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Basic reference models and performance parameters of Internet Protocol packet network transmission in the mobile-satellite service

M Series

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Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R M.1636

Basic reference models and performance parameters of Internet Protocol packet network transmission in the mobile-satellite service

(Questions ITU-R 85/8, ITU-R 87/8, ITU-R 112/8 and ITU-R 233/8)

(2003)

Summary

This Recommendation provides basic reference models and definitions of performance parameters of Internet Protocol packet network transmission in the mobile-satellite service (MSS). The defined reference models and performance parameters are intended as a technical basis on which the performance objectives and availability are developed, in combination with the technical and operational characteristics for packet network transmission in the MSS.

The ITU Radiocommunication Assembly,

considering

a) that Internet Protocol (IP) packet transmission has become one of major services in modern communication networks including mobile-satellite systems;

b) that hypothetical reference circuits, technical characteristics, performance objectives and availability requirements have been stipulated for conventional MSS in a number of existing Recommendations;

c) that technical characteristics and performance should be defined on the basis of IP packet layers, in addition to basic digital transmission performance of MSS bearer links;

d) that definitions are needed for reference models, technical characteristics and performance parameters as a technical basis for the development of IP packet transmission in MSS;

e) that studies are continuing for performance and availability of IP packet transmission in other forums of ITU-T and ITU-R;

f) that properties inherent to MSS should be taken into consideration when performance objectives and availability requirements are discussed for IP packet network transmission;

g) that studies conducted using a basic reference model of IP packet data transmission are meaningful, however, advanced reference models are needed to conduct study for more advanced IP packet data transmission in MSS,

recommends

1 that the basic reference models in Annex 1 should be applied as a minimum set of IP packet transmission in MSS;

2 that the technical characteristics in Annex 2 should be used for studies and definition of performance parameters and availability for IP packet applications in MSS defined in Annex 1;

3 that the performance parameters and definitions in Annex 3 should be employed for IP packet transmission in MSS defined in Annex 1.

Annex 1

Basic reference models of IP packet transmission in MSS

1 Introduction

MSS systems provide mobile application with worldwide coverage. Recently IP packet transmission has been introduced in some MSS systems. However, IP packet transmission networks are not formally structured. A hypothetical reference connection has not been well defined for IP packet transmission networks. It is therefore important to define the use of MSS links in IP packet transmission services and to establish a reference model on which characteristics and performance can be discussed for MSS.

2 Basic reference model for IP packet transmission in MSS

MSS links will not be used as high-speed backbone links of IP core networks. They are intended as part of the access portion to an edge router, in the global IP network. Two applications for MSS links are considered. The first is a user-terminal to router (R) access connection as shown in Fig. 1. The second considers a larger capacity connection between a mobile local area network (LAN) and an edge router as illustrated in Fig. 2.

