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

International data transmission systems

General description and operational procedures for international SDH leased circuits

ITU-T Recommendation M.1301

(Formerly CCITT Recommendation)

ITU-T M-SERIES RECOMMENDATIONS

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

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ITU-T Recommendation M.1301

General description and operational procedures for international SDH leased circuits

Summary

This Recommendation provides a general description of international synchronous digital leased circuits with an SDH presentation to the Customer, and of the basic requirements for their effective operation. The case of mixed SDH/PDH leased circuits is also described.

Source

ITU-T Recommendation M.1301 was prepared by ITU-T Study Group 4 (2001-2004) and approved under the WTSA Resolution 1 procedure on 19 January 2001.

Keywords

Digital leased circuit, digital path, international synchronous digital leased circuit, network termination equipment, path OverHead (POH), path terminating equipment, path termination point, section OverHead (SOH), synchronous Digital Hierarchy (SDH), trail, trail Termination Point (TTP).

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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ITU-T Recommendation M.1301

General description and operational procedures for international SDH leased circuits

1 Scope

This Recommendation defines international synchronous digital leased circuits with an SDH presentation to the Customer (hereafter called SDH leased circuits) which are transported via STM-N transmission links over a variety of transmission media using a number of network technologies. The case of mixed SDH/PDH leased circuits is also described.

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; all 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.

[1] ITU-T G.701 (1993), *Vocabulary of digital transmission and multiplexing and Pulse Code Modulation (PCM) terms*.

[2] ITU-T G.703 (1998), *Physical/electrical characteristics of hierarchical digital interfaces*.

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[66] ITU-T X.790 (1995), *Trouble management function for ITU-T applications*.

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3 Terms and definitions

General terminology and definitions relating to this Recommendation are provided in ITU-T G.701 [1] and ITU-T M.60 [27]. For the purposes of this Recommendation, the following definitions also apply:

3.1 SDH digital path: a subset of a Digital Trail carrying the SDH payload and associated Path OverHead (POH) through the layered transport network between the two Path Termination Points (PTPs) within the Path Terminating Equipment (PTE). The SDH digital path usually comprises both access network portions and core transport network portions. The network portions comprise one or more SDH regenerator and/or multiplex sections, each of which has an associated Section OverHead (SOH). An SDH digital path may be bidirectional or unidirectional and may comprise both Customer-owned portions and Network Operator (NO)-owned portions.

3.2 SDH digital trail: the complete end-to-end connection carrying the SDH payload and associated POH through the layered transport network between the two Trail Termination Points (TTPs).

3.3 SDH leased circuit: a subset of a SDH digital path between the two Network Terminating Equipments (NTEs). An SDH leased circuit may be bidirectional or unidirectional. The SDH leased circuit end points are at the boundaries between the NO(s), or between the NO and the End-user Customer. At this point, the SDH signal contains the SOH, the payload and the associated POH. However, it should be noted that due to regulatory and/or commercial conditions, access to the POH for In-Service Monitoring (ISM) purposes may not be possible at this point by the NO e.g. when the Customer owns the PTE. The Customer should use the standard POH defined in ITU-T G.707 [3]. This is an issue for further study.

For the purposes of this Recommendation, the terms "path" and "trail" are assumed to be synonymous.

3.4 Service Level Agreement (SLA): an SLA or Contract is a set of appropriate procedures and targets formally or informally agreed between Network Operators/Service Providers (NOs/SPs) or between NOs/SPs and Customers, in order to support ITU-T Recommendations, achieve and maintain specified Quality of Service (QoS). The SLA may be an integral part of the Contract. These procedures and targets are related to specific circuit/service availability, error performance, Ready For Service (RFS) date, Mean Time Between Failures (MTBF), Mean Time to Restore Service (MTRS), Mean Time To Repair (MTTR).

4 Abbreviations

This Recommendation uses the following abbreviations:

ADM Add-Drop Multiplex

AIS Alarm Indication Signal

API Access Point Identifier

ATM Asynchronous Transfer Mode

BBE Background Block Error

[1] Maintenance of SDH systems designed to meet the long-term error performance of ITU-T G.826 should be maintained to ITU-T M.2101.1.

BIP-n	Bit Interleaved Parity – nth level
B-ISDN	Broadband-Integrated Services Digital Network
CP	Customer's Premises
CRC	Cyclic Redundancy Checksum
CSES	Consecutive Severely Errored Second
DCS	Digital Cross-connect System
EMS	Element Management System
ES	Errored Second
HO-TCM	Higher Order – Tandem Connection Monitoring
IG	International Gateway
IP	Internet Protocol
ISM	In-Service Monitoring
LAPD	Link Access Protocol for D-channel
LO-TCM	Lower Order – Tandem Connection Monitoring
MS	Multiplex Section
MTBF	Mean Time Between Failures
MTRS	Mean Time to Restore Service
MTTR	Mean Time To Repair
NE	Network Element
NMC	Network Management Centre
NMS	Network Management System
NNI	Network Node Interface
NO	Network Operator
NOC	Network Operations Centre
NTE	Network Terminating Equipment
OC-n	Optical Carrier – nth level
OS	Operations System
PDH	Plesiochronous Digital Hierarchy
POH	Path OverHead
PTE	Path Terminating Equipment
PTP	Path Termination Point
QoS	Quality of Service
RFS	Ready For Service
RS	Regenerator Section
SDH	Synchronous Digital Hierarchy
SES	Severely Errored Second
SLA	Service Level Agreement

SMS	Service Management System
SOH	Section OverHead
SP	Service Provider
STM-N	Synchronous Transport Module – Nth level
TCM	Tandem Connection Monitoring
TE	Terminal Equipment
TIC	Terminal International Centre
TM	Terminal Multiplexer
TMN	Telecommunication Management Network
TNC	Terminal National Centre
TTP	Trail Termination Point
UNI	User Network Interface
UTC	Universal Coordinated Time
VC-n	Virtual Container – nth level

5 General description of international synchronous digital leased circuits

An international synchronous digital leased circuit with SDH presentation to the Customer is comprised of an SDH transmission trail between Network Terminating Equipments (NTEs). The NTEs may be simple connectors, intelligent loopback devices or more sophisticated equipment. Both the national and international portions of the leased circuit may be provided by more than one NO.

The TTPs may be owned, operated and maintained by the NO/SP or the Customer. Where the Customer owns the TTPs, the POH shall be made available to the NO/SP for operation and maintenance purposes. The detailed use of the POH is for further study. The interface to the Customer may be an electrical interface as described in ITU-T G.703 [2] and ITU-T G.707 [3], or an optical interface as described in ITU-T G.707 [3] and ITU-T G.957 [19].

