics and thus obtaining a real time view of the effect of the network on the traffic passing through that network. The data available are listed in RFC 1213 [6] and RFC 2011 [8]. RFC 1213 [6] has been updated by RFCs 2011 [8], 2012 [9] and 2013 [10] but only RFC 2011 [8] is applicable to this Recommendation. RFCs 1213 [6] and 2011 [8] include interface statistics, IP statistics, ICMP statistics, TCP statistics, EGP statistics and SNMP statistics. Only interface statistics and IP statistics should be used for performance measurement. This is because they will cover all traffic of all types and they will not be affected by the differences between the different protocols (e.g. the re-transmission of packets by TCP).

This kind of measurement has the advantages of minimising impact on customer's traffic and testing every route through the network. Problems on links or routers can also be quickly identified. It should be noted, however, that non-intrusive measurements can realistically be done only within one IPOD since it may be difficult or undesirable for one operator to access the routers in another's IPOD. Results of non-intrusive measurements might be exchanged between connecting operators over a TMN X-interface.

The application of MIB monitoring inside an IPOD is described in Appendix I.

The measurements have to be made in pairs, which should be done 15 minutes apart except for those interfaces that are running at 1 Gbit/s or above. In the latter case, the readings should be separated by the time given in Table A.1 or less.

7 Intrusive performance measurement

Intrusive measurement techniques are used when it is difficult or impossible to use non-intrusive measurements. One example could be one-way IP packet transfer delay (IPTD) and IP packet delay variation (IPDV). IPTD measurements require high resolution clocks accurate in frequency and phase. Another example is during the provisioning and turn-up process before applying live traffic to the network resources concerned. Intrusive measurements may also be used to evaluate error performance e.g. IP packet error ratio (IPER) and IP packet loss ratio (IPLR). It is not possible to measure packet discard ratio by this technique, as discarded packets cannot be identified separately from lost packets. For this reason the IPLR performance objectives in Table 3 have been increased to cover those packets discarded by the routers. Intrusive measurements are usually restricted to BGRs and OBGRs because of the practical problems of making such measurements at every router.

7.1 One-way IP Packet Transfer Delay (IPTD)

This test is carried out between all pair combinations of OBGRs within an IPOD. All OBGR pairs should produce IPTD results within the performance objectives specified in Table 3. The test consists of sending a stream of time-stamped packets, distributed throughout the traffic, from one OBGR to the other. The time each packet is received is recorded. The time each packet was transmitted is subtracted from the received time to produce the one-way delay result for that packet. The worst case IPTD should be recorded and the number of test packets used should be sufficient to give a 95% confidence in this result. The same test should also be carried out on the connecting link between the OBGRs of neighbouring IPODs and end-to-end. The results for these two cases should be within the limits of Table 4 and Table 2 respectively.

7.2 One-way IP Packet Delay Variation (IPDV)

This test is carried out between all pair combinations of OBGRs within an IPOD using a similar test packet stream as for IPTD. All the OBGR pairs should produce an IPDV within the performance objectives specified in Table 3. One sequence of test packets is transmitted from one OBGR to the other. The one-way delay is calculated as above. The smallest IPTD figure is subtracted from the greatest to produce the delay variation and the number of test packets used should be sufficient to give a 95% confidence in this result (i.e. less than 5% of the population of IPTD values are not captured). The result should be within the limits specified in Table 3. The same test should also be carried out on the connecting link between the OBGRs of neighbouring IPODs and end-to-end. The results for these two cases should be within the limits of Table 4 and Table 2 respectively.

7.3 IP Packet Loss Ratio (IPLR)

This test is carried out between all pair combinations of OBGRs within an IPOD. All OBGR pairs should produce IPLR results within the performance objectives specified in Table 3. The test consists of sending a stream of numbered packets, distributed throughout the traffic, from one OBGR to the other. At the receiving OBGR the packets are checked to see if any are missing. The total number of missing packets is recorded, together with the total number of packets sent. The ratio between the two figures is the IPLR. The number of test packets used should be sufficient to give a 95% confidence in this result. The same test should also be carried out on the connecting link between the OBGRs of neighbouring IPODs and end-to-end. The results for these two cases should be within the limits of Table 4 and Table 2 respectively.

