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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Quality of service and network performance

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Multicast IP performance parameters

Recommendation ITU-T Y.1544

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Recommendation ITU-T Y.1544

Multicast IP performance parameters

Summary

Recommendation ITU-T Y.1544 extends the framework of Recommendation ITU-T Y.1540 to the point-to-multipoint, or multicast case. It also expands the key Y.1540 concepts with details needed to define parameters for the point-to-multipoint configuration.

The performance of point-to-multipoint packet transfer to a set of destinations can first be considered a set of point-to-point packet transfers, and characterized using any or all of the point-to-point parameters found in Recommendation ITU-T Y.1540. This Recommendation defines parameters that are specific to the point-to-multipoint case.

There are three general categories of point-to-multipoint parameters which focus on different entities in this network topology: parameters that describe the Source performance, parameters that describe the performance at one or more Destinations, and parameters that can be applied to describe the performance of subsections of the multicast tree. In its present version, this Recommendation primarily addresses Destination performance.

This Recommendation also specifies a complete set of parameters for the access and disengagement phases of communication. This aspect goes beyond the scope of Recommendation ITU-T Y.1540, which covers only the information transfer phase.

Source

Recommendation ITU-T Y.1544 was approved on 14 July 2008 by ITU-T Study Group 12 (2005-2008) under Recommendation ITU-T A.8 procedure.

FOREWORD

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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.

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Multicast IP performance parameters

1 Scope

This Recommendation defines parameters that may be used in specifying and assessing the performance of speed, accuracy, dependability, and availability of IP packet transfer of international Internet protocol (IP) data communication services. The parameters apply to point-to-multipoint IP service and to the network portions that provide, or contribute to the provision of, such service in accordance with the normative references specified in clause 2.

In particular, this Recommendation relies on the same layered model and generic performance model defined in [ITU-T Y.1540] for point-to-point communication. The scope of this Recommendation extends [ITU-T Y.1540] to an area that was left for further study: point-to-multipoint communication.

The scope of this Recommendation also includes performance parameters that are relevant to specific multicast protocols. The protocols currently covered are versions 2 and 3 of the Internet group management protocol. Inclusion of these protocols expands beyond the scope of [ITU-T Y.1540] to cover the access and disengagement communication functions.

The operation of multicast routing protocols is evident to users and their hosts, primarily in terms of the network's ability to deliver packets from sources to destinations. This Recommendation does not specify performance parameters for these protocols. Table 1 illustrates the coverage of this Recommendation, in terms of the 3-by-3 matrix (defined in [ITU-T I.350]).

Table 1 – Partial scope of this Recommendation

Criterion / Function	Speed	Accuracy	Dependability
Access	Multicast group membership performance parameters (clause 8)		
User information transfer	Multipoint packet transfer performance parameters (clause 6)		
Disengagement	Multicast group membership performance parameters (clause 8)		

As stated above, the topic of availability is also included in the scope of this Recommendation.

The reader of this Recommendation should be familiar with the concepts and definitions of [ITU-T I.350] and [ITU-T Y.1540].

The outline of this Recommendation follows the outline of Y.1540 to the extent possible, in order to simplify references and comparisons. Therefore, the unique multicast access and disengagement material appears near the end of the body of this Recommendation.

2 References

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

[ITU-T I.350] Recommendation ITU-T I.350 (1993), *General aspects of quality of service and network performance in digital networks, including ISDNs.* <http://web.itu.int/rec/T-REC-I.350/>

[ITU-T Y.1540] Recommendation ITU-T Y.1540 (2007), *Internet protocol data communication service – IP packet transfer and availability performance parameters.* <http://web.itu.int/rec/T-REC-Y.1540/>

[IETF RFC 3376] IETF RFC 3376 (2002), *Internet Group Management Protocol, Version 3.* <http://www.ietf.org/rfc/rfc3376.txt?number=3376>

[IETF RFC 3513] IETF RFC 3513 (2003), *Internet Protocol Version 6 (IPv6) Addressing Architecture*. <http://www.ietf.org/rfc/rfc3513.txt?number=3513>

3 Abbreviations and definitions

3.1 Abbreviations

This Recommendation uses the following abbreviations:

$A(T_{av})$	Fraction of destinations in the available state during T_{av}
CRE	Commence Reference Event
E_n	Number of errored packet outcomes at destination n
EL	Exchange Link
ER	Edge Router
F_n	Number of lost spurious outcomes at destination n
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
IPDR	IP packet Duplicate Ratio
IPDV	IP packet Delay Variation
IPER	IP packet Error Ratio
IPLR	IP packet Loss Ratio
IPOR	Octet-based IP packet rate
IPPR	IP Packet rate
IPRE	IP packet transfer Reference Event
IPRR	IP packet Reordered Ratio
IPSLBR	IP packet Severe Loss Block Ratio
IPTD	IP packet Transfer Delay
ISP	Internet Service Provider
JRE	Join Reference Event
L_n	Number of lost packet outcomes at destination n
LL	Lower Layers, protocols and technology supporting the IP layer
LRE	Leave Reference Event

M_{av}	The minimum number of packets recommended for assessing the availability state
MP	Measurement Point
NS	Network Section
NSE	Network Section Ensemble
PDV	Packet Delay Variation
PIM	Protocol Independent Multicast
PMO	Percent Meeting Objective
R_n	Number of successful packets at Destination n, with respect to a population of interest
R_{max}	Maximum number of successful packets at all Destinations in a group, $max(R_n)$
S	The number of packets a Source transmits that constitute the population of interest
T_{av}	Minimum length of time of IP availability; minimum length of time of IP unavailability
T_{max}	Maximum IP packet delay beyond which the packet is declared to be lost
T_{Jmax}	Waiting time for completion of an IGMP Join operation
T_{Lmax}	Waiting time for confirmation of an IGMP Leave
T_{POI}	Interval of time corresponding to transmission of the population of interest
$T_{R,n}$	Interval corresponding to reception of the population of interest at destination n
T_r	Result-recording time interval (availability)
TRE	Termination Reference Event

3.2 Definitions

The primary purpose of this Recommendation is to define new terms and performance parameters. Most of the new terms appear in the clauses where they are defined in detail.