FIGURE 1

User-terminal to router connection

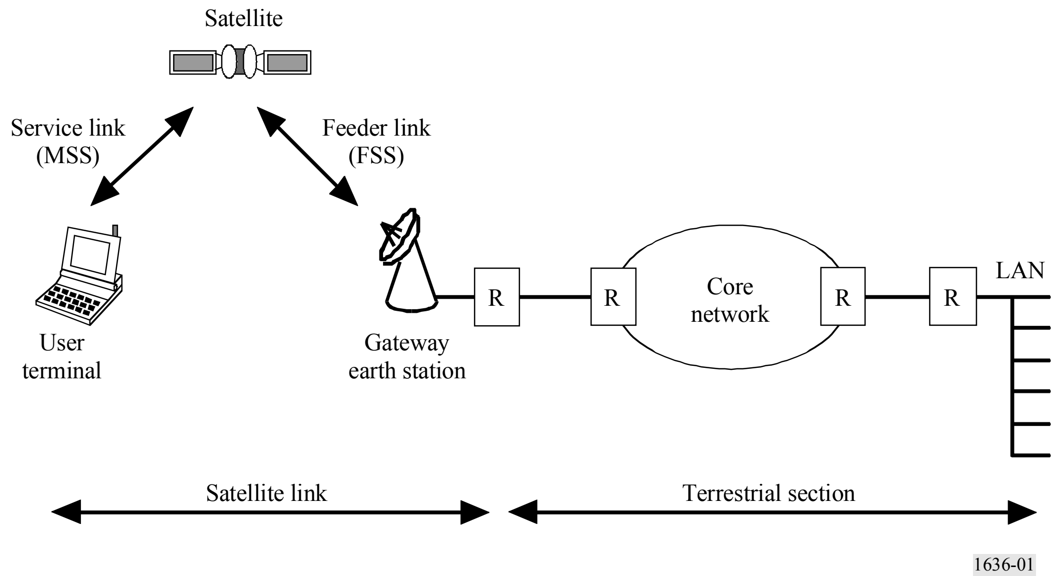
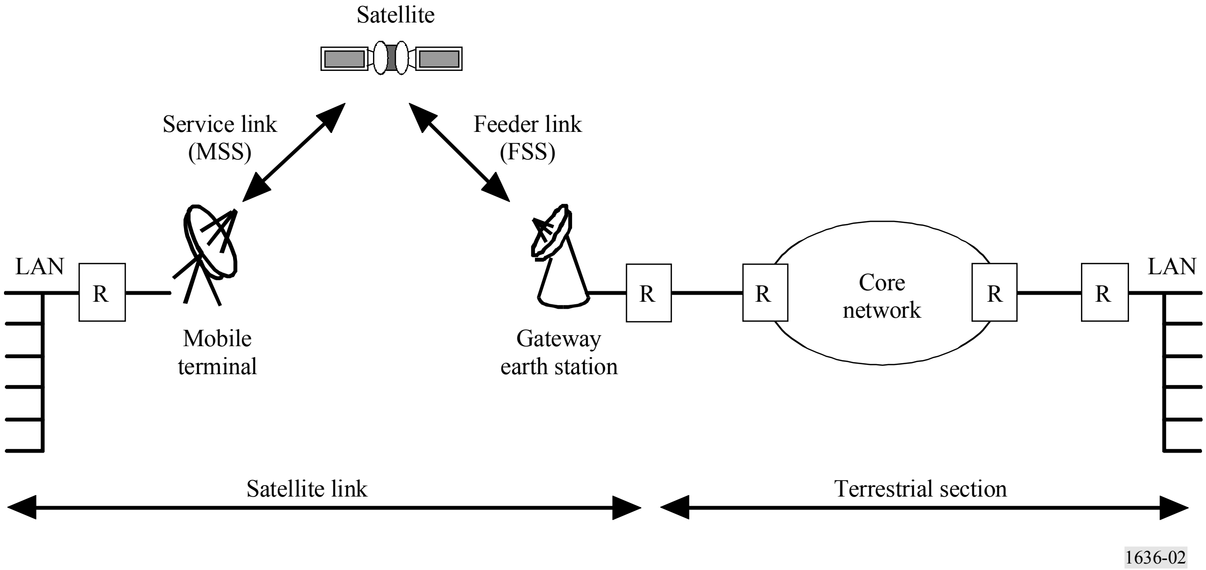


FIGURE 2

LAN to router connection



2.1 Reference models

The classification of MSS topologies is shown in Table 1 and the corresponding routing is shown in Fig. 3. This Recommendation covers reference models denoted by a “Yes” in Table 1.

Both GSO and non-GSO satellite systems are included. Non-GSO systems cover low Earth orbit (LEO) and medium Earth orbit (MEO) satellites but not high Earth orbit (HEO) satellites. Bent-pipe systems are assumed because on-board processing adds extra processing time and inter-satellite links (ISLs) require additional propagation delay.