The SDH leased circuit shall employ the frame structures, POH and SOH defined in ITU-T G.707 [3] and is transported over an SDH network at varying STM-N levels of the SDH, or over a mixed SDH/PDH network. The SDH leased circuit may be provisioned manually or semi-automatically via TMN facilities as described in ITU-T M.3208.1 [56]. Before provisioning, the parties concerned shall agree on the payload structure at the interfaces and the use of the POH and SOH. DCEs connected to the leased circuit may have test loopback facilities as described in ITU-T V.54 [64] or ITU-T X.150 [65].

The path overhead for the leased circuit should be configured as specified in ITU-T G.707. In the case of a VC3, the signal label byte C2 should be set as specified in 9.3.1.3/G.707. In the case of a VC12, the V5 byte should be set as specified in 9.3.2.1/G.707.

NOTE – Some aspects of the POH need further clarification e.g. the case of LO-TCM requires valid J2, N2 and V5 bytes.

5.1 Leased circuit configuration

Figure 1 shows the basic constituent parts of an international point-to-point leased circuit without showing the SDH equipments that support the leased circuit.

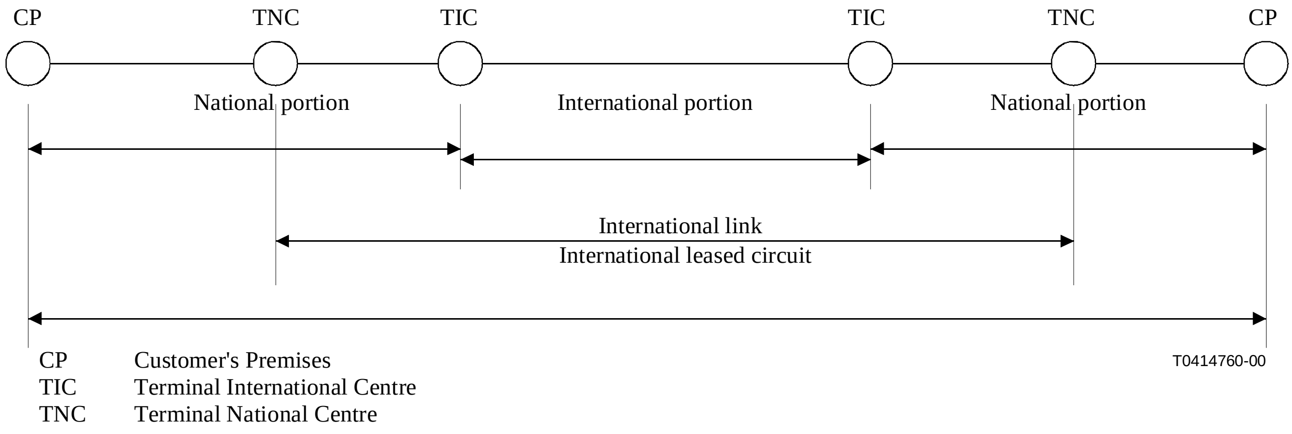

Figure 1/M.1301 – Constituent parts of an international leased circuit

The national portions of the leased circuit may in fact cross more than one NO and the responsibility for providing the circuit may be a SP who owns only part or even none of the network equipment supporting the circuit. The SP will negotiate with NOs (providers) to assign network paths as required, and with the Customer regarding visits to their premises for any installation of terminal equipment and testing of the circuit.

An expanded version of Figure 1 based on Figure III.1/G.826 [14] shows a leased circuit existing between two NTEs via various International Gateways (IGs) in a multi-operator network, but the end-to-end digital path existing between two Terminal Equipments (TEs) includes a private network(s) as shown below in Figure 2:

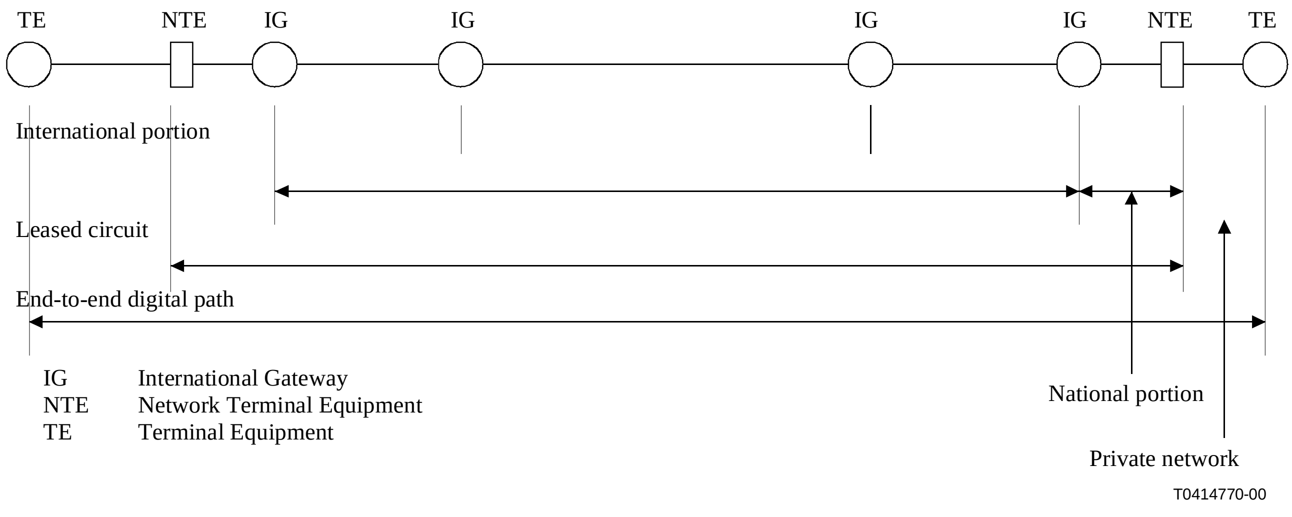

Figure 2/M.1301 – Constituent parts of an SDH leased circuit and digital path

The portion between the NTE and TE may be outside the NO's control, provided by a private network over which a public NO has no control. Thus in the case of SDH leased circuits, end-to-end performance objectives cover only the portion situated between the two NTEs.