3.2.1 Terms defined elsewhere

This Recommendation extends [ITU-T Y.1540] to the point-to-multipoint topology, all terms and performance parameters defined in [ITU-T Y.1540] apply here as well.

3.2.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.2.1 joining or leaving a multicast group: The process to add (or remove) a member from a multicast group.

3.2.2.2 multicast group: A multicast group is a set of hosts that have indicated their intention to receive packets on a specific multicast group address. This set of hosts and their associated egress measurement points provide a key qualification to the point-to-multipoint population of interest.

3.2.2.3 multicast group address: This is a destination address that allows potentially any host to receive packets of this group from a multicasting source host. In IPv4, a multicast group address is a special destination address range (224.0.0.0/4), historically known as Class D. The best current practice for IPv4 multicast address assignment may be found in [b-IETF RFC 3171]. In IPv6, multicast addresses all have the prefix FF00::/8. Address assignments within this range are specified in [IETF RFC 3513].

3.2.2.4 permissible multicast group egress measurement points: One or more egress measurement points may be designated permissible when the Source to Destination path of at least one member of a multicast group includes that specific egress point, and the minimum set of egress points to cover all group members are identified.

4 Multipoint considerations for the layered model of performance for IP service

The layered model for IP service (clause 4 of [ITU-T Y.1540]) also applies to the point-to-multipoint case. The only additional performance-related consideration is the reproduction of packets in multicast routers. When required, a multicast router is required to reproduce the packets of a given multicast group, to send them on two or more egress links toward their destinations.

5 Multipoint considerations for the generic IP service performance model

The main additional consideration with respect to the existing service performance model (clause 5 of [ITU-T Y.1540]) is that the multicast routing information is distinctly different from the global routing information. The purpose of multicast routing information is to build the multicast distribution tree applicable to each source/group, or applicable to many groups when sharing multicast trees. Multicast routing may be derived from the unicast routing information already available (as is done with protocol independent multicast (PIM)).

The additional constraints of the multicast routing information have the desired consequence of designating more egress measurement points (MP) as *permissible*. In general, all IP packets (and fragments of packets) leaving a basic section (as defined in [ITU-T Y.1540]: a basic section is either an exchange link (EL), a network section (NS), a Source host or a Destination host) should only be forwarded to other basic sections as *permitted* by the available multicast routing information.

At a given time (because routing information is not static), and relative to a given end-to-end IP service and a basic section or network section ensemble (NSE):

– an ingress MP is a *permissible ingress MP* if the crossing of this MP into this basic section or NSE is permitted by the multicast routing information;

– an egress MP is a *permissible egress MP* if the crossing of this MP leads into another basic section that is permitted by the multicast routing information.

The packet outcomes defined in clause 5 of [ITU-T Y.1540] are all phrased in terms of permissible ingress MP and egress MP. This Recommendation defines point-to-multipoint parameters in terms of the elementary point-to-point outcomes, and often uses the point-to-point parameters as well. As a result, outcomes are evaluated with respect to a single permissible ingress MP and a single permissible egress MP. Restricting the outcome definitions to pairs of ingress and egress MP avoids the complexity of outcome combinations when multiple egress MPs are permissible for a single ingress reference event (e.g., a point-to-multipoint outcome might be: <success, success, loss, success> at four destinations; each combination of loss, success, errored, or others would require a new point-to-multipoint outcome definition, and this is not manageable or particularly useful as an alternative to using the point-to-point outcomes).

6 Multipoint IP packet transfer performance parameters

Clause 6 of [ITU-T Y.1540] defines performance parameters with emphasis on the point-to-point case. This clause also expands the key Y.1540 concepts with details needed to define parameters for the point-to-multipoint case.

The performance of point-to-multipoint packet distribution to a set of Destinations can be considered a set of point-to-point packet transfers, and characterized using any or all of the point-to-point parameters. In addition, this Recommendation defines parameters that are specific to the point-to-multipoint case below.

There are three general categories of point-to-multipoint parameters which focus on different entities in this network topology: parameters that describe the Source performance, parameters that describe the performance at one or more Destinations, and parameters that can be applied to describe the performance of subsections of the multicast tree. In its present version, this Recommendation primarily addresses Destination performance.

6.1 Populations of interest and group Membership

Most of the Y.1540 performance parameters are defined over sets of packets called *populations of interest*. For the *point-to-multipoint case*, the population of interest is usually the total set of packets that have been sent from the Source to a set of Destinations that have registered as members of a specific multicast group, forming the Matrix as illustrated in Figure 1. The measurement points in the typical NSE "UNI-to-UNI" case are the MP at the Source and Destinations.

