International Telecommunication Union

ITU-T G.808.1

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

(02/2010)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital networks – General aspects

Generic protection switching – Linear trail and subnetwork protection

Recommendation ITU-T G.808.1

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Recommendation ITU-T G.808.1

Generic protection switching – Linear trail and subnetwork protection

Summary

Recommendation ITU-T G.808.1 defines the generic functional models, characteristics and processes associated with various linear protection schemes for circuit-switched connection-oriented layer networks; e.g., optical transport networks (OTN), synchronous digital hierarchy (SDH) networks and packet-switched layer networks, e.g., asynchronous transfer mode (ATM) networks and Ethernet transport networks.

It also defines the objectives and applications for these schemes. Protection schemes described in this Recommendation are trail protection and subnetwork connection protection with various monitoring alternatives for individual signals or groups of signals. Furthermore, survivability offered by the link capacity adjustment scheme (LCAS) is described.

Generic functional models, characteristics and processes for ring protection and interconnected subnetwork (e.g., ring) protection schemes are defined in other Recommendations.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.808.1	2003-12-14	15
1.1	ITU-T G.808.1 (2003) Amend. 1	2005-07-14	15
2.0	ITU-T G.808.1	2006-03-29	15
2.1	ITU-T G.808.1 (2006) Amend. 1	2009-01-13	15
3.0	ITU-T G.808.1	2010-02-22	15

FOREWORD

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

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 received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Recommendation ITU-T G.808.1

Generic protection switching – Linear trail and subnetwork protection

1 Scope

This Recommendation provides an overview of generic aspects of linear protection switching. It covers protection schemes applicable to circuit-switched and packet-switched layer networks; e.g., optical transport networks (OTNs), synchronous digital hierarchy (SDH), asynchronous transfer mode (ATM) and Ethernet transport based protection schemes. Overviews of ring protection and dual node subnetwork (e.g., ring) interconnection schemes will be provided in other Recommendations.

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 G.783] Recommendation ITU-T G.783 (2006), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*.

[ITU-T G.798] Recommendation ITU-T G.798 (2004), *Characteristics of optical transport network hierarchy equipment functional blocks*.

[ITU-T G.805] Recommendation ITU-T G.805 (2000), *Generic functional architecture of transport networks*.

[ITU-T G.806] Recommendation ITU-T G.806 (2009), *Characteristics of transport equipment – Description methodology and generic functionality*.

[ITU-T G.841] Recommendation ITU-T G.841 (1998), *Types and characteristics of SDH network protection architectures*.

[ITU-T G.842] Recommendation ITU-T G.842 (1997), *Interworking of SDH network protection architectures*.

[ITU-T G.870] Recommendation ITU-T G.870/Y.1352 (2008), *Terms and definitions for optical transport network (OTN)*.

[ITU-T G.873.1] Recommendation ITU-T G.873.1 (2006), *Optical Transport Network (OTN): Linear protection*.

[ITU-T I.630] Recommendation ITU-T I.630 (1999), *ATM protection switching*.

[ITU-T I.732] Recommendation ITU-T I.732 (2000), *Functional characteristics of ATM equipment*.

[ITU-T M.495] Recommendation ITU-T M.495 (1988), *Transmission restoration and transmission route diversity: Terminology and general principles*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 General terms defined in [ITU-T G.805]:

a) adapted information (AI).

b) characteristic information (CI).

c) link connection.

d) network.

e) serial compound link connection.

f) subnetwork.

g) trail.

3.1.2 Action-related terms:

3.1.2.1 switch: [ITU-T G.870].

3.1.3 APS protocol-related terms:

3.1.3.1 1-phase: [ITU-T G.870].

3.1.3.2 2-phase: [ITU-T G.870].

3.1.3.3 3-phase: [ITU-T G.870].

3.1.4 Protection class-related terms:

3.1.4.1 trail protection: [ITU-T G.870].

3.1.4.2 subnetwork connection protection: [ITU-T G.870].

The determination of a fault condition on a serial compound link connection within the protected domain can be performed as follows:

3.1.4.2.1 sublayer monitored (/S): [ITU-T G.870].

3.1.4.2.2 non-intrusive monitored (/N): [ITU-T G.870].

3.1.4.2.3 inherent monitored (/I): [ITU-T G.870].

3.1.4.2.4 test monitored (/T): [ITU-T G.870].

3.1.4.3 network connection protection: [ITU-T G.870].

3.1.4.4 individual: [ITU-T G.870].

3.1.4.5 group: [ITU-T G.870].

3.1.5 Protection subclass-related terms:

3.1.5.1 end-to-end overhead/OAM (e): [ITU-T G.870].

3.1.5.2 sublayer overhead/OAM (s): [ITU-T G.870].

3.1.6 Component-related terms:

3.1.6.1 protected domain: [ITU-T G.870].

3.1.6.2 bridge: [ITU-T G.870].

3.1.6.3 permanent bridge: [ITU-T G.870].

3.1.6.4 broadcast bridge: [ITU-T G.870].

3.1.6.5 **selector bridge**: [ITU-T G.870].

3.1.6.6 **selector**: [ITU-T G.870].

3.1.6.7 **selective selector**: [ITU-T G.870].

3.1.6.8 **merging selector**: [ITU-T G.870].

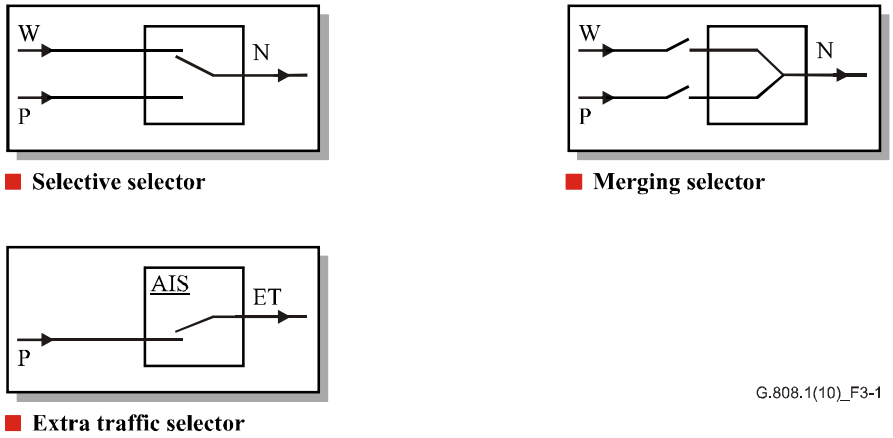


Figure 3-1 – Protection selectors

3.1.6.9 **head end**: [ITU-T G.870].

3.1.6.10 **tail end**: [ITU-T G.870].

3.1.6.11 **sink node**: [ITU-T G.870].

3.1.6.12 **source node**: [ITU-T G.870].

3.1.6.13 **intermediate node**: [ITU-T G.870].

3.1.7 **Fault condition-related terms**:

3.1.7.1 **signal degrade (SD)**: [ITU-T G.805].

3.1.7.2 **signal fail (SF)**: [ITU-T G.805].

3.1.7.3 **signal degrade group (SDG)**: [ITU-T G.870].

3.1.7.4 **signal fail group (SFG)**: [ITU-T G.870].