Five types of SDH leased circuits can be identified:

1) NO to NO circuit, where the NOs terminate the POH. This includes mixed SDH/SONET interworking where the POH and SOH is terminated and rebuilt, e.g. VC-3 to STS-1;

2) end-user Customer to end-user Customer circuit where the POH is terminated at the end-user Customer's premises, but there is a facility for communication between the end-user Customer's terminal equipment. In this case the NOs transporting the circuit act as transit operators;

3) end-user Customer to NO circuit where one NO hands off the leased circuit to another NO. This is a subset of type 2) where one NO is acting as a Customer of another NO, and again could involve SDH/SONET interworking;

4) mixed SDH/PDH leased circuit where the traffic is accepted/delivered at one end in a PDH interface and at the other end buried in a SDH interface e.g. 2 Mbit/s PDH to STM-1 where the Customer has access to 1920 kbit/s in PDH at one end and VC-12 in SDH at the other end;

5) PDH leased circuit with SDH presentation to the Customer.

Other types of SDH leased circuits include point-to-multipoint circuits, dedicated semi-permanent or reconfigurable circuits (with time-of-day switching) as described in ITU-T M.3208.1 [56], and unidirectional circuits (e.g. video broadcast circuits).

5.2 Network interfaces

Most (if not all) SDH leased circuits will employ SDH equipment and transmission systems to provide a synchronous digital path between the end points of the circuit (apart from types 4) and 5) where PDH equipment will be at one or both ends of the circuit). This may include sitting an SDH Add-Drop Multiplexer (ADM) or Terminal Multiplexer (TM) on the CP at the end of the access network transport link. The location of the interface (NTE) to the Customer depends as much on regulatory constraints as it does on technical decisions.

ITU-T G.707 [3] and ITU-T G.708 [4] define the Network Node Interfaces (NNIs) for SDH that apply to both electrical and optical interfaces. It is clear from existing equipment practice that both electrical and optical interfaces are being offered to Customers as desired.

The User Network Interfaces (UNIs) already being offered to users cover a broad range from the so-called "ATM25" interface at 25.6 Mbit/s to STM-4 (OC-12) at 622 Mbit/s and even STM-16 (OC-48) at 2.4 Gbit/s. The main Recommendations covering these are summarized below:

- I.432.1 [20] – General characteristics of B-ISDN User-Network Interfaces physical layer;
- I.432.2 [21] – 155 520 kbit/s and 622 080 kbit/s B-ISDN UNI operation;
- I.432.3 [22] – 1544 kbit/s and 2048 kbit/s B-ISDN UNI operation;
- I.432.4 [23] – 51 840 kbit/s B-ISDN UNI operation;
- I.432.5 [24] – 25 600 kbit/s B-ISDN UNI operation;
- G.703 [2] – Physical/electrical characteristics of hierarchical digital interfaces;
- G.707/Y.1322 [3] – Network Node Interface (NNI) for the SDH;
- G.708 [4] – Bit rates and multiplexing structures for sub-STM-0 interfaces;
- G.957 [19] – Optical interfaces for equipments and systems relating to the SDH.

Concatenated versions of SDH bandwidths are also in use to provide very high bandwidth transmission "pipes" for ATM and IP. This concatenation may be contiguous within one SDH signal or virtual using a number of SDH signals. When using virtual concatenation, differential delays need to be carefully controlled and some kind of frame reference signal is required.

5.3 Timing and network synchronization

The timing feed at each end of an international SDH leased circuit should be derived from a primary reference clock operating in accordance with ITU-T G.811 [8]. In general, the SDH leased circuit timing will be derived from the SDH network supporting it and not from the Customer's equipment. The network clock is normally used to drive the Customer's equipment. If the leased circuit is provided by multiple NOs, agreement must be reached on the source of the master clock or the provision of appropriate facilities to take account of timing differences.

5.4 Designations

The form of designations for international SDH leased circuits will be described in ITU-T M.1400 [38]. The details of this are for further study.

5.5 Performance

Three key areas of performance need to be checked when bringing-into-service or maintaining an SDH leased circuit. These are:

– error performance;

– timing performance;

– availability performance.

ITU-T M.2101 [49] defines the error performance limits and allocation of the SDH digital trails which support SDH leased circuits. ITU-T G.811 [8], ITU-T G.812 [9], ITU-T G.822 [10], ITU-T G.823 [11], ITU-T G.824 [12] and ITU-T G.825 [13] define the timing performance which should be maintained. Delay performance is for further study. ITU-T G.827 [15] defines the physical layer availability for a digital path.

6 Operational procedures

ITU-T M.2110 [51] covers the setting up and Bringing-Into-Service (BIS) of international digital paths. Maintenance issues are covered in ITU-T M.2120 [52]. General operational procedures for locating and clearing transmission faults are covered in ITU-T M.2130 [53]. The performance limits for bringing-into-service and maintenance of international SDH paths and multiplex sections are defined in ITU-T M.2101 [49].

The BIS (provisioning) of SDH leased circuits is increasingly based on the TMN approach to network and service management since the SDH transmission equipment that supports the leased circuits consists of highly intelligent software-intensive Network Elements (NEs) that are managed by SDH Element Management Systems (EMSs) and higher level Network Management Systems (NMSs). This includes the exchange of information electronically across TMN Q and X interfaces for management purposes, both within one NO/SP, and between NO/SPs since these circuits will often cross a number of NO/SP jurisdictions. ITU-T M.3208.1 [56], ITU-T M.3208.2 [57] and ITU-T M.3208.3 [58] define TMN management services for configurable and reconfigurable leased circuits within a multi-operator environment.

Also, the maintenance (fault reporting, localization and testing) of these SDH leased circuits will be increasingly based on remotely managed test resources from a Network Management Centre (NMC) or Network Operations Centre (NOC). These test resources may be a mixture of built-in capabilities within the network equipment (e.g. POH, SOH, TCM, etc.) or remote test heads attached at strategic network access points e.g. a Digital Cross-connect System (DCS) used to configure the circuits. The following subclauses outline the procedures for Fault, Configuration, Administration and Performance Management, which are four of the key TMN managed functional areas defined in ITU-T M.3010 [55] and ITU-T M.3400 [61]. A new Recommendation in the M.3208.x-series is being drafted on TMN test management.

6.1 Control and sub-control stations

A dual control or a control and sub-control relationship shall be agreed at the BIS stage. Where a control and sub-control relationship exists, responsibilities will be as described in ITU-T M.80 [28], ITU-T M.90 [29], ITU-T M.1012 [30] and ITU-T M.1013 [31]. However, in order to achieve the fastest possible response times for maintenance activities on behalf of Customers, it is acceptable for both terminal stations of an international SDH leased circuit to assume control station status. It is essential however for the control stations involved to develop effective mechanisms and procedures for coordinating maintenance activities, and that they inform each other of specific maintenance actions as rapidly as possible to avoid confusion. TMN management systems operating over X interfaces between NO/SPs can greatly facilitate this process.