7.4 IP Packet Error Ratio (IPER)

This test is carried out between all pair combinations of OBGRs within an IPOD. All OBGR pairs should produce IPER results within the performance objectives specified in Table 3. The test consists of sending a stream of packets, distributed throughout the traffic, from one OBGR to the other. Each packet contains error checking bits. At the receiving OBGR each packet is checked for errors. The total number of errored packets is recorded, together with the total number of packets received. The ratio between the two figures is the IPER. The number of test packets used should be sufficient to give a 95% confidence in this result. The same test should also be carried out on the connecting link between the OBGRs of neighbouring IPODs and end-to-end. The results for these two cases should be within the limits of Table 4 and Table 2 respectively.

8 Non-intrusive performance measurement using MIB monitoring

As described earlier, the performance of an IPOD (including an individual AS) can be assessed by interrogating all the routers in that system for performance data and thus obtaining a real time view of the effect of the network on the traffic passing through that network. For any given link between any two routers, IPER and IPLR can be measured.

The measurements can be made for every link in the IPOD or for specified links. Those links, which are chosen for any particular measurement, shall be known as a 'population of interest'. The MIB of an OBGR can be interrogated for comparison with the MIB of the neighbouring OBGR in order to obtain the performance of the connecting link between the neighbouring IPODs.

The MIB in each router should be interrogated for the required counts. Those needed include:

- ifInUcastPkts;
- ifInNUcastPkts;
- ifInDiscards;
- ifInErrors;
- ifInUnknownProtos;

•	ifOutUcastPkts;
•	ifOutNUcastPkts;
•	ifOutDiscards;
•	ifOutErrors.

For definitions of these counts, see RFC 1213 [6]. These readings should be made twice, separated by a specified time interval. This time interval between readings will depend on the data rate of the interface whose statistics are being collected. The time interval for each bit rate and procedures for dealing with counter roll-over are shown in Annex A.

Figure 4 shows the passage of packets from one router to the next and the three points at which packet loss or packet errors can occur and be detected by MIB monitoring.

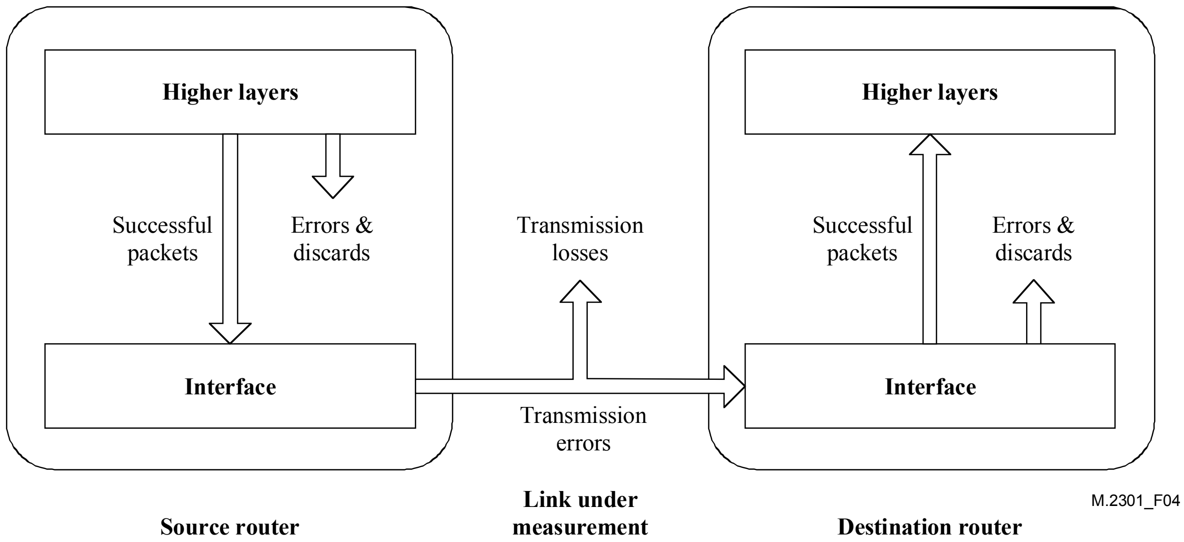

Figure 4/M.2301 – The points at which packet loss and errors can occur

8.1 IP performance events

8.1.1 Total IP packets received

Total IP packets received is a count of the number of packets received at an interface.