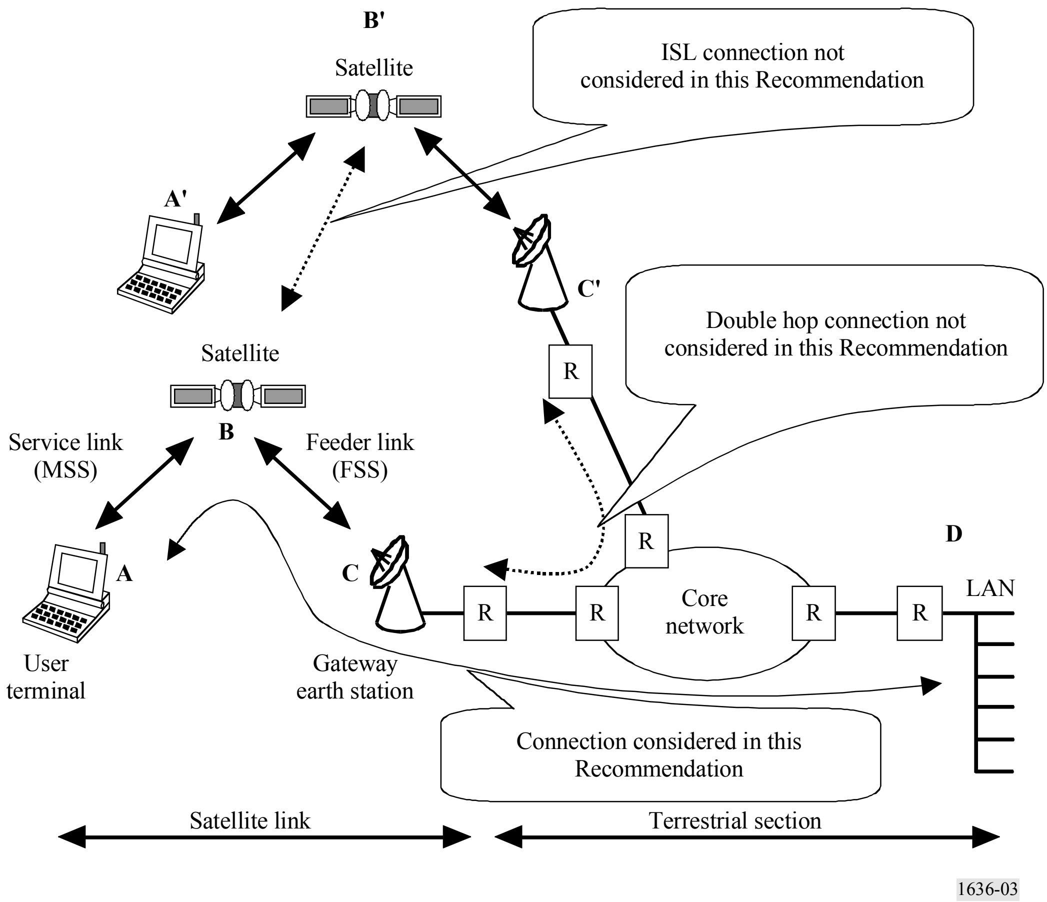
TABLE 1

Classification of MSS system configurations

Characteristics	Route	GSO	HEO	MEO	LEO
Single hop	A-B-C-D	Yes	No	Yes	Yes
Double hop – no ISL	A-B-C-B-A' or A-B-C-C'-B'-A'	No	No	No	No
Double hop – via ISL	A-B-B'-A'	No	No	No	No

FIGURE 3

Packet routing considered in this Recommendation



These models provide definitions of the MSS section and interface points in the entire IP packet network. It should be noted that the satellite section consists of a service link in the MSS and a feeder link categorized as FSS. All discussion in this Recommendation will be based on these models for consideration of technical characteristics and performance of IP packet services in the MSS.

2.2 Usage of a physical connection for logical connections

Due to the nature of multiple access of MSS by a number of users, there may be many cases for the use of a satellite bearer circuit by user IP connections. The simplest case is a dedicated use of a satellite bearer circuit for a single IP connection by one user (Fig. 4a). In this case, the satellite bearer circuit is considered to have fixed transmission capacity. There is another case where multiple users share capacity of a satellite bearer circuit. In the latter case, a portion of fixed capacity within the satellite bearer circuit is assigned to each of the multiple users (Fig. 4b). From the viewpoint of each user, it is theoretically possible in the case of Fig. 4c to change the assigned capacity dynamically during the use by multiple users based on the concept of “best effort service”. Dynamic capacity allocation is taken into consideration in this Recommendation. In this context, a “user” refers to a user mobile terminal to the satellite link. A LAN output that is connected to the satellite link is therefore a user even though the LAN accommodates multiple IP service users.