It is possible for a third-party centre to be designated as the control station. In this situation the leased circuit may not be routed via this centre, nor need this centre be situated in a terminal or transit country of the leased circuit. Clearly, close co-operation is required between the SP and the NOs providing the leased circuit. In some cases, the international SDH leased circuit may be provided by one NO/SP acting as a "one stop shop", i.e. a primary SP (sometimes called a "retailer") who sub-contracts other parts of the SDH leased circuit to another NO to carry on their behalf (sometimes called a "wholesaler"). One or more NOs involved with providing the SDH trail may use cooperating network/service management systems communicating via TMN X interfaces (see ITU-T M.3320 [59]) to provision and maintain the SDH leased circuit (see ITU-T M.3208.1 [56], ITU-T M.3208.2 [57] and ITU-T M.3208.3 [58]).

6.2 BIS procedures

The basic BIS procedures for SDH leased circuits should be similar to those defined in existing ITU-T M.1370 [34], ITU-T M.1380 [36] and ITU-T M.2110 [51]. These include the preliminary exchange of information about the leased circuit configuration and interfacing, designation and routing, bringing-into-service schedule and coordination between stations, contact personnel details, details of any special maintenance or fault reporting arrangements, performance limits and test equipment to be used, and measurements against limits (see ITU-T M.80 [28], ITU-T M.90 [29], ITU-T M.1012 [30], ITU-T M.1013 [31], ITU-T M.1045 [32], ITU-T M.1400 [38] and ITU-T M.1510 [39]). The test equipment used should conform to ITU-T O.172 [62] and ITU-T O.181 [63].

Checks of individual SDH network equipment comprising the circuit should be performed. This should include confirming the interworking of alarms, e.g. Alarm Indication Signal (AIS) and, ideally, simulated error transmissions to check other alarm operations at both local and distant ends. Specific checks of POH, SOH and payload structure should be made to verify the agreed format. Note that full end-to-end checks of POH cannot be made until the VC-n path is equipped. This may require the Customer to connect their CPE to the SDH interface. An unequipped VC-n path may create spurious alarms and inhibit protection switching actions.

BIS tests should ideally include periods of normal industrial activity to be representative of typical network conditions. Performance limits of ES, SES and BBE counts should be met simultaneously for the test results to be considered acceptable. Typical performance objectives, allocations and limits are given in ITU-T M.2101 [49] for SDH digital paths and multiplex sections and in ITU-T M.1340 [33] for mixed PDH/SDH leased circuits, however routed. The possible development and application of performance objectives for other parameters such as transmission delay, timing jitter, etc., are for further study. All test results obtained during the BIS tests should be retained as a "fingerprint" of the SDH leased circuit for possible future reference during maintenance activities.

In the past PDH world, to reflect operational requirements for out-of-service testing, test durations of 24 hours, of 1 hour and of 15 minutes were often used. In an all-SDH transport environment with inherent ISM capabilities, much shorter provisioning and BIS testing time-scales can be achieved. With regard to bringing-into-service testing, the 1-month evaluation period suggested in

ITU-T G.826 [14] and ITU-T G.828 [16] is not realistic in an operational environment (see ITU-T M.2101). A shorter test duration is required, particularly with strong commercial pressures to put a leased circuit into service or restore it after repair. However, it must be recognized that test results obtained over 24 hours or less are inherently less reliable.

It should be noted then that a 24-hour or less test duration can be expected to give a particularly reliable indication of transmission performance. National circuit portions and international circuit portions may be set up and tested simultaneously or consecutively. However, careful harmonization of these procedures is required to ensure overall end-to-end performance is acceptable.

6.2.1 Section-by-section testing and In-Service Monitoring (ISM)

BIS procedures will increasingly use TMN and ISM techniques, but end-to-end tests of the overall leased circuit may require appropriate personnel to be present at the Customer's premises in the two end points. The cooperation of staff, e.g. at the TICs/IGs or Customer Care Centre may also be required to overcome language or technical difficulties where the leased circuit crosses NO/SP and/or international boundaries. It may be easier to perform BIS tests on a section-by-section basis although an overall end-to-end check must be performed. One of the major issues for SDH leased circuits is that the SDH transport network supporting them will often be optical fibre transmission systems and there may not be readily available test access points in transport network sections. New SDH leased circuits may be added to existing higher-order transport network bearers (see 6.2.3). The use of ISM capabilities built into the SDH NEs coupled to EMSs and NMSs can greatly assist.

6.2.2 National circuit portions

Before setting up the national circuit portions, suitable performance limits for the national circuit portions should be developed and exchanged between the Network Operators/Service Providers involved, always ensuring that the overall end-to-end performance can be achieved.

6.2.3 International circuit portions

Using the in-service performance monitoring available, and if the error performance of the supporting transport system is acceptable, all new circuits should be tested for 15 minutes.

In the case where a number of circuits using the same higher-order transport system are brought into service at the same time, and in-service performance monitoring is not available, the first circuit should be tested for 24 hours, and the remaining circuits could be tested for 15 minutes each. Any portions of the circuit, which are not supported by the higher-order transport system, should be tested for 24 hours.

The performance limits given in ITU-T M.1340 [33] should be met for any mixed PDH/SDH leased circuits. Performance limits for SDH leased circuits are given in ITU-T M.2101 [49]. Where there is little confidence regarding the capabilities of a particular international transport system, or where the short duration test objectives were not met, a 24-hour test should be performed using the limits given in ITU-T M.1340 [33] or ITU-T M.2101 [49] as appropriate. In the event that the 24-hour limits are not met, Network Operators/Service Providers should agree to an appropriate course of action.

Where the international circuit portion extends significantly beyond the tributary interfaces of a particular international higher-order transport system (e.g. where a transit routing involves the interconnection of two international SDH systems) additional tests may be required. NOs/SPs should ensure that all parts of the international circuit portion are fully tested. Suitable additional limits should be agreed between the NOs/SPs involved. Consistency with ITU-T M.1340 [33] and ITU-T M.2101 [49] should be sought wherever possible.

6.2.4 BIS using an alternative international link

If any portion of the link, which would normally be used to carry the international leased circuit, is restored onto an alternative route before BIS testing is commenced, or during BIS testing, then testing may proceed, or continue, if the following three criteria are met:

1) The performance of the alternative link is known to be acceptable;

2) The alternative link uses the same transmission media as the original link;

3) The length of the alternative link is not substantially different from the original link.

If these criteria are not met, then testing should be postponed, or halted, until the original link is returned to service.