We designate a set of N Destinations, $D = \{D_1, D_2, D_3, D_4, D_5, ... D_N\}$, registered for the multicast group included in the population of interest.

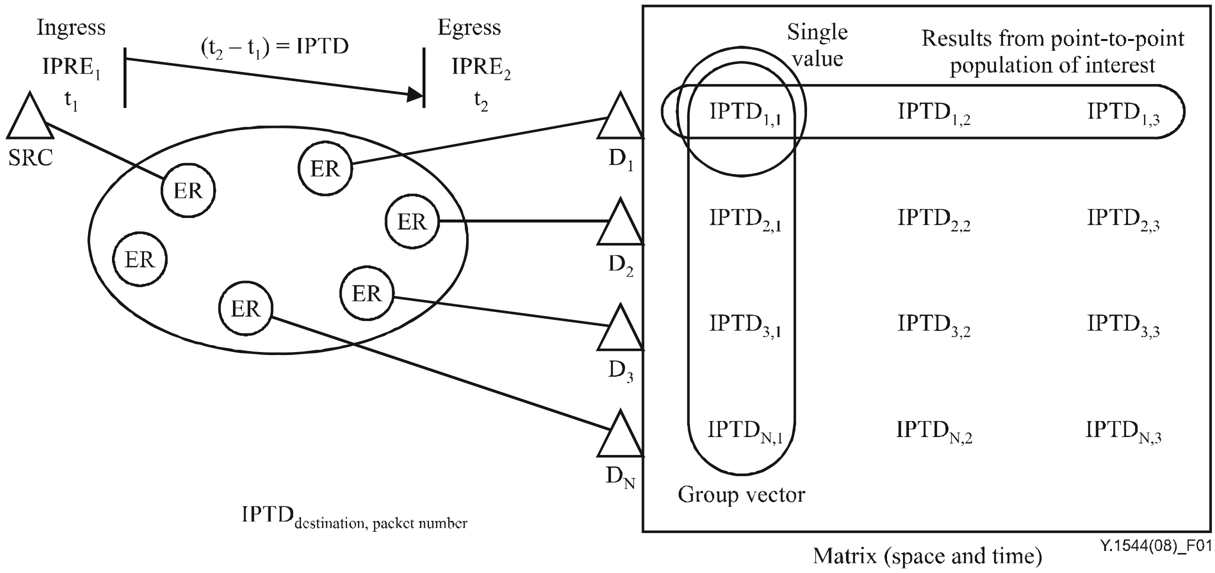

Figure 1 – Illustration of point-to-multipoint terms

Descriptions of the population of interest must include:

1) The interval of time from the first to the last ingress reference events (at the Source MP in the UNI-UNI case), T_{POI}. The corresponding time interval at a particular egress MP n is $T_{R,n}$.
2) The number of packets in the population (all such packets must correspond to ingress reference events).
3) The set of permissible ingress and egress MP during T_{POI}.
4) Other qualifying aspects from the packet header, such as the source and group addresses, differentiated services code point, etc.

It is important to note that the set of permissible ingress and egress MPs may change during T_{POI}. In some forms of point-to-multipoint communication, the Source transmits to the multicast group continuously, and Destinations may join or leave the group whenever they wish (this would correspond to a user viewing the live television channels offered in an IPTV system). A Destination's group membership activity determines the portion of the population of interest that is relevant to the calculation of its point-point parameters. Thus, when a Source has transmitted S packets during T_{POI}, and a specific Destination n joins the group while T_{POI} is in progress, then the number of packets relevant to calculating that Destination's point-to-point parameters is S_n. The first packet considered to count toward S_n is the packet corresponding to the commence reference event (CRE). If a Destination leaves the group during T_{POI}, then the last packet considered to count toward S_n is the packet corresponding to the termination reference event (TRE). Therefore, the packets counted toward S_n are limited by CRE, TRE, or the boundaries of the population of interest.

Likewise, the count of packets as successfully delivered to a particular Destination, R_n, are limited by CRE, TRE, or the boundaries of the population of interest. Figure 2 illustrates the effects of group membership status changes on the relevant point-to-point population count and the received packet count.

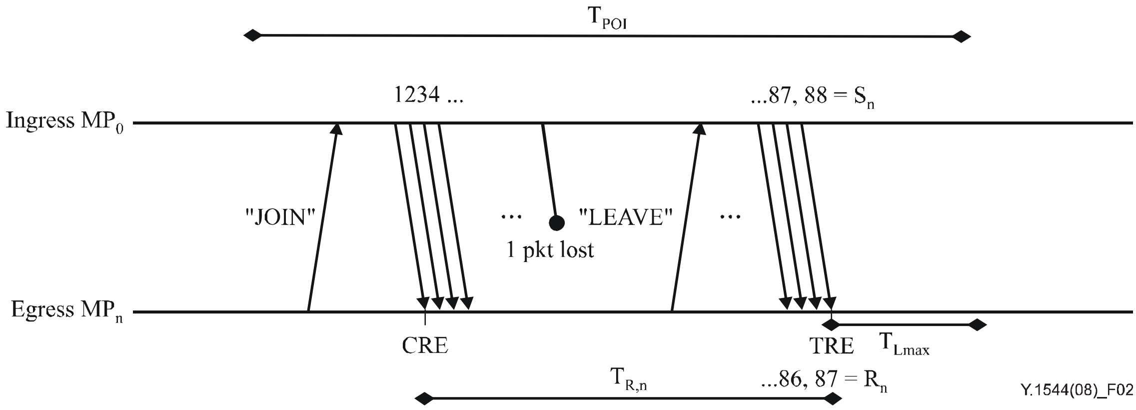

Figure 2 – Effect of changing group membership on the point-to-point population of interest