The total number of packet received across an interface is given by the sum of:

•	ifInUcastPkts;
•	ifInNUcastPkts;
•	ifInDiscards;
•	ifInErrors;
•	ifInUnknownProtos.

Let this be known as ifInTotal.

The number successfully delivered to a higher-layer protocol is given by the sum of:

•	ifInUcastPkts;
•	ifInNUcastPkts.

Let this be known as ifInOk.

Alternatively this can be defined mathematically as follows:

Define:

ifInTotal = ifInUcastPkts + ifInNUcastPkts + ifInDiscards + ifInErrors + ifInUnknownProtos

ifInOK = ifInUcastPkts + ifInNUcastPkts

Define:

ifInErrored = ifInErrors + ifInUnknownProtos

8.1.2 Total IP packets transmitted

Total IP packets transmitted is a count of the number of packets submitted to an interface for onward transmission.

The total number of packets submitted to an interface is given by the sum of:

- ifOutUcastPkts;
- ifOutNUcastPkts.

Let this be known as ifOutTotal.

The number successfully transmitted over the link is given by the sum of:

- ifOutUcastPkts;
- ifOutNUcastPkts;

minus the sum of:

- ifOutDiscards;
- ifOutErrors.

Let this be known as ifOutOk.

Or expressed mathematically:

ifOutTotal = ifOutUcastPkts + ifOutNUcastPkts.

Then:

ifOutOK = ifOutTotal – (ifOutDiscards + ifOutErrors).

8.1.3 IP Packet Error Ratio (IPER)

IP packet error ratio is the ratio of total errored IP packet outcomes to the total of successful IP packet transfer outcomes, plus errored IP packet outcomes, in a population of interest.

The number of packets received, which are errored, is given by the sum of:

- ifInErrors;
- ifInUnknownProtos.

Let this be known as ifInErrored.

The packet error ratio is the ratio of ifInErrored to ifInTotal.

Or expressed mathematically:

IPER = (ifInErrors + ifInUnkownProtos)/ifInTotal.

8.1.4 IP Packet Loss Ratio (IPLR)

IP packet loss ratio is the ratio of total lost IP packet outcomes to total transmitted IP packets in a population of interest.

The packet loss ratio is the ratio of packets received and delivered to the higher layer to the number of packets submitted for transmission i.e. ifInOk to ifOutTotal.

Or expressed mathematically:

IPLR = (ifInUcastPkts + ifInNUcastPkts)/ifOutTotal.

8.1.5 IP Packet Discard Ratio (IPDR)

IP packet discard ratio is the ratio of total discarded IP packet outcomes to total transmitted IP packets in a population of interest. Discarded packets are those packets which are deliberately lost although they are without error. Packets are usually discarded because there is insufficient buffer space to store the packets while they await processing. Thus IP packet discard ratio is a measurement of network congestion.

The number of packets discarded is given by the sum of:

- ifInDiscards;
- ifOutDiscards.

Let this be known as ifDiscardTotal.

The packet discard ratio is the ratio of ifDiscardTotal to ifOutTotal.

Expressing this mathematically gives:

IPDR = (ifInDiscards + ifOutDiscards)/ifOutTotal.

9 Performance objectives for IP networks

The figures given in the following tables are based on a hypothetical reference model consisting of two access links and eight IPODs connected by seven OBGR-to-OBGR connecting links, for a total length of 27,500 km. Since the stringent IPTD objectives of QoS classes 0 and 2 cannot be guaranteed on such long distances, a reduced reference model consisting of two access links and three IPODs connected by two OBGR-to-OBGR connecting links, for a total length of 10,000 km has been used for these QoS classes.