If a single unavailability event occurs during the BIS test, and the cause of this event is precisely known and not recurrent, then this event should be ignored in the test results.

6.2.5 End-to-end test

It will normally be required to perform an end-to-end test to confirm overall integrity and stability. A 24-hour test duration is recommended. Test limits should include allowances for the international and the two national circuit portions. NOs/SPs should pay particular attention to highlighting any problems that may be associated with the interworking of separately timed networks, especially for the first circuit provision that uses a particular equipment configuration. In particular, the jitter/wander performance requirements of ITU-T G.823 [11], ITU-T G.824 [12] and ITU-T G.825 [13] should be respected as appropriate to the leased circuit and supporting transport network.

Depending upon the loopback capabilities provided by the NTEs at the Customer's premises, it may be possible to perform end-to-end tests, combined with ISM, from intermediate points within the network (e.g. at TICs).

Where loop tests are employed it is proposed that no special additional performance allowance is made (i.e. doubling of limits is not recommended).

6.2.6 Alternative end-to-end test

If NOs/SPs agree, based upon experience of similar network conditions, and in-service performance monitoring is available on the entire international transport system, a 2-hour end-to-end monitoring test may be performed. In this case, the BIS procedure is as follows:

1) The national circuit portion is brought into service according to existing national procedures;

2) No international circuit portion test is carried out, as this portion has already been tested according to the procedures of ITU-T M.1370 [34] or ITU-T M.2110 [51] and in-service performance monitoring is being used to ensure that the performance of the higher-order transport system is acceptable;

3) For wholly SDH-routed circuits using a continuous POH, an end-to-end monitoring test of two hours is performed to verify the cross-connection capabilities of any digital cross-connect equipment used to configure the leased circuit. This test may be performed to a loopback at one or both ends. The performance limits for this test are given in Table 1/M.1340 [33] for mixed SDH/PDH leased circuits and in ITU-T M.2101 [49] for SDH-only leased circuits. There should be no clock slips or periods of unavailability during this test. If these conditions cannot be met, then the 24-hour test, as described above, should be carried out. For mixed SDH/PDH transported circuits, it may not be possible to perform a full end-to-end test, especially in the case of CPE owned by the end-user. In this case, a partial end-to-end test combined with ISM should be performed.

As mentioned in 6.2.5, Network Operators/Service Providers should pay particular attention to highlighting any problems that may be associated with the interworking of separately timed networks, as these may not be evident from a 2-hour test. Where the performance limits are not met, fault localization should be performed and the faults rectified.

6.3 Maintenance procedures

The basic maintenance procedures for SDH leased circuits should be similar to those defined in existing ITU-T M.1375 [35], ITU-T M.1385 [37], ITU-T M.2120 [52] and ITU-T M.2130 [53]. These include fault reporting, sectionalization, localization and restoration procedures, with appropriate exchange of information between NOs/SPs and with Customers. ISM facilities should be used whenever possible for fault sectionalization, localization and diagnosis. Further information on fault management is contained in Annex A.

It should be noted that, for more extensive measurements involving intrusive testing, the circuit will be interrupted and the service to the Customer affected. This in turn may impact the SLA/Contract and result in penalties or rebates. Maintenance tests should therefore be kept as short as possible to avoid significantly extending out-of-service time. As with BIS procedures, any test equipment used should conform to ITU-T O.172 [62] and ITU-T O.181 [63]. Maintenance performance thresholds and procedures for protection of SDH leased circuits should in general follow the same principles defined in ITU-T M.20 [25], ITU-T M.34 [26], ITU-T M.2100 [48], ITU-T M.2101 [49], ITU-T M.2102 [50], ITU-T M.2120 [52] and ITU-T M.2130 [53].

Round-the-clock "help-desks" and TMN modules enable test and monitoring to be centralized and activated, for improved Customer service. For example, prompt information to the Customer about the fault condition detected and countermeasures planned, direct intervention of suitable technical teams, etc. can be driven from a Service Management System (SMS) situated in a Customer Care Centre and/or NMS situated in a NOC or NMC. The aim is to always respect the SLA contractual commitments to the Customers.

6.3.1 Performance monitoring and data collection

Performance data is normally collected in terms of event counts associated with the performance parameters indicated in ITU-T G.826 [14], ITU-T G.828 [16], ITU-T M.2100 [48] and ITU-T M.2101 [49] using ISM. The performance primitives (anomalies and defects) are processed by the SDH NEs into performance parameters and accumulated over 15-minute and 24-hour intervals. The current and historical performance data is time stamped and stored in performance registers which are then interrogated by the Operations System (OS) managing the NEs and reported upwards to the NMS and SMS managing the SDH leased circuit service supported by the SDH network. Performance events are collected and stored independently for each direction of transmission of the circuit. The SDH path is monitored using the BIP-8 code with even parity provided in the POH byte B3. Additional monitoring capability for high bit rate VC-4-Xc trails is under study. Performance event counts are inhibited during periods of unavailability as defined in ITU-T G.826 [14], ITU-T G.828 [16] and ITU-T G.827 [15]. Any change of availability state is also time stamped and recorded in the performance registers. Full details of performance monitoring by SDH NEs are given in ITU-T G.707 [3], ITU-T G.783 [5], ITU-T G.784 [6] and ITU-T M.2101 [49]. Further information on transport network event correlation and handling of performance data can be found in ITU-T M.2140 [54].

Where the SDH leased circuit crosses a number of SDH sections, performance monitoring may include Tandem Connection Monitoring (TCM) using the B3 bytes in the VC-n overhead of each of the higher-order VCs that make up the Tandem Connection (TC) as described in ITU-T G.707 [3]. The TC also has a 32 kbit/s data link provided by part of the N1 byte in the first VC-n of the TC, which uses a LAPD message protocol to convey trace, status and performance report information.

As stated earlier, regardless of who owns the CPE, the SDH POH specified in ITU-T G.707 [3] shall be used by the SDH digital path and made available at suitable monitoring points along the route. In the case of an end-Customer or another operator owning the POH terminating equipment, it may not be possible for one operator to access the POH at the ends of the digital path. However, the POH provided includes remote anomaly and defect information seen by the POH terminating equipment and returned to the distant end. Thus it is possible to assess the end-to-end error performance of the complete bidirectional path from one access point within the path i.e. from the user's viewpoint. However, it should be noted that not all VC-n SDH paths contained within a higher layer SDH signal can be monitored simultaneously on some SDH equipment.