3.1.7.5 **server signal degrade (SSD)**: [ITU-T G.806].

3.1.7.6 **server signal fail (SSF)**: [ITU-T G.806].

3.1.7.7 **trail signal degrade (TSD)**: [ITU-T G.806].

3.1.7.8 **trail signal fail (TSF)**: [ITU-T G.806].

3.1.8 **Architecture-related terms**:

3.1.8.1 **1+1 (protection) architecture**: [ITU-T G.870].

3.1.8.2 **1:n (protection) architecture (n ≥ 1)**: [ITU-T G.870].

3.1.8.3 **m:n (protection) architecture**: [ITU-T G.870].

3.1.8.4 **$(1:1)^n$ protection architecture**: [ITU-T G.870].

3.1.9 **External commands-related terms**:

3.1.9.1 **lockout of protection transport entity #i (LO #i)**: [ITU-T G.870].

3.1.9.2 **lockout of normal traffic signal #i**: [ITU-T G.870].

3.1.9.3 **clear lockout of normal traffic signal #i**: [ITU-T G.870].

3.1.9.4 **freeze**: [ITU-T G.870].

3.1.9.5 **forced switch for normal traffic signal #i (FS #i)**: [ITU-T G.870].

3.1.9.6 **forced switch for null signal (FS #0)**: [ITU-T G.870].

3.1.9.7 **forced switch for extra traffic signal (FS #ExtraTrafficSignalNumber)**: [ITU-T G.870].

3.1.9.8 **manual switch for normal traffic signal #i (MS #i)**: [ITU-T G.870].

3.1.9.9 **manual switch for null signal (MS #0)**: [ITU-T G.870].

3.1.9.10 **manual switch for extra traffic signal (MS #ExtraTrafficSignalNumber)**: [ITU-T G.870].

3.1.9.11 **exercise signal #i (EX)**: [ITU-T G.870].

3.1.9.12 **clear (CLR)**: [ITU-T G.870].

3.1.10 **State-related terms**:

3.1.10.1 **do not revert normal traffic signal #i (DNR #i)**: [ITU-T G.870].

3.1.10.2 **no request (NR)**: [ITU-T G.870].

3.1.10.3 **wait-to-restore normal traffic signal #i (WtR)**: [ITU-T G.870].

3.1.11 **Operation-related terms**:

3.1.11.1 **revertive (protection) operation**: [ITU-T G.870].

3.1.11.2 **non-revertive (protection) operation**: [ITU-T G.870].

3.1.12 **Signal-related terms**:

3.1.12.1 **traffic signal**: [ITU-T G.870].

3.1.12.2 **normal traffic signal**: [ITU-T G.870].

3.1.12.3 **extra traffic signal**: [ITU-T G.870].

3.1.12.4 **null signal**: [ITU-T G.870].

3.1.13 **Switching-related terms**:

3.1.13.1 **bidirectional (protection) switching**: [ITU-T G.780].

3.1.13.2 **unidirectional (protection) switching**: [ITU-T G.780].

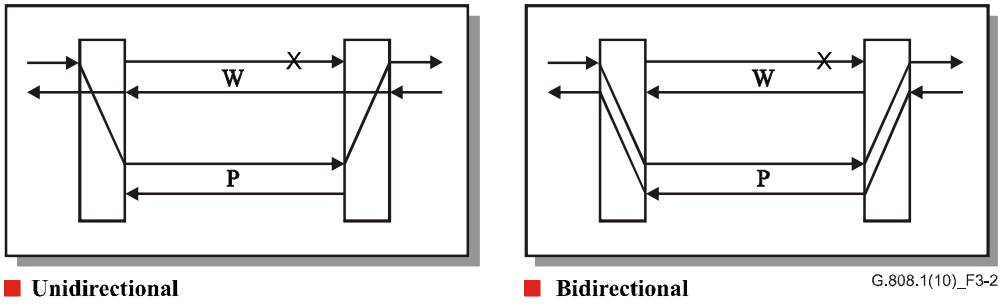


Figure 3-2 – Switching types

3.1.14 **Time-related terms**:

3.1.14.1 **detection time**: [ITU-T G.870].

3.1.14.2 **hold-off time**: [ITU-T G.870].

3.1.14.3 **wait-to-restore time**: [ITU-T G.870].

3.1.14.4 **switching time**: [ITU-T G.870].

3.1.15 **Transport entity-related terms**:

3.1.15.1 **transport entity**: [ITU-T G.870].

3.1.15.2 **transport entity protection**: [ITU-T G.870].

3.1.15.3 **protection transport entity**: [ITU-T G.870].

3.1.15.4 **working transport entity**: [ITU-T G.870].

3.1.15.5 **active transport entity**: [ITU-T G.870].

3.1.15.6 **standby transport entity**: [ITU-T G.870].

3.1.15.7 **group**: [ITU-T G.870].

3.1.16 **Other terms**

3.1.16.1 **protection**: [ITU-T G.870].

3.1.16.2 **restoration**: [ITU-T G.870].

3.1.16.3 **escalation**: [ITU-T G.870].

3.1.16.4 **hitless protection switch**: [ITU-T G.870].

3.1.16.5 **impairment**: [ITU-T G.870].

3.1.16.6 **network survivability**: [ITU-T G.870].

3.1.16.7 **protection ratio**: [ITU-T G.870].

3.1.16.8 **subnetwork interworking**: [ITU-T G.870].

3.1.16.9 **survivable network**: [ITU-T G.780].

3.1.16.10 **switch event**: [ITU-T G.870].

4 Abbreviations

This Recommendation uses the following abbreviations:

ABR Available Bit Rate

AI Adapted Information

AIS Alarm Indication Signal

AP Access Point

APS Automatic Protection Switching

ATM Asynchronous Transfer Mode

AU Administrative Unit

BER Bit Error Rate

CC Continuity Check

CI Characteristic Information

CP Connection Point

DEG DEGraded

ET	Extra Traffic (signal)
F4	Flow #4 (ATM)
FDI	Forward Defect Indication
HO	Hold Off
IMG	Inverse Multiplexed Group
LCAS	Link Capacity Adjustment Scheme
MPLS	Multi-Protocol Label Switching
MS	Multiplex Section
N	Normal (signal)
NE	Network Element
NIM	Non-Intrusive Monitoring
NR	No Request
NUT	Non-pre-emptible Unprotected Traffic
OAM	Operations, Administration and Maintenance
OCh	Optical Channel
OH	Overhead
OTN	Optical Transport Network
P	Protection
PDH	Plesiochronous Digital Hierarchy
POH	Path OverHead
PP	Pointer Processing
PU	Port Unit
RDI	Remote Defect Indication
REI	Remote Error Indication
RI	Remote Information
RS	Regenerator Section
SD	Signal Degrade
SDG	Signal Degrade Group
SDH	Synchronous Digital Hierarchy
SEL	Selector
SES	Severely Errored Second
SF	Signal Fail
SFG	Signal Fail Group
SIM	Survivability of Inverse Multiplexed link connections
SNC	SubNetwork Connection
SNC/I	Inherently monitored Subnetwork Connection protection
SNC/N	Non-intrusively monitored Subnetwork Connection protection