The IPODs have been allocated two thirds of the overall end-to-end performance objective and the connecting links one third. The access links have *each* been allocated 17.5% of the total connecting link allocation (i.e. 5.83% of the total end-to-end performance objective). The performance objectives for a single IPOD or connecting link between adjacent IPODs are derived by apportioning the end-to-end performance objectives. In the case of IPER, this can produce a slightly pessimistic view of the error ratio, especially for increasing values of IPER. This depends on the error statistics and their relationship to the packet length statistics.

9.1 End-to-end IP flow

The following performance objectives are specified for an end-to-end IP flow through two or more IPODs:

Table 2/M.2301 – IP QoS class definitions and network performance objectives for an end-to-end IP flow

Parameter / QoS Class	IPTD	IPDV	IPLR	IPER	IPDR
Class 0	100 ms	50 ms	5×10^{-4} (Note 1)	5×10^{-5}	5×10^{-4}
Class 1	400 ms	50 ms	5×10^{-4} (Note 1)	5×10^{-5}	5×10^{-4}
Class 2	100 ms	U	5×10^{-4}	5×10^{-5}	5×10^{-4}
Class 3	400 ms	U	5×10^{-4}	5×10^{-5}	5×10^{-4}
Class 4	1 s	U	5×10^{-4}	5×10^{-5}	5×10^{-4}
Class 5	U	U	U	U	U

NOTE 1 – Some applications (e.g. MPEG-2) may require IPLR $< 5 \times 10^{-5}$.

NOTE 2 – "U" means "unspecified" or "unbounded". When the performance relative to a particular parameter is identified as being "U" the ITU-T establishes no objective for this parameter and any default Y.1541 [5] objective can be ignored. When the objective for a parameter is set to "U", performance with respect to that parameter may, at times, be arbitrarily poor.

9.2 IP flow across a single IPOD

The following performance objectives are specified for an IP flow across a single IPOD. There are 8 IPODs in the reference model, and therefore the performance objective for one IPOD is given by the formulae:

Single IPOD objective = End-to-end objective × 2/3 × 1/8 (for QoS classes 1, 3, 4 and 5).

Single IPOD objective = End-to-end objective × 2/3 × 1/3 (for QoS classes 0 and 2).

Table 3/M.2301 – IP QoS class definitions and network performance objectives for an IP flow across a single IPOD

Parameter / QoS Class	IPTD	IPDV	IPLR	IPER	IPDR
Class 0	11 + P ms (Note 3)	FFS	1.1×10^{-4} (Note 1)	1.1×10^{-5}	1.1×10^{-4} (Note 1)
Class 1	22 + P ms (Note 3)	FFS	4.2×10^{-5} (Note 1)	4.2×10^{-6}	4.2×10^{-5} (Note 1)
Class 2	11 + P ms (Note 3)	U	1.1×10^{-4}	1.1×10^{-5}	1.1×10^{-4}
Class 3	22 + P ms (Note 3)	U	4.2×10^{-5}	4.2×10^{-6}	4.2×10^{-5}
Class 4	72 + P ms (Note 3)	U	4.2×10^{-5}	4.2×10^{-6}	4.2×10^{-5}
Class 5	U	U	U	U	U

NOTE 1 – Some applications (e.g. MPEG-2) may require more stringent IPLR.

NOTE 2 – "U" means "unspecified" or "unbounded". When the performance relative to a particular parameter is identified as being "U" the ITU-T establishes no objective for this parameter and any default Y.1541 [5] objective can be ignored. When the objective for a parameter is set to "U", performance with respect to that parameter may, at times, be arbitrarily poor.

NOTE 3 – If the route distance between OBGRs across the IPOD exceeds 200 km then a propagation delay term, P, is added. This is calculated by multiplying the route distance (in km) by 5, dividing by 1000 and rounding down to an integer. This effectively allows 1 ms for each integer multiple of 200 km. See Table 6 for calculation of route distance when only air distance is known.