Other point-to-point outcomes can be represented in a similar way. Lost packet outcomes for destination n are counted as L_n (and $L_n = 1$ in Figure 2 above), errored packet outcomes are E_n, spurious packet outcomes as F_n, and so forth. Thus, for each point-to-multipoint population of interest, there are sets of counts as follows:

$$\overline{S} = \{S_1, S_2, ..., S_N\} \quad \overline{R} = \{R_1, R_2, ..., R_N\} \quad \overline{L} = \{L_1, L_2, ..., L_N\}$$

and sets of point-to-point parameters, such as:

$$\overline{IPLR} = \{IPLR_1, IPLR_2, ..., IPLR_N\} \quad \overline{IPDV} = \{IPDV_1, IPDV_2, ..., IPDV_N\}$$

where the indices are for destinations (these are vectors of point-to-point parameter results).

On the other hand, the set of permissible MPs for a NS may be revised due to routing adaptation to equipment failures during T_{POI}. This category of changes to the permissible set is expected to be infrequent.

The names of the point-to-multipoint parameters employ two adjectives with the meaning below:

- **Global**: equal weighting given to all *packets* in the population of interest;
- **Group**: equal weighting given to the point-to-point parameters calculated for each *destination* that is a member of the group.

Both types of parameters take the possibility of group membership changes into account.

Some parameters can be taken as more primary than others. For example, a global packet loss ratio result of zero indicates that all packets have been delivered to all destinations, and there is no need to investigate any per-destination point-to-point results for that population of interest.

Thus, we have the situation illustrated below for point-to-multipoint topologies with N Destinations.

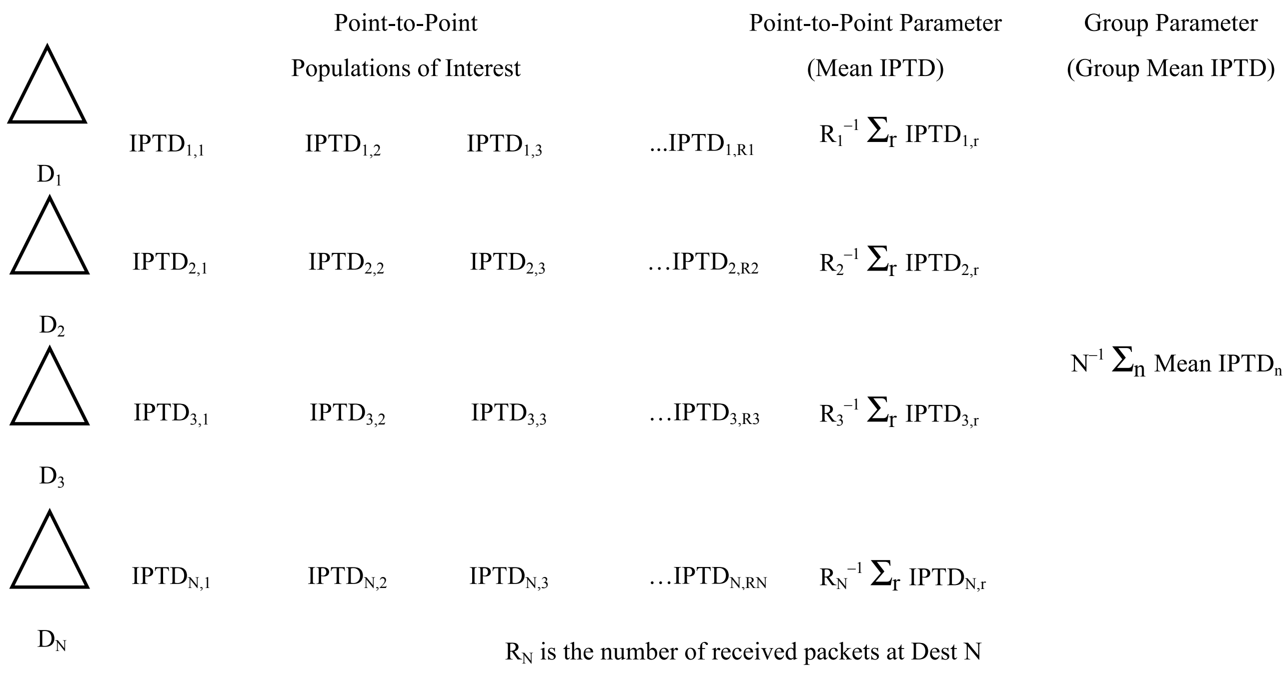

Figure 3 – Illustration of a point-to-multipoint group parameter calculation

Note that with Group parameters, *any* statistic can be applied to the point-to-point populations of interest, and then *any* statistic can be applied to the point-to-point parameters, not just the mean as illustrated in Figure 3. With Global parameters, *any* statistic can be applied to the complete matrix of point-to-point results. Appendix II discusses the possibilities in more detail.

6.2 Loss-related parameters

Usually, loss ratios are calculated with respect to the total packets sent. In point-to-multipoint configurations, it can also be useful to compare the successful packet transfers among destinations using the destination with the largest number of successful transfers as the reference.