SNC/Ne	SNC/N, monitoring of end-to-end OH
SNC/Ns	SNC/N, monitoring of sub-layer OH
SNC/S	SNCP with Sublayer monitoring
SNC/Ss	SNC/S, monitoring of sublayer OH
SNC/T	SNCP with Test trail monitoring
SNC/Te	SNC/T, monitoring of end-to-end OH
SNC/Ts	SNC/T, monitoring of sublayer OH
SNCG	Subnetwork Connection Group
SNCG/I	Inherently monitored Subnetwork Connection Group
SNCG/N	Non-intrusively monitored Subnetwork Connection Group
SNCP	SubNetwork Connection Protection
SOH	Section OverHead
SSD	Server Signal Degrade
SSF	Server Signal Fail
STM-N	Synchronous Transport Module, level N
TCP	Termination Connection Point
TSD	Trail Signal Degrade
TSF	Trail Signal Fail
TSI	TimeSlot Interchange
TT	Trail Termination
TU	Tributary Unit
UBR	Unspecified Bit Rate
UPSR	Unidirectional Path Switch Ring
VC	Virtual Channel (ATM)
VCG	Virtual Concatenation Group
VC-n	Virtual Container-n
VC-n-Xv	Virtual concatenation of X virtual containers (of level n)
VP	Virtual Path (ATM)
VPI	Virtual Path Identifier
W	Working
WTR	Wait-to-Restore

5 Conventions

This Recommendation uses the following terms:

– **A**: Endpoint designation used when describing a protected domain; A is the source end of protected signals for which switch request signalling is initiated from the other, Z, end.

– **Z**: Endpoint designation used when describing a protected domain; Z is the end at which switch request signalling is initiated.

Sm	lower order VC-m layer (n = 11, 12, 2)
Sn	higher order VC-n layer (n = 3, 4, 4-Xc) or lower order VC-3 layer
Sn-Xv	VC-n-Xv layer
X, Y, Z	Layer (for non-specified layers) or group size designations

6 Individual and group protection concept

The individual protection concept applies to the situations where it is useful to protect only a part of the traffic signals which need high reliability. The rest of the traffic signals in the network layer remains unprotected. This helps to reduce the necessary bandwidth for protection.

The group protection concept applies to the situations where:

i) it is useful to protect a large number (but not all) of the traffic signals transported via the same server layer trails, with protection times in the same order as individual protection (of a small set of traffic signals). Fast protection switching is obtained through the treatment of a logical bundle of transport entities as a single entity after the commencement of protection actions;

ii) the protection of a group of traffic signals that realize a single traffic signal by means of e.g., virtual concatenation, inverse multiplexing.

The complexity of the protection process is reduced by treating the group of signals as a single entity, within a single protection process. The status of the working and protection groups is represented by SF-Group and SD-Group indications.

The complexity can be further reduced by the introduction of an additional test signal (transported over the same server layer trails), of which the SF and SD indications are used to represent the status of the group. The disadvantage of this latter complexity reduction technique is the inability to monitor the individual signals in each group for their connectivity, continuity and performance. One of these faults within one of the signals in the group will not be detected, and thus not protected.

7 Architecture types

The protection architecture can be a 1+1, a 1:n, a m:n, or a $(1:1)^n$ architecture type.

Possible advantages of the 1+1 architecture include:

1) low complexity;

2) for the case of unidirectional switching, the possibility to support dual node interconnection of protected subnetworks.

Possible disadvantages of the 1+1 architecture include:

3) 100% extra capacity.

Possible advantages of the 1:n, m:n, $(1:1)^n$ architecture include:

1) possibility to provide protection access; the protection transport entity/bandwidth can transport an extra traffic signal during periods when the protection transport entity/bandwidth is not required to transport a normal traffic signal;

2) extra capacity restricted to 100/n % or m × 100/n %;

3) for the case of m:n, protection is possible for up to m faults.

Possible disadvantages of the 1:n, m:n, $(1:1)^n$ architecture include:

4) complexity;

5) for the case of SNC protection class, the need for additional sublayer termination functions at ingress and egress points of the protected domain on each working and protection transport entity;

6) does not support dual node interconnection of protected subnetworks;

7) $n \geq 2$: each of the n working transport entities must be routed via different facilities and equipment to prevent the existence of common points of failure that cannot be protected by the single protection transport entity in a 1:n and $(1:1)^n$ architecture.

NOTE 1 – Typically, n+1 alternative paths between two nodes in the network will not be available. As such, 1:n and $(1:1)^n$, with $n \geq 2$, architectures will not provide adequate protection for the n normal traffic signals transported normally via the n working transport entities. n = 1 seems the only reasonable choice.

NOTE 2 – In ATM, protection access is not explicitly required to allow usage of the normally unused protection bandwidth; ABR and UBR traffic could use this protection bandwidth by means of an over-subscription of the bandwidth of the server signal containing the protection transport entity. The ABR/UBR higher layer control mechanism is assumed to reduce the traffic when the protection is actually used. The ingress/egress nodes of the protection domain do not have to align with ingress/egress nodes of ABR/UBR traffic. This adds flexibility to the network and reduces complexity.

7.1 1+1 protection architecture

In the 1+1 architecture type, a protection transport entity is dedicated as a backup facility to the working transport entity with the normal traffic signal bridged onto the protection transport entity at the source endpoint of the protected domain. The normal traffic on working and protection transport entities is transmitted simultaneously to the sink endpoint of the protected domain where a selection between the working and protection transport entity is made, based on some predetermined criteria, such as signal fail and signal degrade indications. See Figure 7-1.