NOTE 4 – The delay performance limits are derived from the formulae above the table after having removed, from the overall end-to-end IPTD, the delay resulting from the network length (137 ms for QoS classes 1, 3, 4 and 5; 50 ms for QoS classes 0 and 2). The distance-dependent factor, P, might result in the overall end-to-end flow performance objectives not being met for the case of large IPODs. For example, in some extreme geographical cases, or with a satellite hop, it may not be possible to meet the overall end-to-end delay performance limits. As a result, some highly interactive IP-based services may not be viable.

9.3 Single link between two adjacent IPODs

The following performance objectives are specified for the single link between the two OBGRs across the boundary between two IPODs. There are 8 IPODs in the reference model, and therefore the performance objective for one connecting link between adjacent IPODs is given by the formulae:

Single link objective = End-to-end objective × 1/3 × 0.65 × 1/7 (for QoS classes 1, 3, 4, 5).

Single link objective = End-to-end objective × 1/3 × 0.65 × 1/2 (for QoS classes 0 and 2).

Table 4/M.2301 – IP QoS class definitions and network performance objectives for a single link between OBGRs

Parameter / QoS Class	IPTD	IPDV	IPLR	IPER	IPDR
Class 0	5 + P ms (Note 1)	FFS	5.4×10^{-5}	5.4×10^{-6}	5.4×10^{-5}
Class 1	8 + P ms (Note 1)	FFS	1.5×10^{-5}	1.5×10^{-6}	1.5×10^{-5}
Class 2	5 + P ms (Note 1)	U	5.4×10^{-5}	5.4×10^{-6}	5.4×10^{-5}
Class 3	8 + P ms (Note 1)	U	1.5×10^{-5}	1.5×10^{-6}	1.5×10^{-5}
Class 4	27 + P ms (Note 1)	U	1.5×10^{-5}	1.5×10^{-6}	1.5×10^{-5}
Class 5	U	U	U	U	U

NOTE 1 – If the route distance between OBGRs of adjacent IPODs exceeds 200 km, then a propagation delay term, P, is added. This is calculated by multiplying the route distance (in km) by 5, dividing by 1000 and rounding down to an integer. This effectively allows 1 ms for each integer multiple of 200 km. See Table 6 for calculation of route distance when only air distance is known.

NOTE 2 – The delay performance limits are derived from the formulae above the table after having removed, from the overall end-to-end IPTD, the delay resulting from the network length (137 ms for QoS classes 1, 3, 4 and 5; 50 ms for QoS classes 0 and 2). The distance-dependent factor, P, might result in the overall end-to-end flow performance objectives not being met for the case of large distances between IPODs. For example, in some extreme geographical cases, or with a satellite hop, it may not be possible to meet the overall end-to-end delay performance limits. As a result, some highly interactive IP-based services may not be viable.

9.4 Access Links

The following performance objectives are specified for the access link between the NI and the AG. The performance objective for one access link is given by the formula:

Access link objective = End-to-end objective × 1/3 × 0.175

Table 5/M.2301 – IP QoS class definitions and network performance objectives for a single access link

Parameter / QoS Class	IPTD	IPDV	IPLR	IPER	IPDR
Class 0	3 + P ms (Note 1)	FFS	3×10^{-5}	3×10^{-6}	3×10^{-5}
Class 1	15 + P ms (Note 1)	FFS	3×10^{-5}	3×10^{-6}	3×10^{-5}
Class 2	3 + P ms (Note 1)	U	3×10^{-5}	3×10^{-6}	3×10^{-5}
Class 3	15 + P ms (Note 1)	U	3×10^{-5}	3×10^{-6}	3×10^{-5}
Class 4	50 + P ms (Note 1)	U	3×10^{-5}	3×10^{-6}	3×10^{-5}
Class 5	U	U	U	U	U

NOTE 1 – If the route distance of an access link exceeds 200 km, then a propagation delay term, P, is added. This is calculated by multiplying the route distance (in km) by 5, dividing by 1000 and rounding down to an integer. This effectively allows 1 ms for each integer multiple of 200 km. See Table 6 for calculation of route distance when only air distance is known.