FIGURE 4a

Satellite link for single user connection

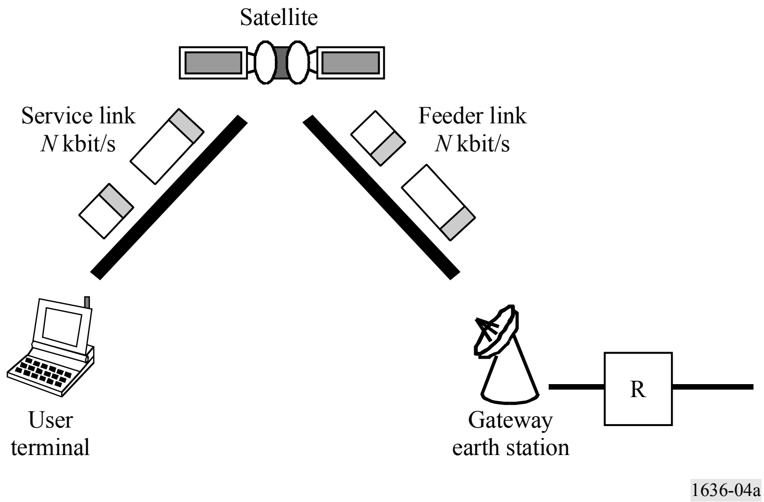


FIGURE 4b

Satellite link shared by multiple user connections with fixed capacity allocation

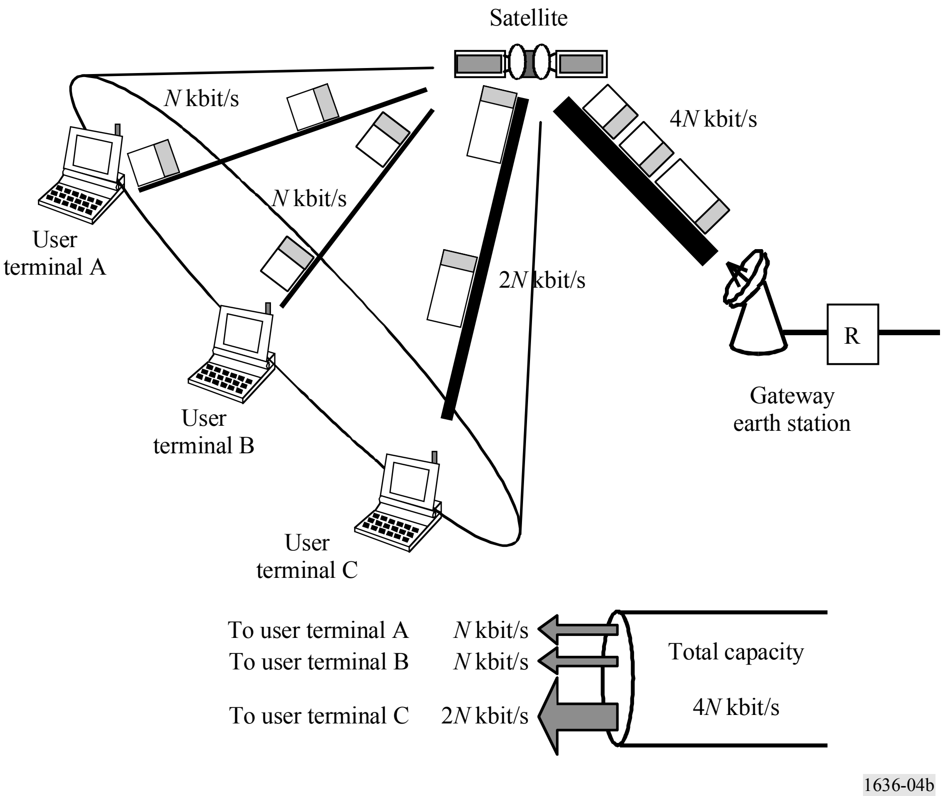
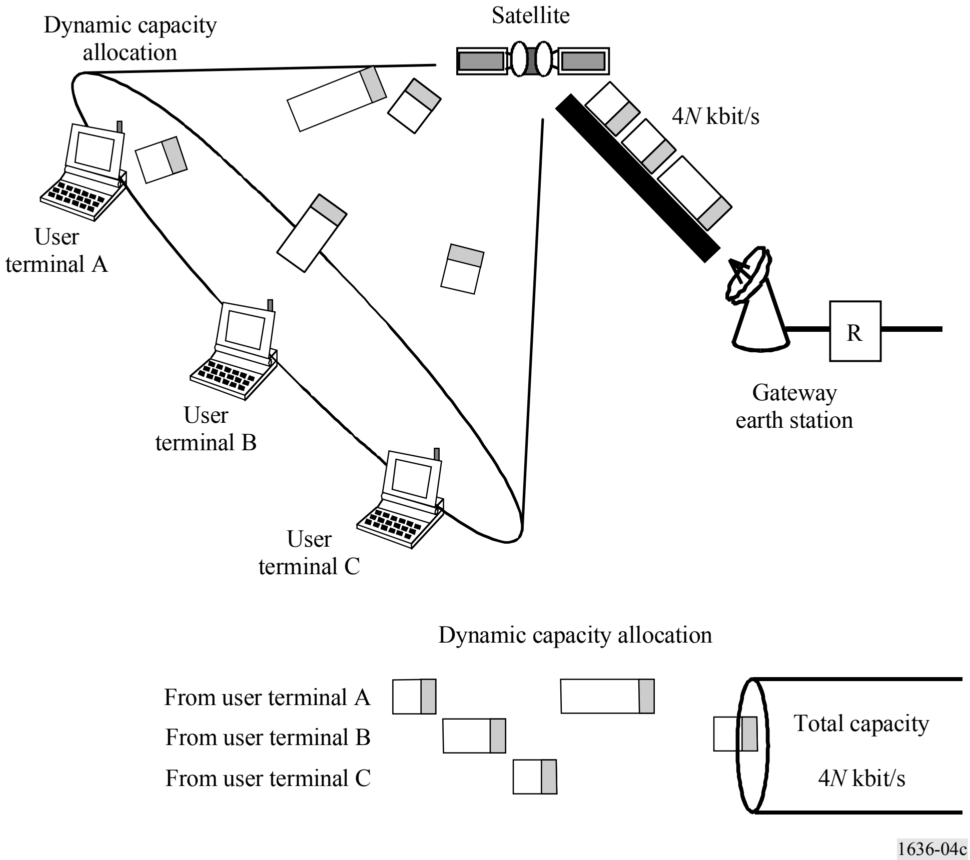