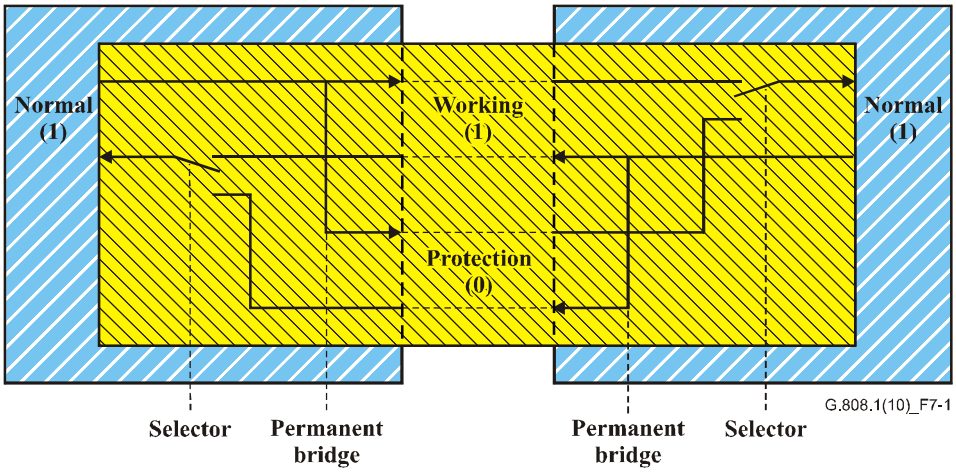


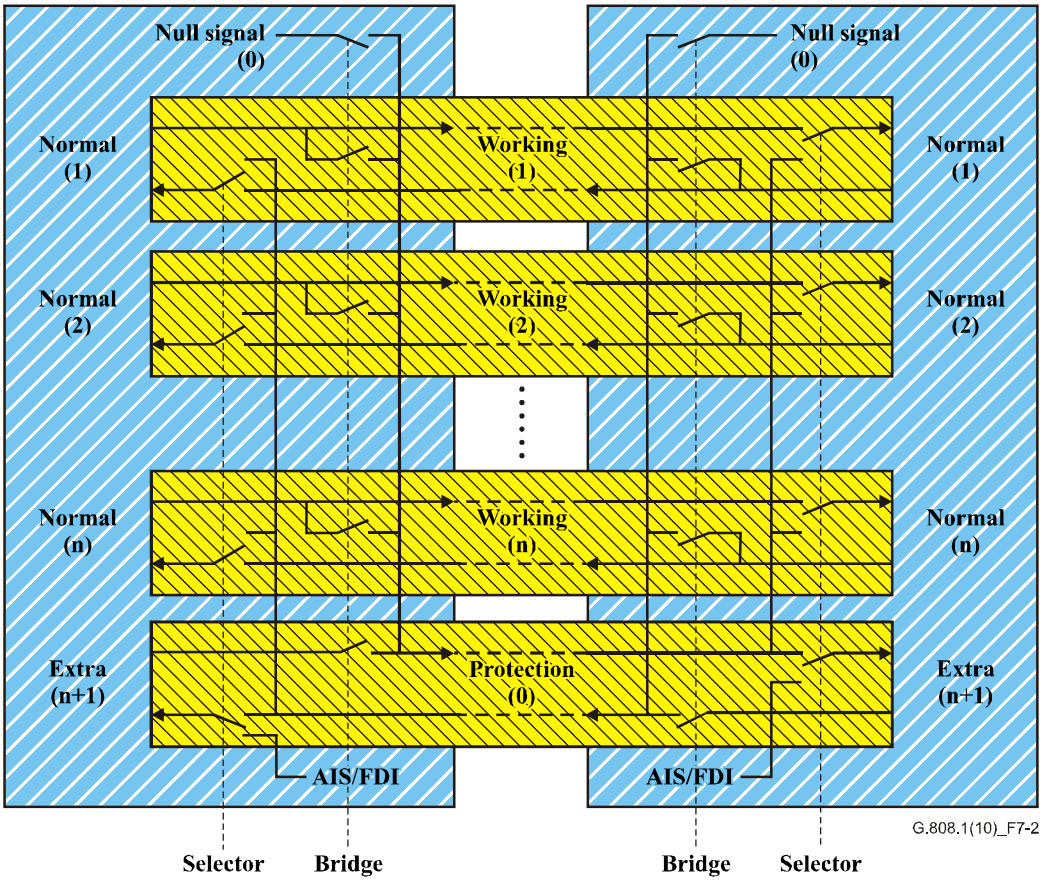
Figure 7-1 – 1+1 protection architecture

7.2 1:n protection architecture

In the 1:n architecture type, a dedicated protection transport entity is a shared backup facility for n working transport entities. The bandwidth of the protection transport entity should be allocated in such a way that it may be possible to protect any of the n working transport entities in case the protection transport entity is available.

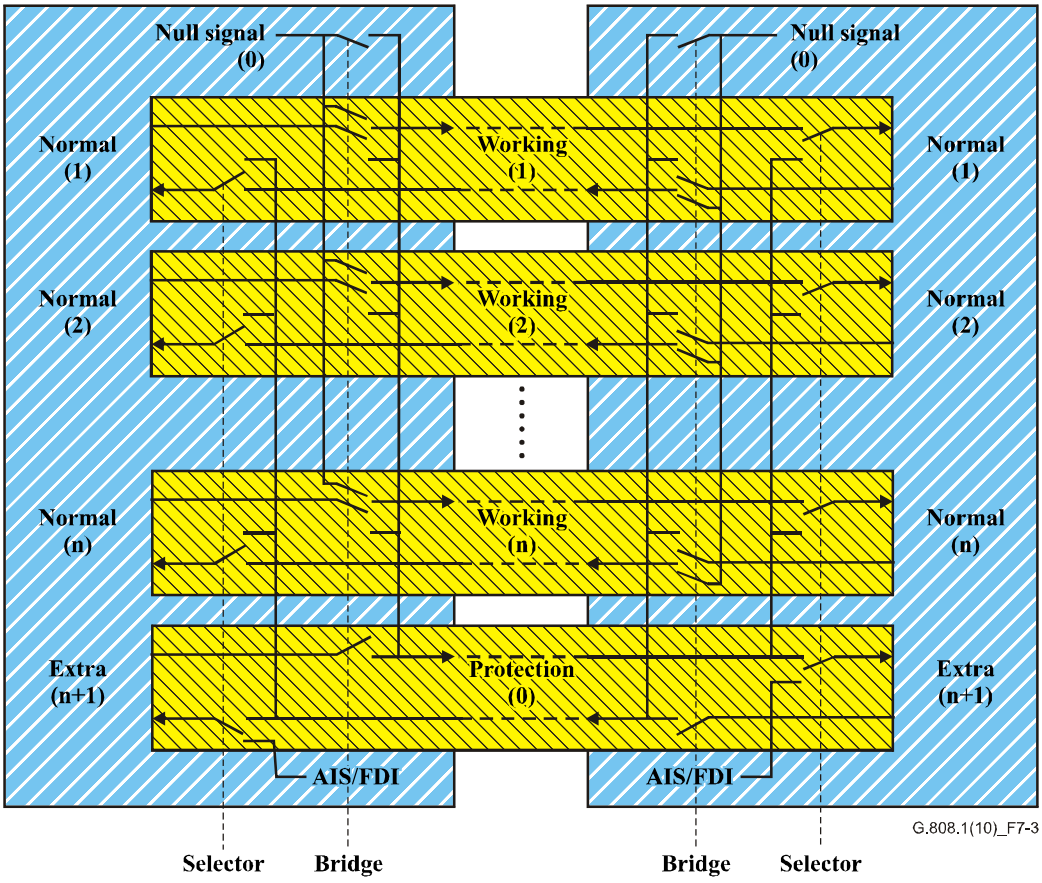
When a working transport entity is determined to be impaired, its normal traffic signal must be transferred from the working to the protection transport entity at both the source and sink endpoints of the protected domain. It is noted that, when more than one working transport entities is impaired, only one normal traffic signal can be protected.

The bridge can be realized in two ways: selector bridge or broadcast bridge. With selector bridge connectivity (Figure 7-3), the normal traffic signal is connected either to the working transport entity, or to the protection transport entity. With broadcast bridge connectivity (Figure 7-2) the normal traffic signal is permanently connected to the working transport entity, and occasionally to the protection transport entity also. Interworking between the two options is guaranteed.



Broadcast bridge option: Normally permanently connected to working and occasionally to protection.