NOTE 2 – The delay performance limits are derived from the formula above the table after having removed, from the overall end-to-end IPTD, the delay resulting from the network length (137 ms for QoS classes 1, 3, 4 and 5; 50 ms for QoS classes 0 and 2). The distance-dependent factor, P, might result in the overall end-to-end flow performance objectives not being met for the case of long access links. For example, in some extreme geographical cases, or with a satellite hop, it may not be possible to meet the overall end-to-end delay performance limits. As a result, some highly interactive IP-based services may not be viable.

9.5 Calculation of route distance

Table 6 contains the formulae for calculating the route distance when only air distance is known.

Table 6/M.2301 – Calculated route distance

Air route distance d	Calculated route distance
d < 1000 km	d × 1.5 km
1000 ≤ d < 1200 km	1500 km
d ≥ 1200 km	d × 1.25 km

Annex A

Procedures for reading router MIB registers

This annex contains procedures for reading router MIB registers. Table A.1 contains the elapsed time required between readings of the MIB values depending on the interface bit rate.

Table A.1/M.2301 – Elapsed time between readings of MIB values

ITU Designation	ATIS T1 Designation	Data rate (Mbit/s)	Elapsed time
IEEE 802.2 Ethernet	IEEE 802.2 Ethernet	10	24 hrs
E3		34	12 hrs
	DS3	45	12 hrs
IEEE 802.3u Ethernet	IEEE 802.3u Ethernet	100	140 mins
STM-1	STS-3/OC-3	155	3 hrs
STM-4	STS-12/OC-12	622	50 mins
IEEE 802.3z GbE	IEEE 802.3z GbE	1000	14 mins
STM-16	STS-48/OC-48	2488	10 mins
IEEE 802.3ae GbE	IEEE 802.3ae GbE	10 000	1 min

When making non-intrusive measurements, the MIB in each router is read twice, once at the start of the measurement period and once at the end. The end reading will generally be greater than the start. In that case, the start is subtracted from the end to produce the value for the parameter being measured. On some occasions the counter will 'roll-over' (that is, reach maximum count and start again at zero). The values in Table A.1 have been so chosen that this will not happen twice during one measurement period.

When roll-over happens, the end reading will be less than the start. Before the correct value can be calculated it is necessary to determine whether the counter is 32 bit or 64 bit. All MIBs accessed by SNMP v1 use 32 bit counters, as v1 does not support 64 bit counters. If SNMP v2c or v3 is being used it is possible that some of the counters are 64 bit. The 64 bit counters have the letter 'HC' (meaning High Capacity) in the counter name. For example, the counter ifHCInUcastPkts has 64 bits whereas ifInUcastPkts has 32 bits.

Now consult Figure A.1 to find out how to calculate value from the two counter readings.