Global loss ratio: The overall loss ratio for all registered destinations and a packet population of interest, calculated as the sum of all lost packet outcomes divided by the sum of packets transmitted to each destination while a member of the specified group.

Using the concepts and symbols introduced above, the mathematical representation of this parameter is:

$$\frac{\sum_{n=1}^{N} L_n}{\sum_{n=1}^{N} S_n}$$

Mean group loss ratio: The mean group loss ratio for all registered destinations and a packet population of interest is calculated as the sum of all point-to-point IP packet loss ratios (IPLR) divided by the number of registered destinations that were members of the specified group during T_{POI}.

The mathematical representation of this parameter is:

$$\frac{\sum_{n=1}^{N} IPLR_n}{N} \text{ where } IPLR_n = \frac{L_n}{S_n}$$

Loss ratio range over group: The loss ratio range is determined from the minimum and maximum values of the point-to-point IP packet loss ratios for the set of Destinations in the group and a population of interest. Both the maximum and the minimum are recorded, and both values are given to indicate the range.

The mathematical representation of this parameter is:

$$\max(\overline{IPLR}), \min(\overline{IPLR})$$

This parameter may be based on a low percentile and a high percentile, such as 1% and 99% or other values, rather than minimum and maximum, because these cannot be known with certainty when sub-sampling the population. In any case, the basis of the range must be included with the results. See Appendix I for further discussion.

Comparative group delivery ratio: The ratio between the number of successful IP packet transfer outcomes, R_n, for a particular registered destination D_n, and the largest number of successful IP packet transfer outcomes at another registered destination, designated R_{max}, for the population of interest, where both destinations were registered group members throughout T_{POI}. The mathematical representation of this parameter is:

$$R_n / R_{\max}$$

Note that the use of R_{max} enables a destination-only assessment, but R_{max} may not equal the transmitted packet count, S for the population of interest. Also, note that the one's-complement of this parameter would be the comparative group loss ratio.

6.3 Burst loss or outage-related parameters

Parameters in this category are to be determined through further study (and might be added as an annex).

6.4 Delay-related parameters

Global mean one-way delay: The overall mean one-way delay for all registered destinations, calculated as the sum of one-way delays for all successful IP packet transfer outcomes divided by the total successful IP packet transfer outcomes at all registered destinations.

Using the concepts and symbols introduced above, the mathematical representation of this parameter is:

$$\frac{\sum_{n,r}^{N,R_n} IPTD_{n,r}}{\sum_{n=1}^{N} R_n}$$

Group mean one-way delay: The overall mean one-way delay for all registered destinations, calculated as the sum of mean IPTD delays for all Destinations divided by the number of registered destinations (N). This parameter is illustrated in Figure 3.

The mathematical representation of this parameter is:

$$\frac{\sum_{n=1}^{N} mean(IPTD_n)}{N} \text{ where } mean(IPTD_n) = R_n^{-1} \sum_{r}^{R_n} IPTD_{n,r}$$

One-way mean delay range over group: This range is determined from the minimum and maximum values of the point-to-point mean one-way IP packet transfer delay for the set of destinations in the group and a population of interest. Both the minimum and the maximum are recorded, and the range is the difference between the maximum and the minimum.

The mathematical representation of this parameter is:

$$\max(\overline{mean(IPTD)}), \min(\overline{mean(IPTD)})$$

6.5 Delay variation-related parameters

One-way delay variation range over group: This range is determined from the minimum and maximum values of the point-to-point one-way IP packet delay variation for the set of Destinations in the group and a population of interest, using the 2-point packet delay variation expressed as the $1\text{-}10^{-3}$ quantile of one-way delay minus the minimum one-way delay. If a more demanding service is considered, one alternative is to use the $1\text{-}10^{-5}$ quantile, and in either case the quantile used should be recorded with the results. Both the minimum and the maximum are recorded, and both values are given to indicate the range.

The mathematical representation of this parameter is:

$$\max(\overline{IPDV}), \min(\overline{IPDV})$$

6.6 Packet rate-related parameters

[ITU-T Y.1540] specified two rate parameters in Appendix III: both packet-based and octet-based rates. This Recommendation elevates the definitions to normative status, and introduces point-to-multipoint parameters on packet rate. This approach results in Group parameters.

Point-to-point IP packet rate (IPPR): For a given population of interest, the IP packet rate at an egress MP is the total number of IP packet transfer reference events observed at that egress MP during a specified time interval divided by the time interval duration, T_R (equivalently, the number of IP packet transfer reference events per service-second).

Accounting for the possibility that destinations may join or leave a group during T_{POI}, the mathematical representation of this parameter is:

$$R_n / T_{R,n}$$

where $T_{R,n}$ is the time interval that corresponds to the packets constituting CRE, LRE, or the boundaries of the population of interest, as appropriate.

Point-to-point octet-based IP packet rate (IPOR): For a given population of interest, the octet-based IP packet rate at an egress MP is the total number of octets transmitted in IP **packet payloads and headers** that result in an IP packet transfer reference event at that egress MP during a specified time interval divided by the time interval duration, T_{POI} (equivalently, the number of octets in the IP packets resulting in IP packet reference events per service-second).

Group mean packet rate: The overall mean packet rate for all registered destinations, calculated as the sum of IPPR for all Destinations divided by the number of registered destinations (N).