6.3.2 Performance history, thresholding and reporting

Performance history data are necessary to assess the recent performance of SDH leased circuits and transmission systems. Such information can be used to sectionalize faults and locate sources of intermittent errors. Performance monitoring thresholds may be set in the SDH NEs by the OS and threshold crossings detected and notifications generated as described in ITU-T M.20 [25], ITU-T M.34 [26], ITU-T M.2101 [49], ITU-T M.2102 [50], ITU-T M.2120 [52] and ITU-T M.2140 [54]. These notifications are normally generated autonomously.

When thresholds of unacceptable or degraded performance levels are reached, maintenance action should be initiated independently of the performance measurement. A degraded performance result can be used to generate a fault report (commonly known as a "trouble ticket") to alert maintenance staff that SLA/Contract guarantees are not being met and action needs to be taken. This may include alerting the service billing system that a Customer is due for a discount or rebate. Other thresholds may be used for maintenance and longer-term quality analysis. The OS will use real time processing to assign maintenance priorities to these threshold crossings and information, using the performance supervision process described in ITU-T M.20 [25].

In general, two types of thresholds are used depending on the accumulation period for anomalies and defects. 15-minute monitoring periods with thresholds of ES, SES and BBE counts are used to detect transitions to or from unacceptable performance. 24-hour monitoring periods with thresholds of ES, SES and BBE counts are used to detect transitions to degraded performance. The thresholds are usually programmable from the OS to suit specific operating requirements. This may vary with importance of the circuit(s) supported by the path, transport technology employed or SLA/Contract values agreed with a Customer. Further information on performance thresholding is given in ITU-T M.2101 [49], ITU-T M.2102 [50], ITU-T M.2120 [52] and ITU-T M.2140 [54].

6.3.3 Maintenance intervention tests

Maintenance intervention tests should be kept as short as possible to avoid significantly extending the out-of-service time, and should be of a duration appropriate to the nature of the fault report received. It is assumed that, for maintenance intervention tests, the circuit shall only be withdrawn from service with the Customer's agreement, unless the circuit has completely failed. Where the leased circuit uses only part of the SDH transmission equipment channels, it may be possible to connect test equipment to monitor the performance of spare capacity. The data from such tests may provide a useful indication of the overall performance of the SDH transport network supporting the leased circuit.

The duration of maintenance intervention tests will be dependent upon the nature of the fault report that has been received. Where a fault report suggests that the leased circuit has failed completely, a short test of basic integrity should be performed. Such tests, which are interpreted on a simple pass or fail basis, should normally be limited to a duration of 15 minutes with no SESs being observed.

Where a fault report suggests that there has been an overall degradation of service, but that the circuit has not failed completely, a longer duration test will be appropriate. Where a longer duration test is to be performed, NO/SPs should agree a suitable test date and time with the Customer. The Customer may wish to retain access to the circuit until a more convenient time when a substantial out-of-service period may be more tolerable. When a 24-hour test is performed, NO/SPs should use the same limits that were developed for the initial BIS tests.

6.3.4 Test configurations

Several test measurement configurations are possible (see Figure 1/M.2110 [51] for guidance). Any loopback facilities that may be available should be used when appropriate. DCEs connected to the leased circuits may have test loopback facilities as described in ITU-T V.54 [64] and ITU-T X.150 [65]. Care must be taken to avoid the simultaneous operation of multiple loopbacks on a particular circuit. Once the need for a loopback no longer exists, then care should be taken to ensure that it is removed.

For digital loops, the continuity of a digital leased circuit can be tested, even through to the distant Customer's installation, if the specifications are compatible between NO/SPs. However, this requires the agreement of the NO/SPs and, in any case, of the Customer, since their circuit cannot be used at that time. In some networks, control of these loopbacks may be carried out using the TMN management capabilities. The details of these loopbacks for SDH are for further study.

6.3.5 Test access at DCS equipment

An increasing number of transmission systems and circuits are configured using DCS equipment within transmission stations. These equipments are used to switch faulty digital paths over to standby paths when necessary. They also often provide the capability to divert transmission systems and circuits to test ports to which test equipment can be connected and used to measure performance and diagnose faults. Furthermore, this test equipment may be remotely controlled, possibly by the same management system that controls the DCS equipment. In any event, control of the two must be carefully synchronized. In some cases, simultaneous multiple access to test equipment (a "remote test head") is possible by multiple operational staff as multiple user sessions, with scripted test sequences.

It is desirable that DCS equipment is capable of providing monitoring of selected digital paths before taking the path out of service. This allows in-service performance assessment and/or confirmation that a fault exists before breaking the path. Most DCS equipment provides both a "monitor" and a "split and terminate" functionality on the test ports. While the digital path is being monitored in-service, no interruption is experienced. Once a fault has been confirmed, the faulty path is split and the fault diagnosed. SDH DCS equipment is now commonplace in SDH transport networks, but SDH ADMs may also be used for test access. DCS and ADM equipment itself may be a useful source of fault and performance information from the built-in ISM.

6.3.6 Returning-to-service tests

Returning-to-service tests should be of a duration that is appropriate to the nature of fault that has been cleared and should include observation of any network alarm facilities that may be available. Where a fault has caused a general degradation of service, a returning-to-service test with a short duration (e.g. 15 minutes) may not be appropriate and a longer-term test (e.g. 1 hour or 24 hours) should be used.

Following corrective maintenance, the Customer should be asked to confirm that their application is functioning correctly. Only then can the service be said to be restored. When a fault is cleared, appropriate clearance information should be passed to any control or sub-control stations or customer care centres that have been involved with initial fault reporting and localization.

6.3.7 Planned maintenance

In cases of planned maintenance on the NO/SP's installations – transmission equipment, power equipment, cabling, etc. – which would cause or risk some performance degradation or unavailability of the digital leased circuit, reference is to be made to ITU-T M.1540 [46] and the terms of the SLA/Contract with the Customer.

7 Maintenance records

NO/SPs should ensure that up-to-date information is held on file to assist maintenance activities. Clause 6/M.1370 [34] and clause 6/M.1380 [36] provide details of information that should be available for PDH supporting systems and leased circuits respectively. The same kind of information should be kept for SDH leased circuits and supporting transport systems, together with any POH-specific or SOH-specific information in use by the circuit. In addition, a record should be kept of any particular maintenance agreement with the Customer, including for example a SLA/Contract. See also ITU-T M.1510 [39], ITU-T M.1530 [41], ITU-T M.1532 [42], ITU-T M.1535 [43], ITU-T M.1537 [44] and ITU-T M.1539 [45] for further information. Maintenance staff should refer to such agreements when dealing with a fault reported by the Customer. During maintenance operations, reference should be made to previous test results that are applicable to the circuit under test. Original BIS test results should be available for all leased circuits.