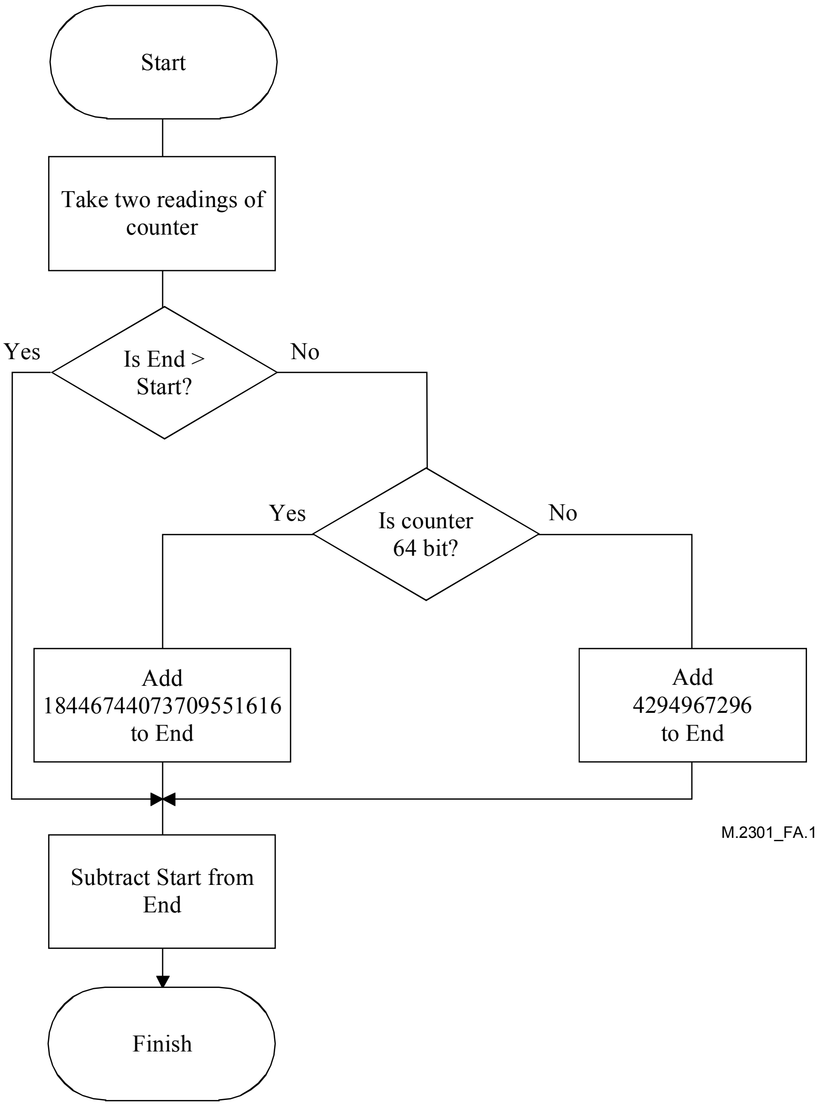

Figure A.1/M.2301 – Flowchart to determine MIB counter values

It should be noted that most IP network equipment uses a SNMP management interface, but other types of protocol are not precluded.

Appendix I

Performance within an IPOD

I.1 Single link between two adjacent routers

When an individual link or router is added to an existing AS, it could be tested by the methods defined in this Recommendation. An operator of IP networks may wish to use the non-intrusive performance measurement technique, defined in clause 8, to monitor its network on a regular basis. This will enable links and routers with a poor performance to be quickly identified and will also give early warning of a need to re-engineer the network to cope with increasing traffic. Trouble spots can be identified and dealt with before user traffic is badly affected.

The performance objectives for a connecting link between routers are derived by apportioning the end-to-end performance objectives. In the case of IPER, this can produce a slightly pessimistic view of the error ratio, especially for increasing values of IPER. This depends on the error statistics and their relationship to the packet length statistics.

Table I.1 specifies the performance objectives for each link between adjacent routers within the same AS:

Table I.1/M.2301 – IP QoS class definitions and network performance objectives for a single link between routers

Parameter / QoS Class	IPTD	IPDV	IPLR	IPER	IPDR
Class 0	5 + P ms (Note 1)	FFS	5.4×10^{-5}	5.4×10^{-6}	5.4×10^{-5}
Class 1	8 + P ms (Note 1)	FFS	1.5×10^{-5}	1.5×10^{-6}	1.5×10^{-5}
Class 2	5 + P ms (Note 1)	U	5.4×10^{-5}	5.4×10^{-6}	1.5×10^{-5}
Class 3	8 + P ms (Note 1)	U	1.5×10^{-5}	1.5×10^{-6}	1.5×10^{-5}
Class 4	27 + P ms (Note 1)	U	1.5×10^{-5}	1.5×10^{-6}	1.5×10^{-5}
Class 5	U	U	U	U	U

NOTE 1 – If the route distance between routers exceeds 200 km, then a propagation delay term, P, is added. This is calculated by multiplying the route distance (in km) by 5, dividing by 1000 and rounding down to an integer. See Table 6 for calculation of route distance when only air distance is known.

NOTE 2 – The distance-dependent factor, P, might result in the overall end-to-end flow performance objectives not being met for the case of large IPODs. For example, in some extreme geographical cases, or with a satellite hop, it may not be possible to meet the overall end-to-end delay performance limits. As a result, some highly interactive IP-based services may not be viable.

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