Figure 7-2 – 1:n protection architecture (broadcast bridge)

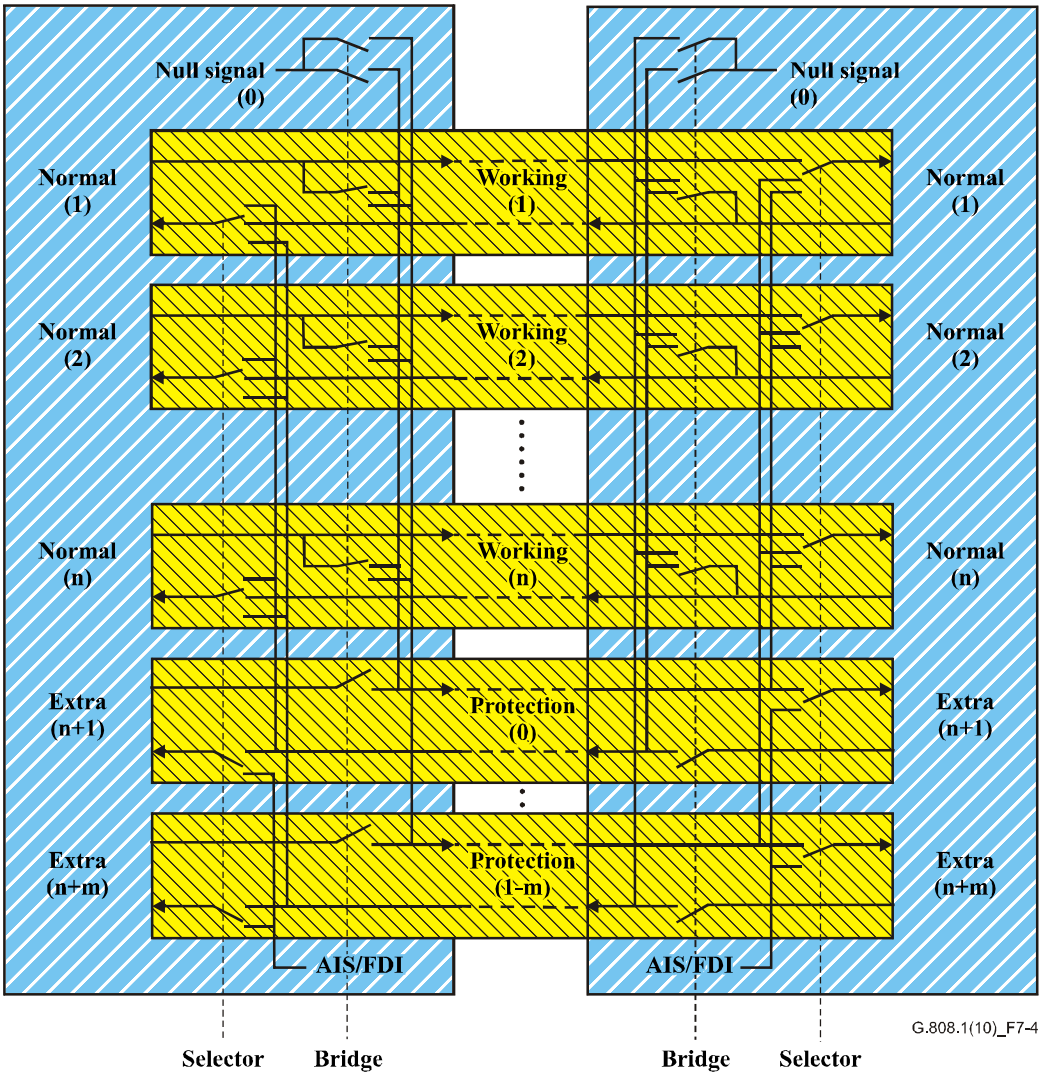


Selector bridge option: Normally connected to either working or protection.

Figure 7-3 – 1:n protection architecture (selector bridge)

7.3 m:n protection architecture

In the m:n architecture type, m dedicated protection transport entities are sharing backup facilities for n working transport entities, where m ≤ n typically. The bandwidth of each protection transport entity should be allocated in such a way that it may be possible to protect any of the n working transport entities in case at least one of the m protection transport entities is available. When a working transport entity is determined to be impaired, its normal traffic signal first must be assigned to an available protection transport entity followed by transition from the working to the assigned protection transport entity at both the source and sink endpoints of the protected domain. It is noted that when more than m working transport entities are impaired, only m working transport entities can be protected. See Figure 7-4.

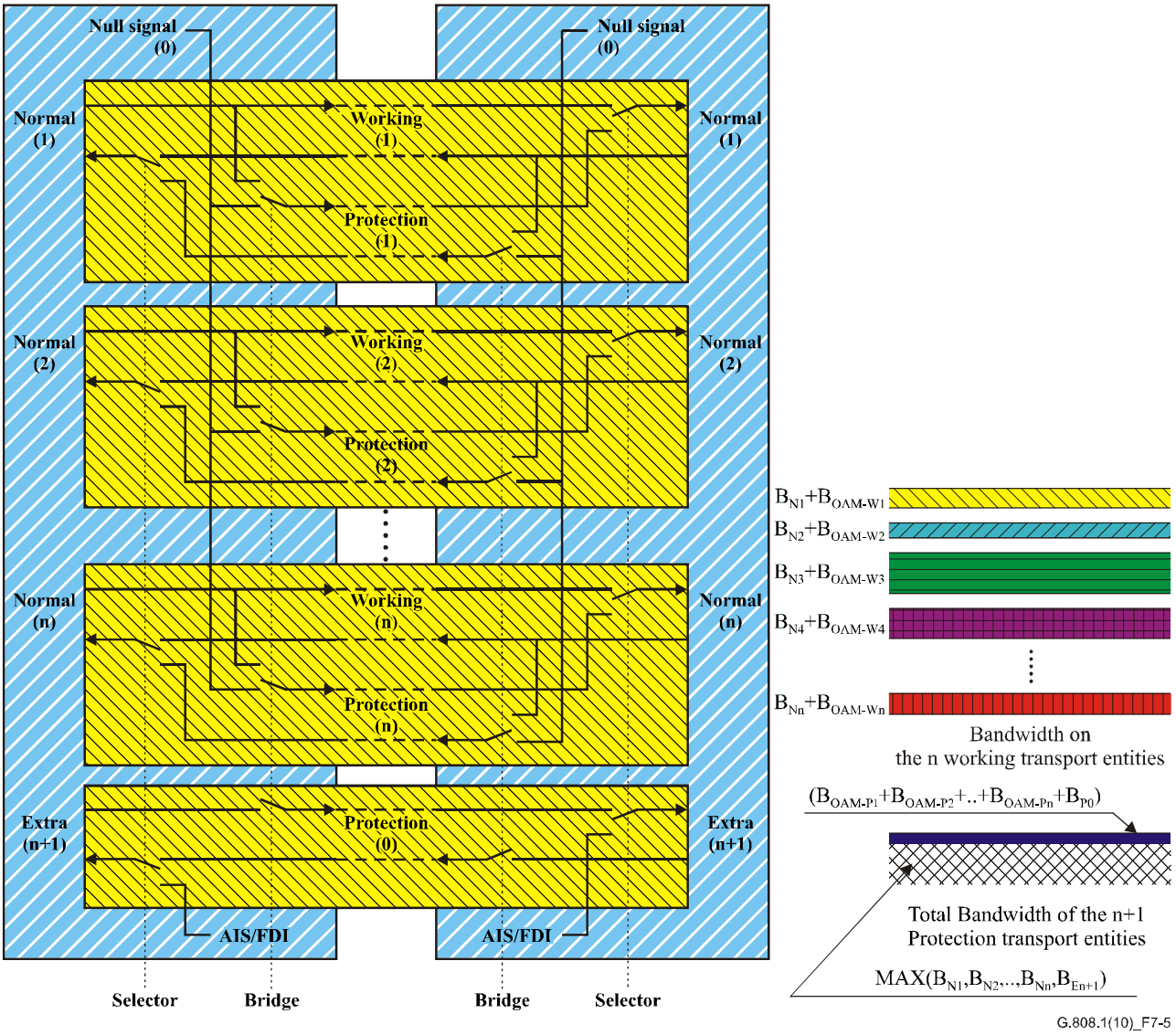


Broadcast bridge option: Normally permanently connected to working and occasionally to protection.