Group mean octet-based IP packet rate: The overall mean packet rate for all registered destinations, calculated as the sum of IPOR for all Destinations divided by the number of registered destinations (N).

The mathematical representations of these parameters are:

$$mean(\overline{IPPR}) = \frac{\sum_{n=1}^{N}(IPPR_n)}{N} \quad \text{and} \quad mean(\overline{IPOR}) = \frac{\sum_{n=1}^{N}(IPOR_n)}{N}$$

One-way packet rate range over group: This range is determined from the minimum and maximum values of the point-to-point mean one-way IP packet rate for the set of Destinations in the group and a population of interest. Both the minimum and the maximum are recorded, and the range is the difference between the maximum and the minimum.

The mathematical representation of this parameter is:

$$\max(\overline{IPPR}), \min(\overline{IPPR})$$

(and similar for octet-based rate).

6.7 Packet duplication and replication parameters

The revised version of [ITU-T Y.1540] adds new packet transfer outcomes to address the possibility of unexpected packet replication and duplication during transfer for the point-to-point case. Also, there are new parameters to express the prevalence of these outcomes over a population of interest. Unwanted replication and duplication are expected to be infrequent, since IP multicast protocols have features explicitly designed to detect improper packet reproduction in the multicast tree (the reverse path forwarding check). However, it is a simple matter to construct the point-to-multipoint versions of IP reordered packet ratio (IPRR) and IP packet duplicate ratio (IPDR) following the specifications for loss ratio parameters above, if reordering and duplication prove critical to assess.

6.8 Comparison with objectives (general calculation for all parameters)

Typically, the users of performance parameters need to make comparisons with objectives. This clause treats the point-to-multipoint parameters as a general case. Results collected for a population of interest and a set of registered destinations should be compared with an objective, O, as follows:

Percent meeting objective (PMO): The percentage of total destinations with point-to-point performance that is categorized as meeting the stated objective for a specific population of interest.

The objectives are evaluated over sets of point-to-point parameters, such as the following for IPLR:

$$\frac{Count(\overline{IPLR} \mid IPLR_n \le O_{IPLR})}{Count(\overline{IPLR})} \times 100$$

where the Count( ) function determines the number of elements in the set that meets the stated condition.

6.9 Organization of parameters according to use case

This clause categorizes the performance parameters according to the audience most likely to benefit from the results expressed in those terms. In Table 2, customer representatives are the persons responsible for a large community of users, and may act on the user's behalf for contract negotiations or bill-paying. Network operators and individual users are also included.

Table 2 – Point-to-multipoint performance parameters organized by use case

	Customer representative-oriented parameters	Network operator-oriented parameters
Throughput (rates)	Min and max rates over group	Mean, min and max rates
Loss	Group loss ratio	Loss ratio range over group
Delay	Global mean	Delay range over group
Delay variation	Range over group	Range over group

The point-point metrics are best suited for the needs of individual users.

Availability is important to all categories, and parameters are defined in clause 7.

7 Point-to-multipoint IP service availability parameters

The point-to-point unidirectional availability service function defined in [ITU-T Y.1540] should be used to evaluate the availability of the multicast path between a Source and any individual Destination.

Group IP service availability: Given *D,* a set of N Destinations (or group) intending to receive packets from a Source, the point-to-multipoint IP service availability parameter is defined as the ratio of Destinations in the (point-to-point) available state, N_{av}, (during a specific evaluation interval T_{av}), and the total destinations N (where point to-point availability is as specified in [ITU-T Y.1540]).

The fraction of destinations in the available state during T_{av} can be expressed as:

$$A(T_{av}) = N_{av} / N$$

Mean group IP service availability: The mean fraction of available destinations over a result-recording interval, $T_r = I \times T_{av}$, is:

$$mean(A(T_{av}), T_r) = I^{-1} \sum_i A(T_{av})_i$$

where *I* is an integer.

8 Multicast group membership performance parameters

Destination hosts use the Internet group management protocol (IGMP) to indicate their user's desire to "join" (or "leave") a multicast group, meaning that they wish to receive a particular multicast packet stream emanating from a particular source (or no longer desire the stream). IGMP messages are exchanged between the hosts and the designated multicast router on a particular sub-network (e.g., LAN) to communicate registration information. The state of each group's membership is stored in the designated router. Membership must be refreshed periodically, in response to a membership query from the multicast router. If at least one host responds with a membership report to the query on a given sub-net, then the multicast group will be considered active.

When a sub-network includes a switch, then the switch itself may also retain the group membership state in order to restrict the multicast group flow on ports where there is no currently registered host.

IGMP message exchanges are most relevant to user-oriented performance when observed at a destination host's service access interface, or user-network interface (UNI). Stimulus is observed on the ingress direction and the response is observed on the egress direction. In the vernacular of [ITU-T Y.1540], these are ingress and egress measurement points (MPs) that share the same boundary. The group membership parameters are defined using these MP.

Version 1 of the IGMP specification did not include an explicit "leave group" message, relying instead on the periodic membership query to determine that there were no remaining hosts willing to refresh their membership. Version 2 added an explicit "Leave" message format, and this is the basis for the definitions of Disengagement parameters. Note that the specific sub-network technology used and the presence or absence of other hosts on the sub-net registered for the group will determine whether a Leave message causes cessation of the multicast packet flow.

This clause specifies several *provisional values* for waiting times. Provisional values are subject to change, and may be revised (up or down) in the future based on real operational experience. There are circumstances where other values may be suitable, such as when network latency is high.