Existing maintenance records should provide details of test equipment, test access points, test patterns and performance limits that are to be used. Test results from previous maintenance actions on all portions of the leased circuit may provide a useful indication of the overall performance of the SDH transport network supporting the leased circuit. The obligations set out in the leased circuit maintenance contract with the Customer, for example the SLA will be registered, and maintenance staff involved will refer to them whenever they are called in following a fault report by the Customer. In a TMN environment, this information will normally be available on a technician's client terminal connected to the SMS and/or NMS. NOs/SPs should also keep a log of circuit interruptions, over an adequate period, with a view to meeting any claims from Customers.

8 Protection and reserve arrangements

SDH leased circuits will normally be routed via SDH transmission networks employing network and/or sub-network protection e.g. in SDH rings. In some cases, Customers may require or NOs/SPs may decide to also provide alternate routing either at a physical or at a logical level through the network. ITU-T G.841 [17], ITU-T G.842 [18], ITU-T M.2102 [50] and ITU-T M.2130 [53] describe SDH network protection and restoration procedures.

Some NOs/SPs may find it useful to nominate one or more reserve SDH transmission links for restoration purposes. This should be decided by bilateral agreement when designing and provisioning the SDH leased circuit, taking into account its importance and contracted availability normally specified in the SLA. Such reserve links or circuits must be set up or lined up to meet the requirements of the normal SDH leased circuit and, wherever possible, should follow a different route from the normal route of the leased circuit. Further information is given in ITU-T M.2130 [53].

ANNEX A

Fault management

A.1 Initial reception of a fault report

In general, fault information relating to an SDH leased circuit can originate from four sources:

– a Customer trouble report (due to the failure or poor performance of the SDH leased circuit);

– a lower-order system operator (due to the failure or poor performance of a lower-order system that is supported as a channel or VC-n by the SDH leased circuit);

– the SDH leased circuit itself (through network alarms or distant NO);

– a network or higher-order system operator (with notification of the failure or poor performance of the higher-order network that supports this SDH leased circuit or recognition of a transmit problem from this SDH leased circuit).

Trouble reports from Customers and information sent to them may be transmitted over an X interface (see ITU-T M.3320 [59]) as a "trouble ticket" as defined in ITU-T X.790 [66]. This information may include performance reports on how a Customer's leased circuit is performing, and may be part of the SLA within the service contract agreed with the Customer. Note that the Customer may be another NO (wholesaler) providing part of the whole of the leased circuit to a SP (retailer) who in turn supplies the service to an end-user Customer.

A.2 Fault information exchange

When a fault report is received (e.g. a trouble report from a Customer or a connecting NO) the following information should be obtained[2]:

– name, title and contact details for the person reporting the fault;
– time of fault report, recorded in UTC;
– designation of the faulty circuit (see ITU-T M.1400 [38]);
– symptoms of the fault;
– the observed duration of the fault prior to a report being made;
– any associated information that may assist with fault clearance.

It is assumed that the Customer has carried out all the requisite checks using their own application's monitoring and control system, so as to determine that the fault stems from the leased circuit for which the NO(s) are responsible.

Standardized exchange of information procedures are described in the M.15xx-series Recommendations. ITU-T M.1520 [40] defines the standardized information exchange between NOs/SPs. It summarizes the relevant M-series and E-series Recommendations requiring information exchange between NOs/SPs. ITU-T M.1535 [43] defines the principles for maintenance information to be exchanged at the Customer contact point. ITU-T M.1537 [44] defines the basic maintenance information to be exchanged with a Customer. ITU-T M.1539 [45] contains information to be exchanged at the Customer contact point. ITU-T M.1532 [42] defines a network maintenance service performance agreement that may exist between a NO/SP and the Customer.

Through enhanced TMN services, the Customer may keep constant track of the problems encountered on the NO/SP's network in respect of their circuits. This reduces the amount of investigations the Customer has to make in the event of problems with their application. The Customer may use a TMN F interface (see ITU-T M.3300 [60]) and workstation to view fault and performance information via an X interface into the NO/SP. ITU-T M.3320 [59] on requirements for the X interface and a new Recommendation on identification of information to be exchanged via the X interface attempt to define how this exchange of information can take place within a TMN environment in a speedy, more efficient manner than traditional methods.

Note that, in all cases, this information exchange may include Fault, Configuration, Accounting, Performance and Security information – the so-called "FCAPS" TMN managed functional areas.

The Customer wants a speedy restoration of their circuit. They may also wish to know:

– where the fault is located;
– the nature of the fault;
– above all, when the circuit will be restored, either by fault rectification or changeover.

[2] Some NOs/SPs have introduced computerized documentation (e.g. a trouble ticketing system) and exchange of work orders and set up a Leased Circuits "help-desk", which considerably facilitates operations and fault management.

Prior to undertaking corrective maintenance or loop-test activity, the Customer must be asked to give permission for the circuit to be withdrawn from service.

A.3 Fault localization

Figure 1/M.1375 [35] gives a typical example of a systematic and coordinated procedure for efficient fault localization. Initial localization should aim to identify as quickly as possible whether the fault is due to the transport network supporting the leased circuit or any terminal equipment provided and maintained by the NO/SP or the Customer. Subsequent localization should aim to identify the specific link section or equipment that has failed. Where TMN techniques are used, automatic identification of the exact cause of problems may greatly simplify fault monitoring and localization. Where fault localization is not achieved in a reasonable time, NO/SPs shall invoke the agreed escalation procedure (see ITU-T M.1560 [47]) to assist progress.

It may be useful to reference Figure 1/M.1375 [35] for guidance with fault localization and use TMN data where applicable. The latter may be available at various locations within the NO/SP. The SDH network supporting the SDH leased circuit will normally have alarm surveillance implemented. Alarm surveillance detects and reports relevant events and conditions that may occur within the SDH network. These may occur within the NEs themselves comprising the network or associated with the NEs, e.g., building and power alarms. Alarms are indications that are automatically generated by a NE as a result of certain events and conditions, e.g., loss of signal. A persistence check is applied before declaring a failure. The OS managing the NEs normally has the ability to define which events and conditions generate autonomous reports and which shall be reported on request. The NEs also normally have historical alarm data registers. All events are time stamped and recorded in these registers. Full details of fault monitoring and management of SDH NEs are given in ITU-T G.707 [3], ITU-T G.783 [5] and ITU-T G.784 [6] including multiplex section protection facilities. Further information on transport network event correlation is given in ITU-T M.2140 [54].