FIGURE 4c

Satellite link shared by multiple user connections with dynamic capacity allocation



Annex 2

Technical characteristics to support lower layers of IP packet transmission in the MSS

1 Technical characteristics and transmission parameters

Since IP packet transmission application is provided over an MSS digital link, it is natural to describe technical characteristics focusing on transmission parameters. The following parameters are basic information to characterize such MSS digital link in which IP packet transmission application is provided. Conventional definitions are assumed for these parameters.

a) *Bearer transmission characteristics*

– Type of modulation

– Transmission rate (bit/s)

– Scheme of forward error correction (FEC)

– Threshold BER

– Percentage of time better than the threshold BER.

b) *Packet transmission characteristics for Layer 2*

– General description of Layer 2 protocol

– Frame structure for MSS satellite link and packet to frame adaptation

– Packet length

– Packet header structure

– Error control and retransmission capability of Layer 2

– Packet collision control scheme, if necessary

– Protocol stack conversion for MSS satellite link.

c) *Delay characteristics*

– Propagation delay (ms)

In the case of GSO satellite systems, the propagation delay is dependent upon the location of the mobile relative to the satellite orbital location, and is regarded to be constant for each stationary mobile if a slight fluctuation is disregarded. On the other hand, in the case of intermediate circular orbit satellite systems of MEO, the smallest propagation delay at the sub-satellite point is 69 ms and the largest propagation delay at the edge of satellite coverage is 103 ms. The propagation delay will be less for the case of LEO satellite systems.

– Delay jump on satellite handover (ms)

A sudden change of propagation delay may occur as the result of handover from one satellite to another in the non-GSO or GSO satellite constellation. The probability of handover between satellites is different for non-GSO and GSO satellite systems. For GSO systems, it might only occur for non-stationary mobile terminals, due to mobile relocation or blockage due to infrastructure.

In the case of intermediate circular orbit satellite systems of MEO, the largest value of delay jump will be resulted by satellite handover from one satellite located at the low elevation with the largest propagation delay (103 ms) to another with the smallest propagation delay (69 ms). The largest delay jump will be 34 ms for this case.

Annex 3

Performance parameters and definitions for IP packet transmission in the MSS

Introduction

Performance parameters on an IP packet basis are essential in IP packet transmission service over the MSS. The definitions provided in ITU-T Recommendations Y.1540 and Y.1541 should be the basis for this analysis. At the same time, aspects inherent to the MSS should be taken into account. It is inappropriate in MSS applications to pay too much attention to detailed parameters. The special properties of GSO and non-GSO MSS systems should be properly reflected in the definition of general parameters. It is also important to select parameters which are suitable for allocating performance objectives to sections of IP connection including an MSS satellite link.