8.1 Reference events at the Destination UNI

This clause defines several key IGMP reference events, at the ingress and egress MP associated with a particular Destination UNI.

8.1.1 Ingress MP

Join reference event (JRE): Occurs when an IP packet ingress event occurs, and the packet is an IGMP measurement report indicating the desire to join a particular multicast group.

Leave reference event (LRE): Occurs when an IP packet ingress event occurs, and the packet is an IGMP Leave message indicating the desire to leave a particular multicast group.

8.1.2 Egress MP

Commence reference event (CRE): Occurs when an IP packet egress event occurs, and the packet is the first packet observed that is part of a particular multicast group.

Termination reference event (TRE): Occurs when an IP packet egress event occurs, and the packet is the last packet observed that is part of a particular multicast group (and no packets of this group are observed for T_{Lmax} (the waiting time to confirm that a stream has terminated)).

8.2 Communication access parameters

8.2.1 Speed – successful join time

A join attempt succeeds when a properly formatted IGMP membership report message packet enters the ingress MP, and one or more properly formatted multicast packets with the corresponding source and multicast group addresses exit the egress MP within a maximum waiting time, T_{Jmax}. The provisional value of T_{Jmax} is 1 second.

Join time is defined as the interval starting when the first bit of a properly formatted IGMP membership report message packet enters the ingress MP (or JRE), until the last bit of a properly formatted multicast packet with the corresponding source and multicast group addresses exits the egress MP (or CRE). Note that the join time essentially measures the time needed to complete a successful join attempt.

Join time is expressed in seconds, with sufficient resolution to distinguish variability in successive attempts, when present. Multiple measurements of join time may be summarized using statistics such as the minimum, maximum, median, mean, variance, percentiles, etc.

8.2.2 Accuracy – incorrect join outcome and incorrect join ratio

An incorrect join outcome occurs when a properly formatted IGMP membership report message packet enters the ingress MP, and one or more properly formatted multicast packets with incorrect source and/or multicast group addresses exit the egress MP within a maximum waiting time, T_{Jmax}.

An incorrect join outcome is a logical parameter, where attempts that result in an incorrect response are indicated with "1" (e.g., the multicast packets are from the wrong source or group), and other responses are indicated with "0". As an example, consider the IPTV application where the user's request to change from one program channel to another results in the incorrect program being displayed. This would be an incorrect join outcome.

The incorrect join ratio parameter is defined as the ratio of the incorrect join outcomes to total join attempts collected over time at a single host, over many destination hosts, or both. These incorrect join ratios are distinguished by an adjective, such as host incorrect join ratio, or group incorrect join ratio.

8.2.3 Dependability – failed join outcome and failed join ratio

[ITU-T I.350] states that the term dependability "is the performance criterion that describes the degree of certainty (or surety) with which the function is performed regardless of speed or accuracy, but within a given observation interval."

A join attempt fails when a properly formatted IGMP membership report message packet enters the ingress MP, and one or more properly formatted multicast packets with the corresponding source and multicast group addresses does not exit the egress MP within a maximum waiting time, T_{Jmax}.

The failed join outcome is a logical parameter, where failed attempts are indicated with "1" and successful attempts are indicated with "0".

As an example, consider the IPTV application where the user's request to change from one program channel to another results in no change of the program being displayed. This would be a failed join outcome.

The failed join ratio parameter is defined as the ratio of the failed join attempts to total join attempts collected over time at a single host, over many destination hosts, or both. These failed join ratios are distinguished by an adjective, such as host failed join ratio, or group failed join ratio.

8.3 Communication disengagement parameters

8.3.1 Speed – successful leave time

A leave attempt succeeds when a properly formatted IGMP leave group message packet enters the ingress MP, and the flow of multicast packets with the corresponding source and multicast group addresses concludes at the egress MP within a maximum waiting time, T_{Lmax}.

The provisional value of T_{Lmax} is 1 second.

Leave time is defined as the interval starting when the first bit of a properly formatted IGMP leave group message packet enters the ingress MP (or LRE), until the last bit of a properly formatted multicast packet with the corresponding source and multicast group addresses exits the egress MP and no further packets of that group are observed (or TRE). Note that the leave time essentially measures the time needed to complete a successful leave attempt.

Leave time is expressed in seconds, with sufficient resolution to distinguish variability in successive attempts, when present. Multiple measurements of leave time may be summarized using statistics such as the minimum, maximum, median, mean, variance, percentiles, etc.

8.3.2 Accuracy – incorrect leave outcome and incorrect leave ratio

An incorrect leave attempt outcome occurs when a properly formatted IGMP leave group message packet enters the ingress MP, and a flow of multicast packets with the non-matching source and/or multicast group addresses concludes at the egress MP within a maximum waiting time, T_{Lmax}.

The incorrect leave ratio parameter is defined as the ratio of the incorrect leave outcomes to total leave attempts collected over time at a single host, over many destination hosts, or both.

As an example, consider the IPTV application with Picture-in-Picture where the user's request to change the main display from one program channel to another results in the Picture-in-Picture program being affected. This would be an incorrect leave outcome, since the wrong program stream was affected.

8.3.3 Dependability – failed leave outcome and failed leave ratio

A leave attempt fails when a properly formatted IGMP leave group message packet enters the ingress MP, and the flow of multicast packets with corresponding source and multicast group addresses does not conclude at the egress MP within a maximum waiting time, T_{Lmax}.