Figure 7-4 – m:n protection architecture

7.4 $(1:1)^n$ protection architecture

In the $(1:1)^n$ protection architecture, n dedicated protection transport entities sharing the same bandwidth are backup facilities for n working transport entities. The protection bandwidth should be allocated in such a way that it may be possible to protect any of the n working transport entities in case the protection transport bandwidth, and the specific protection transport entity associated with the working transport entity to be switched, is available. When a working transport entity is determined to be impaired, its normal traffic signal must first be assigned to the associated available protection transport entity followed by transition from the working to the assigned protection transport entity at both the source and sink endpoints of the protected domain. It is noted that when more than one working transport entity is impaired, only one working transport entity can be protected. See Figure 7-5.



Broadcast bridge option: Normally permanently connected to working and occasionally to protection.

Figure 7-5 – Bandwidth sharing $(1:1)^n$ protection architecture

All "n" working transport entities are routed via different facilities and equipment (to prevent a common point of failure that cannot be protected). All "n+1" protection transport entities are routed via the same facilities and equipment, diverse from the working facilities and equipment. Refer to Appendix IV for an example.

The bandwidth occupied by each working transport entity is $B_{Wi} = B_{Ni}+B_{OAM-Wi}$; i.e., the bandwidth for the normal traffic signal #i, plus the bandwidth for the tandem connection/segment OAM used to monitor the working transport entity #i. The bandwidth occupied by the protection transport entities is $Bp = MAX(B_{N1}, B_{N2},.., B_{Nn}, B_{En+1}) + (B_{OAM-P1} + B_{OAM-P2} + ... + B_{OAM-Pn} + B_{OAM-P0})$. From a bandwidth perspective, this $(1:1)^n$ protection architecture behaves as a 1:n architecture.

Misconnection of a normal traffic signal #i at the ingress of the protected domain to the output for a normal traffic signal #j ($j \neq i$) at the egress of the protected domain cannot occur. A 3-phase APS protocol is, as such, not required.

Note that this architecture is intended for packet/cell-based traffic, not for constant bit rate-type traffic.

8 Switching types

The protection switching types can be a unidirectional switching type or a bidirectional switching type.

In unidirectional switching, the switching is complete when the traffic signal (service) is selected from standby at the end detecting the fault. For the case of the 1+1 architecture, the selector at the sink end is operated only (without communication with the source end). For the case of the 1:n, m:n, $(1:1)^n$ architectures, the selector at the sink end, as well as the bridge at the source end, are operated.

In bidirectional switching, the traffic signal (service) is switched from the active to the standby transport entity at both ends of the protection span. For the case of the 1+1 architecture, the selectors at the sink and source ends are operated. For the case of the 1:n, m:n, $(1:1)^n$ architectures, the selectors at the sink and source ends, as well as the bridges at the source and sink ends, are operated.

NOTE 1 – All switching types, except 1+1 unidirectional switching, require a communications channel between the two ends of the protected domain; this is called the automatic protection switching (APS) channel. The APS channel is terminated in the connection functions at each end of the protected domain.

Under bidirectional switching protocols, switching (operating selector and bridge) at only one end is not allowed. The two ends communicate to initiate transfer of the normal traffic signal. If the priority of the request of the source end is lower than that of the sink end, or does not exist, the sink end initiates transfer of the normal traffic signal and the source end follows this transfer.

In the unidirectional switching type, possible advantages include:

1) Unidirectional protection switching is a simple scheme to implement and does not require a protocol in a 1+1 architecture.

   NOTE 2 – Unidirectional switching in a 1:n architecture (typically applied in radio/satellite links) requires a protocol to operate between the two endpoints of the protected domain.

2) For a 1+1 architecture, unidirectional protection switching can be faster than bidirectional protection switching because it does not require a protocol.

3) Under multiple failure conditions, there is a greater chance of restoring traffic by protection switching if unidirectional protection switching is used, than if bidirectional protection switching is used.

4) Unidirectional switching allows simple realization of a reliable network by means of cascaded protected subnetworks. Two subnetworks are connected in a dual node interconnect/dual subnetwork interworking architecture.

In the bidirectional switching type, possible advantages include:

1) With bidirectional protection switching, the same equipment is used for both directions of transmission after a failure. This means that there will be fewer disruptions in the service for repair and reversion to the original working path. In unidirectional switching, the following switches occur:

   i) protection switch;

   ii) forced switch for the direction unaffected by the failure;

   iii) revertive switch.

In bidirectional switching, only two switches will occur:

i) protection switch;

ii) revertive switch.

Each switch will result in one or two severely errored seconds. Fewer SESs will result from bidirectional switching.

2) With bidirectional protection switching, if there is a fault in one transport entity of the network, transmission of both transport entities between the affected nodes is switched to the alternative direction around the network. No traffic is then transmitted over the faulty section of the network and so it can be repaired without further protection switching.

3) Bidirectional protection switching is easier to manage because both directions of transmission use the same equipment along the full length of the transport entity.

4) Bidirectional protection switching maintains equal delays for both directions of transmission. This may be important where there is a significant imbalance in the length of the transport entities, e.g., transoceanic links where one transport entity is via a satellite link and the other via a cable link.

5) Bidirectional protection switching also has the ability to carry extra traffic on the protection transport entity.

9 Operation types

The protection operation types can be a non-revertive operation type or a revertive operation type.

In revertive operation, the traffic signal (service) always returns to (or remains on) the working transport entity if the switch requests are terminated. That is, when the working transport entity has recovered from the defect, or the external request is cleared.

In non-revertive operation, the traffic signal (service) does not return to the working transport entity if the switch requests are terminated.

Some protection schemes are inherently revertive. For other schemes either revertive or non-revertive operation is possible. An advantage of non-revertive operation is that, in general, it will have less impact on traffic performance. However, there are situations where revertive operation may be preferred. Examples of cases where revertive operation may be appropriate are:

1) Where parts of the protection transport entity may be taken to provide capacity to meet a more urgent need. For example, where the protection transport entity can be taken out of service to release capacity for use in restoring other traffic.

2) Where the protection transport entity may be subject to frequent rearrangement. For example, where a network has limited capacity and protection routes are frequently rearranged to maximize network efficiency when changes occur in the network.

3) Where the protection transport entity is of significantly lower performance than the working transport entity. For example, where the protection transport entity has a worse error performance or longer delay than the working transport entity.

4) When an operator needs to know which transport entities are carrying normal traffic in order to simplify the management of the network.