2 Definitions of performance parameters

2.1 IP packet related parameters

The following parameters are considered essential. Definitions and interpretation in the context of the MSS are given for each parameter. These parameters will be sufficient to characterize IP packet transfer over an MSS link. Other parameters such as spurious IP packet rate are considered to be too detailed for application to MSS links.

2.1.1 IP packet transfer delay (IPTD)

IPTD is the total transmission delay for an end-to-end IP connection. IPTD can also be defined for a section of the end-to-end connection. IPTD for the end-to-end connection shall be properly allocated to all the sections that form the end-to-end connection.

Since transmission delay is considered by some standard engineers to be large over a satellite link, it is essential to identify an allowable amount for IPTD for the mobile satellite link section including both feeder and service links. IP packet transmission systems are classified to delay sensitive systems and error sensitive systems. A system requirement decides which system to be employed, based on the priority of importance for less delay or less error. IPTD for an MSS link, $IPTD_{sat}$, can be determined separately for each system.

It should be noted that $IPTD_{sat}$ is considered after establishment of a satellite link, and that delay associated with random access transmission for dynamic capacity allocation might be included in signal processing delay for framing and adaptation for the MSS link, denoted by $T_{processing}$ below.

a) *IPTD for delay sensitive systems*

For delay sensitive systems, which have no retransmission capability at Layer 2, $IPTD_{sat}$ is defined as:

$$IPTD_{sat} = T_{propagation} + T_{processing} + T_{buffer}$$

where:

$T_{propagation}$: propagation delay of an MSS link

$T_{processing}$: signal processing delay for framing and adaptation for the MSS link

T_{buffer}: buffering delay at a router or at an interface to connect the MSS link to a terrestrial section.

b) *IPTD for error sensitive systems*

For error sensitive systems, which have a retransmission capability at Layer 2, $IPTD_{sat}$ varies with the number of retransmission times. If a definition of $IPTD_{sat}$ for error sensitive systems is required, it may be described as follows:

$$IPTD_{sat} = \sum_{n=1}^{N+1} \left\{ T_{n,\ propagation} + T_{n,\ processing} \right\} + T_{buffer}$$

where:

N: times for retransmission

$T_{n,\ propagation}$: $T_{propagation}$ for the n-th time transmission

$T_{n,\ processing}$: $T_{processing}$ for the n-th time transmission.

It is to be noted that the large value of $IPTD_{sat}$, after several retransmission trials at Layer 2, in a satellite link might not be meaningful, because the retransmission scheme at Layer 4 or higher might discard the delayed IP packet for its timeout. In addition, it may need a probabilistic term to be considered within the expression to support a retransmission mechanism. These are issues for further study to determine a more appropriate definition of $IPTD_{sat}$ for error sensitive systems.

2.1.2 IP packet delay variation (IPDV)

IPTD varies, it depends on various factors that include congestion in the part of the network considered by this Recommendation as well as framing and retransmission control in Layer 2. IPDV can be defined in many ways as discussed in the ATM Recommendations but for the purpose of this Recommendation it will be assumed to be the difference between the largest IPTD and the smallest IPTD as follows:

For delay sensitive systems, which have no retransmission capability at Layer 2:

$$IPDV = IPTD_{max} - IPTD_{min}$$

where:

$IPTD_{max}$: largest IPTD

$IPTD_{min}$: smallest IPTD.

For error sensitive systems, which have retransmission capability at Layer 2, the statistical method in Appendix 2 of ITU-T Recommendation Y.1541 is applied, where:

$IPTD_{max}$: largest IPTD during a measurement interval

$IPTD_{min}$: smallest IPTD during a measurement interval.

Several values of IPDV are measured over a large time interval, comprising several short measurement intervals. The X% of these IPDV must meet the defined objective. The value of X is to be determined.

Note that the fluctuation of propagation delay also affects IPDV. In the case of non-GSO satellite systems, variation of propagation delay due to satellite movement should be included. In addition, a sudden change of propagation delay may occur as the result of handover from one satellite to another in a satellite constellation.

2.1.3 IP packet loss ratio (IPLR)

IPLR is the ratio of the number of lost IP packets to the total number of transmitted IP packets. In MSS links, a short disruption due to shadowing or blocking may give rise to IP packet loss.