A failed leave outcome is a logical parameter, where failed leave attempts are indicated with "1" and successful attempts are indicated with "0".

The failed leave ratio parameter is defined as the ratio of the failed leave attempts to total leave attempts collected over time at a single host, over many destination hosts, or both. These failed leave ratios are distinguished by an adjective, such as host failed leave ratio, or group failed leave ratio.

As an example, consider the IPTV application where the user's request to change from one program channel to another results in no change of the program being displayed. This scenario could be the result of a failed leave outcome.

9 Summary of performance parameters defined in this Recommendation

Table 3 lists all performance parameters according to the communication function and criterion they assess.

Table 3 – Parameters defined in this Recommendation

Criterion / Function	Speed	Accuracy	Dependability
Access	Successful join time	Incorrect join ratio	Failed join ratio
User Information Transfer	Global mean one-way delay Group mean one-way delay One-way mean delay range over group One-way mean delay variation range over group Point-to-point IP packet rate Point-to-point octet-based IP packet rate Group mean packet rate Group mean octet-based IP packet rate One-way packet rate range over group	Global loss ratio Mean group loss ratio Loss ratio range over group Comparative group delivery ratio	Group IP service availability Mean group IP service availability
Disengagement	Successful leave time	Incorrect leave ratio	Failed leave ratio

Appendix I

Implications of sampling large groups

(This appendix does not form an integral part of this Recommendation)

I.1 Introduction

There are always limitations on the practical size of the group measurements. Specifically, the scale of large multicast groups tends to prevent measurements at every member destination.

I.2 Performance at sample destinations

It should be permissible to measure at a sub-set of the destinations in a group and report the measured range of loss ratio variation, or other parameters.

If the sub-set can be selected with the knowledge of the multicast tree structure, then all of the tree but the final links to the un-sampled destinations can be assessed.

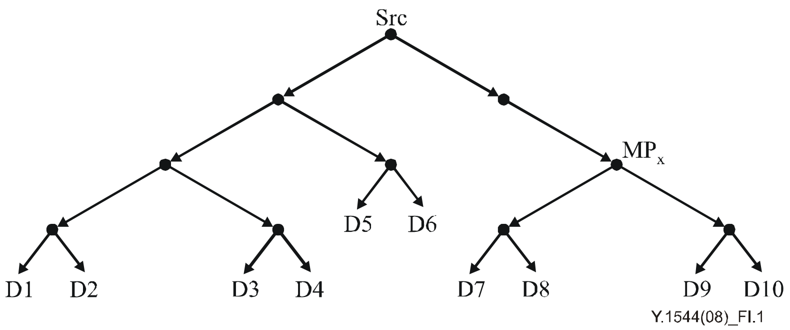

Figure I.1 – Sample of destinations

For example, if the performance of all odd numbered or all even numbered destinations is sampled, then all shared branches and nodes of the tree are assessed.

Note that a population of interest could be defined as described in the body of this Recommendation, and further qualified with a statement such as, "that are successfully delivered to the intermediate node with MP_x". This flexibility allows assessment of a partial multicast tree, where R_x becomes the effective S for this population of interest, and packet loss parameter results for destinations 7 through 10 may assist in the isolation of a cause of loss within the tree.

If objectives are developed for a multicast tree, then the measurement and sampling methodology is critical in determining how the objectives are constructed, and possibly even the numerical values set for the objectives.

The body of this Recommendation specifies several parameters that emphasize the performance range across all destinations in a group. When a sub-set of destinations are measured, it is possible to report the sample range, or to report the range between several percentiles (1% and 99%, for example) because the true performance range of the group cannot be known with certainty.

Appendix II

Alternative parameters using the framework of this Recommendation

(This appendix does not form an integral part of this Recommendation)

II.1 Introduction

It is possible to calculate many different performance parameters using the framework of point-to-point parameters at registered destinations of a multicast group. At the same time, it is impossible to anticipate all the ways that point-to-multipoint parameters might be used, and therefore only the statistics that are anticipated to be relevant for many uses have been specified in the body of this Recommendation. This appendix is intended to give a view of the alternate possibilities.

II.2 Point-to-multipoint performance parameters

The lists that follow give examples of the point-to-multipoint parameters that can be created from packet transfer outcomes, point-to-point parameters. Parameters expressed as ratios are treated separately from continuous-value parameters.

Loss (and other outcomes that use a ratio in the parameter)

- Point-to-point
  - Single outcome
    - A frame is lost/errored/...
  - Calculated values for a population of interest
    - Ratio
- Point-to-multipoint
  - Ratio
    - of Singles
    - of Ratios

Delay (and others that produce results in a continuous range)

- Point-to-point
  - Single value
    - Delay of a frame
    - Delay variation of two frames
  - Calculated values for a population of interest
    - Minimum/maximum
    - Mean/median
    - Range
- Point-to-multipoint
  - Minimum / maximum
    - Singles (→ group vector)
    - Populations of singles (→ matrix)
    - of Min/Mean/Range
  - Mean/median
    - Singles
    - Populations of singles

  - of Min/Mean/Range
- Range
  - of Singles
  - of population of singles
  - of Min/Mean/Range

Bibliography

[b-IETF RFC 3171] IETF RFC 3171 (2001), *IANA Guidelines for IPv4 Multicast Address Assignments*. <http://www.ietf.org/rfc/rfc3171.txt?number=3171>

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