10 Protocol types

Except for the case of 1+1 unidirectional switching, all protection types require that both ends, A and Z, of the protected domain coordinate their actions of bridging and selecting. Different protocols are required according to the type of protection and selector and bridge types. Nodes A

and Z communicate, therefore, with each other via the automatic protection switching (APS) channel.

There are two basic requirements for a protection protocol:

1) The prevention of misconnections.

2) The minimization of the number of communication cycles between A and Z ends of the protected domain, in order to minimize the protection switching time. The communication may be once (Z → A), twice (Z → A and A → Z), or three times (Z → A, A → Z and Z → A). This is referred to as 1-phase, 2-phase, and 3-phase protocols.

The conditions under which the different protocol types can be used are shown in Table 1.

Table 1 – Protocol types related to protection architectures and selector/bridge types

Protocol type	Types of protection using the protocol	Bridge type	Selector type
No protocol	1+1 unidirectional only	Permanent	Selective
1-phase	$(1:1)^n$ architectures	Selector	Selective or merging
	1+1 architectures	Permanent	Selective
2-phase	$(1:1)^n$ architectures	Selector	Selective or merging
	1+1 architectures	Permanent	Selective
3-phase	All architecture types	Any	Selective
		Selector	Merging (cell/packet based technologies)

In the 3-phase protocol type, possible advantages include:

1) operates in all architecture types;

2) prevents a misconnection occurring under all circumstances;

3) operates a selector or bridge only after confirmation of priority with the other end of the protected domain.

In the 3-phase protocol type, possible disadvantages include:

1) triple message exchange necessary between two ends of the protected domain, increasing the switching time.

In the 2-phase protocol type, possible advantages include:

1) reduced switching time compared to the 3-phase protocol;

2) operates in 1+1 and $(1:1)^n$ architectures.

In the 1-phase protocol type, possible advantages include:

1) short switching time, due to single message interchange needed between the two ends of protected domain;

2) operates in 1+1 and $(1:1)^n$ architectures.

In the 1-phase and 2-phase protocol types, possible disadvantages include:

1) they operate a bridge/selector before priority is confirmed by the other end of a protected domain. As such, a switch action may have to be reverted and replaced by other bridge/selector action initiated by the other end.

11 Protection classes and subclasses

11.1 Trail protection

Trail protection is a protection class used to protect a trail across an entire operator's network or multiple operators' networks. It is a dedicated end-to-end protection architecture, which can be used in different network structures: meshed networks, rings, etc. As trail protection is a dedicated protection mechanism, there is no fundamental limitation on the number of NEs within the trails.

Trail protection operates in all combinations of protection architectures, switching and operation.

Trail protection generically protects against faults in the server layer, and connectivity faults and performance degradations in the client layer.

For the case of trail protection, the adapted information (AI) (i.e., the payload of the network layer's characteristic information (CI)) is protected. See Figure 11-1.

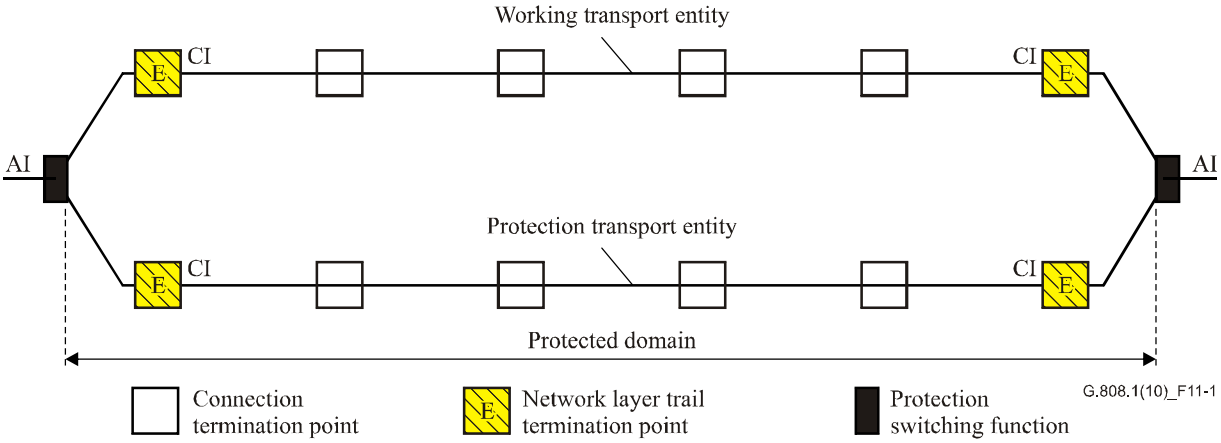


Figure 11-1 – Generic concept of trail protection

NOTE 1 – As 1:1, 1:n, m:n trail protections are linear protection mechanisms, the normal and extra traffic trail termination functions are located in the same NE. In a network application, this implies that the normal and extra traffic patterns must coincide.

Trail protection does not support network architectures which make use of cascaded protected subnetworks in the same layer. Consequently, traffic can be restored under single-fault conditions only. To restore traffic under multiple-fault conditions, SNC protection has to be used, or trail protection has to be supplemented with protection at server layers.

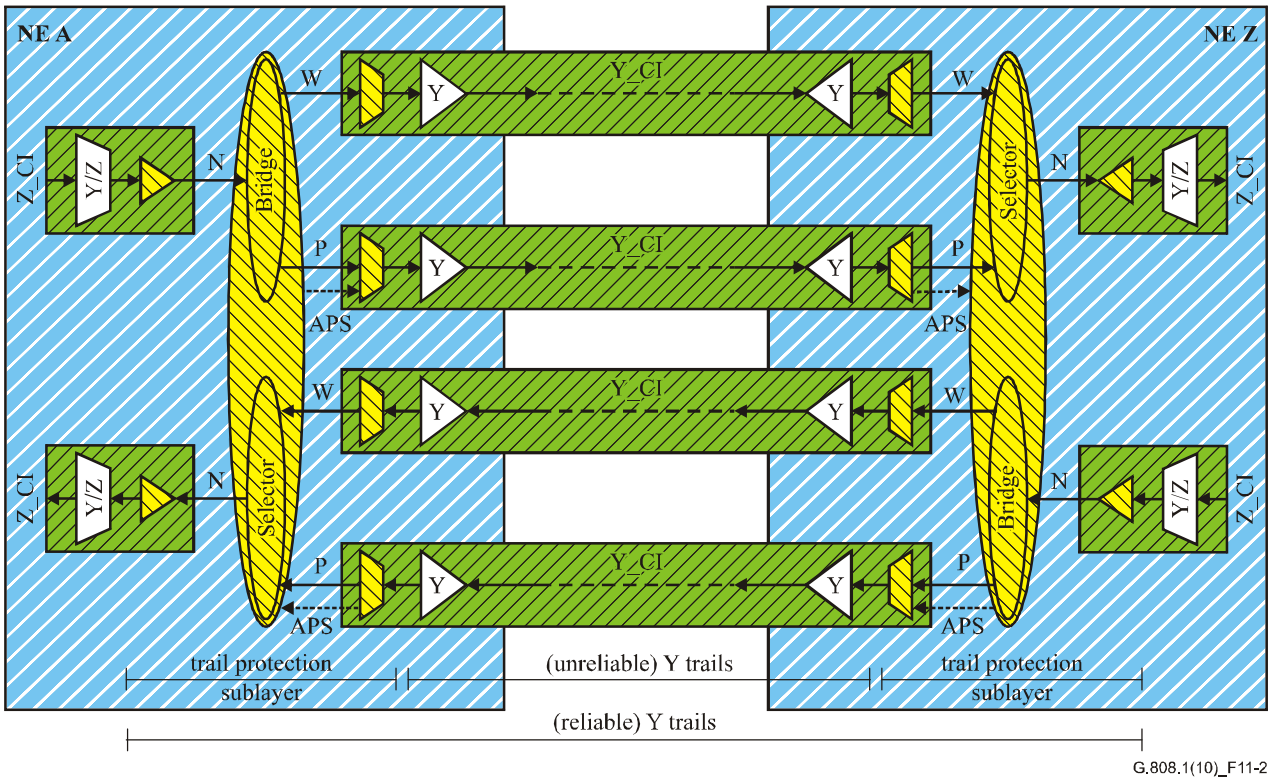
NOTE 2 – For the case of an 1:1, m:n, or $(1:1)^n$ architecture in ATM, the protection trail(s) should contain a signal that allows accurate monitoring of its status. In normal conditions, in which the normal traffic signal is transported via the working trail, there is no signal to be transported via protection. If continuity check (CC) would be inactive, such protection trail will not transport any information under normal fault-free conditions. When a fault occurs, AIS cells are inserted. When the fault is present for a short period only (e.g., due to a "physical layer protection action"), the AIS defect detector at the protection trail endpoint will detect the AIS defect condition for 2 to 3 seconds according to the ITU-T I.610-defined AIS state definition. With CC activated, the AIS defect condition will clear on the receipt of a CC cell, i.e., within a period of 1 second after the traffic interruption was cleared.