2.1.4 IP packet error ratio (IPER)

IPER is the ratio of the number of errored IP packets to the total number of successful and errored IP packets. This general definition is applicable to an MSS link without any special consideration for property of MSS systems.

2.2 Availability

Service availability may be defined for two levels. First, MSS link availability should be defined. Recommendation ITU-R M.828 is the basis for this definition[1].

It is also necessary to define availability for IP levels. In accordance with ITU-T Recommendation Y.1540, an IP packet transmission link is declared to be unavailable if IP packet loss ratio is higher than a given threshold. It is generally appropriate to apply the same threshold as in ITU-T Recommendation Y.1540. The threshold value of 75% for IPLR is provisionally assumed for the duration of 5 min or longer.

3 Consideration of performance objectives

To analyse performance parameters and objectives, it is necessary to take account of the properties of MSS links and their measurement capability in practical operational environments. Special attention should also be paid to consistency with the conventional provisions described in the existing ITU-R M-Series Recommendations.

3.1 IP packet propagation delay and the delay variation in the MSS environment

It is appropriate to discuss $T_{propagation}$ for an MSS link because of its long propagation delay.

The worst case is when a GSO link has a low elevation angle to the horizon. LEO and MEO cases may be better if there are a large number of satellites giving a good coverage of the surface of the Earth.

$T_{propagation}$ is dependent upon the location of the mobile station relative to the satellite orbital location, and may be regarded as constant for the GSO case for each stationary mobile station. On the other hand, variation of $T_{propagation}$ becomes large for non-GSO satellite systems. For example, in the case of intermediate circular orbit MEO satellite systems, the smallest $T_{propagation}$ at the sub-satellite point is 69 ms and the largest $T_{propagation}$ at the edge of satellite coverage is 103 ms. The variation of $T_{propagation}$ is as large as 34 ms. Variation of $T_{propagation}$ will be less for the LEO satellite system cases. Typical values for propagation delay characteristics in each MSS environment are shown in Table 2.

TABLE 2

Typical values for delay characteristics of propagation in each MSS environment

	GSO	MEO	LEO
Maximum propagation delay (ms)	280	80-120	20-60
Satellite handover during call	Unlikely	Every 2 h	Every 10 min
IPDV on handover (ms)	None	< 34	< 4

[1] Recommendation ITU-R M.828 provides the definition for availability of an MSS link on a 10 s basis. Another Recommendation, Recommendation ITU-R M.1476, recommends, for MSSs forming part of ISDN, that the combined MSS radio link unavailability due to propagation should be, provisionally, not more than 0.1% of the time.

3.2 IPLR and IPER[2]

IPLR and IPER are defined in ITU-T Recommendation Y.1541 to be 1×10^{-3} and 1×10^{-4}, respectively for distances that are not defined. It would be necessary to take account of the digital transmission performance that is stipulated for MSS in the present ITU-R M-Series Recommendations[3].

For information, it is considered that there would be a trade-off relationship between reducing transfer delay and reducing packet error for a system design as follows:

a) *IPLR and IPER for delay sensitive systems*

For delay sensitive systems, which have no retransmission capability at Layer 2 that increases transfer delay, IPLR and IPER are determined by performance of satellite channel. It is considered that link blockage and fading statistics could either cause significant packet error, depending upon the channel rate, the FEC block sizes and the system link margins.

b) *IPLR and IPER for error sensitive systems*

There might be a large transfer delay owing to a retransmission at Layer 2 for error sensitive systems. However, packet error could be reduced for end-to-end connection over the satellite channel. It is considered that IPER is determined solely by the strength of the error detection algorithms combined with any redundancy in the packet encoding mechanisms. IPLR will typically be dominated by discard owing to buffer overflows during congestion. Neither of these effects is particularly strongly linked to the satellite channel.

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[2] It is noted in ITU-T Recommendation Y.1540 that performance objectives such as IPLR will be discussed for the period when the objective link is in an available condition.

[3] For instance, Recommendation ITU-R M.1181 recommends for digital MSS links up to 16 kbit/s that the BER should be better than 1×10^{-5} after error correction for not less than 95% of the available time. Another Recommendation, Recommendation ITU-R M.1476, stipulates a better performance objective for MSS forming part of ISDN, such that the BER should be better than 9×10^{-7} after error correction for more than 99% of the available time. Recent advanced MSS systems may achieve better performance even for higher transmission rates.