Initial fault localization should seek to establish whether a fault exists and to determine if it is located within the national circuit portion or elsewhere. The use of network alarm information (available as described above) and measurements of the characteristics of the physical access link up to the Customer connection point, i.e. up to the point where the NO/SP is responsible, may assist. In addition, the higher-order path trace byte J1, which contains a path Access Point Identifier (API) so that a path-receiving terminal can verify its continued connection to the intended transmitter, may assist in the fault location process.

Further fault-finding aids are provided by the C2 signal label byte in the higher-order POH, which is coded to indicate the composition or the maintenance status of the VC-n path, and the G1 path status byte, which conveys the path status and performance back to a VC-n trail termination source as detected by a trail termination sink. This feature permits the status and performance of the complete duplex trail (bidirectional path, i.e., circuit) to be monitored at either end, or at any point along that trail. Full details of these functions are given in ITU-T G.707 [3] along with similar capability for lower-order paths carried by an SDH network. A further facility now being fitted to SDH network equipment is TCM. This can assist in determining if errors are entering a NO/SP's domain or being generated within it.

Where a fault is found to exist outside of the national circuit portion (i.e., within the international portion or distant national portion) it should be referred to a fault reporting point that has responsibility for international maintenance activities. This will typically be the fault reporting point that has responsibility for the international SDH transmission system. When a fault is referred to another fault reporting point, the information given in A.2 should be exchanged. Further localization should seek to identify the faulty element as quickly as possible. Where fault localization (or confirmation of it) is not achieved in a time consistent with the time to remove the fault or restore the circuit as specified in the SLA/Contract, NOs/SPs shall invoke the agreed escalation procedure (see ITU-T M.1560 [47]) to assist progress.

A.4 Circuit restoration

SDH leased circuit restoration will normally be achieved initially via protection switching in the SDH transport network. This may be via SDH ring architectures and various levels of path and section switch protection. In cases of catastrophic failure, this may not be achievable and alternate routing of the circuit may have to be performed manually, or the circuit and its supporting network repaired immediately. Temporary restoration will either use dedicated facilities or available spare capacity (see below). This restoration should only be used when it is clear that the normal international network restoration will not be achieved in reasonable time (see Annex D/M.1560 [47]).

In any event, it has to be decided which option, repair or changeover, is the speedier and stabler way of restoring the leased circuit. NO/SPs should take into account the urgency for restoration for each particular SDH transmission system as mentioned in the preliminary exchange of information for its provision. Where time to restore the circuit is inconsistent with the SLA/Contract, NO/SPs shall invoke the agreed escalation procedure (see ITU-T M.1560 [47]).

A.5 Temporary service restoration

Temporary service restoration may be used when a network failure is localized to the international network and this is affecting SDH leased circuits supported by a major international transmission link. Typical international network failures that may require the use of temporary service restoration include the loss of an undersea cable system or satellite system. Temporary service restoration should only be used when it is clear that normal international network restoration will not be achieved in a reasonable time (see Annex D/M.1560 [47]) using SDH protection switching.

A.5.1 Mechanisms for implementing temporary service restoration

Two basic mechanisms have been identified as follows:

1) To use a dedicated temporary restoration facility which will typically be an international SDH transmission system. If both of the following criteria are met, the dedicated temporary restoration facility may be used:
   a) An international network failure has occurred and it is observed that normal restoration will not be achieved in a reasonable time;
   b) A dedicated temporary restoration facility is available.
2) To use available temporary restoration capacity, which would typically be found within other international SDH transmission systems that connect to the same destination, although probably following a different physical route within the international network. If each of the following criteria are met, the temporary restoration capacity may be used:
   a) An international network failure has occurred and it is observed that normal restoration will not be achieved in a reasonable time;
   b) Any dedicated temporary restoration facility that may have been provided is not available;
   c) Spare restoration capacity (at the channel or VC-n level) is available;
   d) The NO/SPs involved have the technical capability and operating procedures to support the temporary switching of channels between international transport systems.

A.5.2 Time to restore service

NO/SPs should take into account the urgency for restoration for each particular international SDH transmission system as mentioned in the preliminary exchange of information for its provision (see ITU-T M.1045 [32] and ITU-T M.1400 [38]). Where time to restore service seems to be unacceptable, NO/SPs shall invoke the agreed escalation procedure (see ITU-T M.1560 [47]).

A.5.3 Restoration procedure

The following outline procedure is for guidance only. Detailed operating procedures will need to be agreed between the NO/SPs involved taking account of the network infrastructure that is available. This may include the use of a TMN X interface.

When an international SDH transmission system failure occurs and the basic restoration criteria have been met (see A.5.1), the NO/SPs involved will confirm that some form of temporary service restoration is to be used and will agree how this is to be achieved. Service can be restored using the following procedure:

a) confirm that the international SDH transmission link is faulty;

b) implement restoration switching;

c) confirm that the affected leased circuits have been successfully restored.

A.5.4 Returning to normal routing

When service can be restored via its normal route, this should be done as a planned outage (see ITU-T M.1540 [46]).

A.5.5 Information that should be exchanged

Depending upon the proposed restoration method that is to be used, NO/SPs should ensure that suitable preliminary information has been exchanged (e.g., designations and routings for any international SDH transmission systems that may be used for dedicated service restoration).

A.6 Automatic rerouting of international SDH transmission links

For priority links such as those bearing SDH leased circuits, NO/SPs may agree to fit the links with automatic rerouting switches, through requisite monitoring systems. These may be 1+1 or n+1 rerouting systems.

For leased circuits supported on such links, the number of consecutive severely errored seconds (CSES) due to changeover of the SDH transmission system should be minimized in order to fulfil the requirements of the supported services.

A.7 Precautions to be taken in the use of DCSs

DCS equipment types vary. Some handle cross-connecting of low speed VC-n signals and have STM-1 digital access ports. Depending on the bit rate of the digital path to be monitored and tested, one or more VCs of the test port are used for the signal. Other types of DCS equipment are used for higher bit rate signals, for example, cross-connecting STM-1/VC-4 digital paths and fitted with STM-4 digital access ports. Many SDH DCSs have considerably more flexibility than PDH DCSs. For further information on SDH cross-connects, see ITU-T G.783 [5].

For an international SDH leased circuit, the DCS is typically the routing point, since it fulfils a switching function. The DCS must thus offer a very high degree of availability. If a serious fault should nevertheless occur on a DCS, the NO/SP should have available sufficient alternative arrangements to relieve the faulty unit. At changeover, the databases may have to be loaded and it should be checked whether the software version is compatible if the DCS is a backup for another.

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