NOTE 3 – If trail protection is used at path level, this may result in taking up an additional port in a fabric compared to SNC protection. This is the case when the protection selector is located in the egress port of the equipment.

11.1.1 Individual trail protection

Figure 11-2 illustrates the case of 1+1 trail protection and 1:1 trail protection without extra traffic between ingress and egress of the protected domain between NEs A and Z. Two independent trails (in layer network Y) exist which act as working and protection transport entities for the (protected) normal (payload) traffic signal. The TT functions generate/insert and monitor/extract the end-to-end overhead/OAM information to determine the status of the working and protection transport entities. APS information is transported over the protection trail, except for the case of 1+1 unidirectional switching.

The cases of 1:n, m:n and $(1:1)^n$ architectures with/without extra traffic are extensions of the 1+1/1:1 architecture, in accordance with the architecture type descriptions in clause 7.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-2 – 1+1/1:1 trail protection functional model

11.1.2 Group trail protection

Figure 11-3 illustrates the case of 1+1/1:1 group trail protection between NEs A and Z. In this example, two times three parallel independent trails (in layer network Y) exist which act as working and protection transport entity groups for the three (protected) normal (payload) traffic signals. The three parallel normal traffic signals in the group are protected jointly by the trail protection sublayer connection function. The TT functions generate/insert and monitor/extract the end-to-end overhead/OAM information to determine the status of the working and protection transport entities. APS information is transported over one of the protection trails, except for the case of 1+1 unidirectional switching.

The cases of 1:n, m:n and $(1:1)^n$ architectures with/without extra traffic are extensions of the 1+1/1:1 architecture, in accordance with the architecture type descriptions in clause 7.

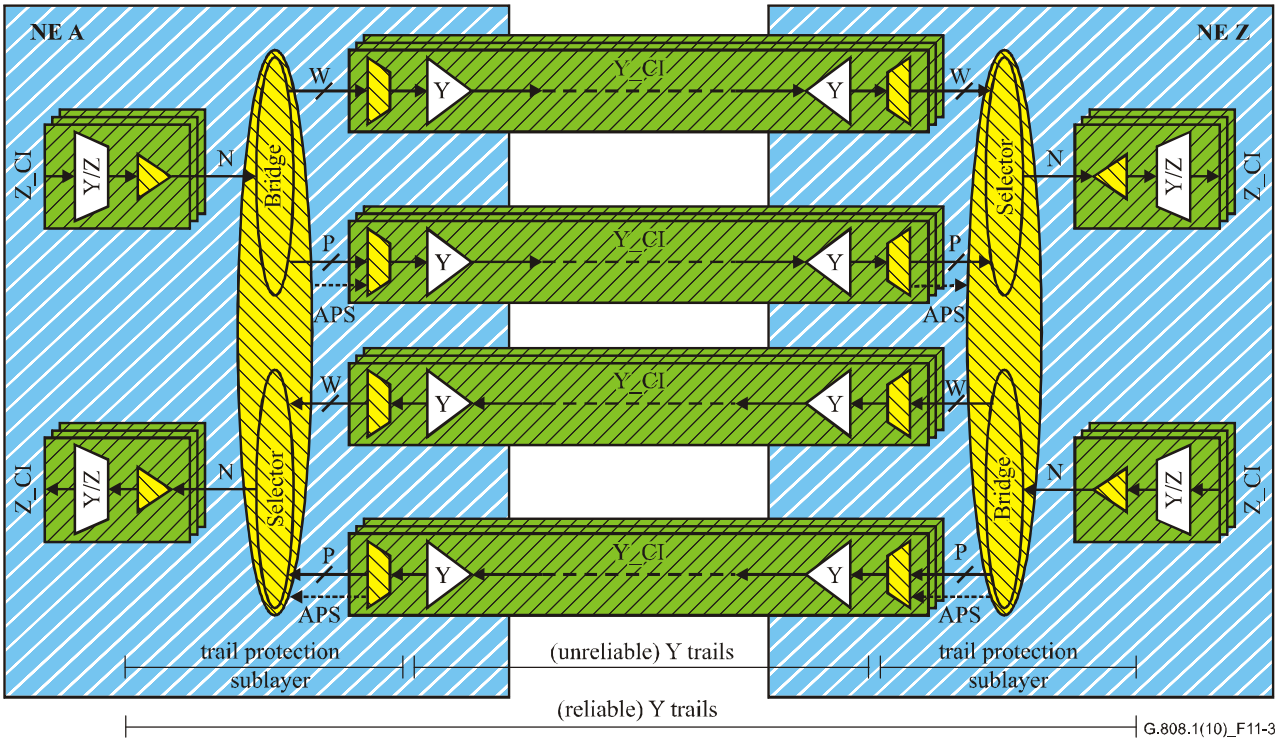


Figure 11-3 – 1+1/1:1 Group trail protection functional model

Figure 11-4 presents additional detail of this protection connection function's processes. Specific for group protection is the SFG/SDG logic process. This process "merges" the three individual trail signal fail (TSF) signals into a single SF group (SFG) and the individual trail signal degrade (TSD) signals into a single SD group (SDG).

The SFG/SDG logic may operate in different modes:

- W-SFG = W1-TSF or W2-TSF or W3-TSF
  P-SFG = P1-TSF or P2-TSF or P3-TSF;
- W-SFG = W1-TSF
  P-SFG = P1-TSF;
- W-SFG = X% of the Wi-TSF signals are active
  P-SFG = X% of the Pi-TSF signals are active;
- idem for SDG.

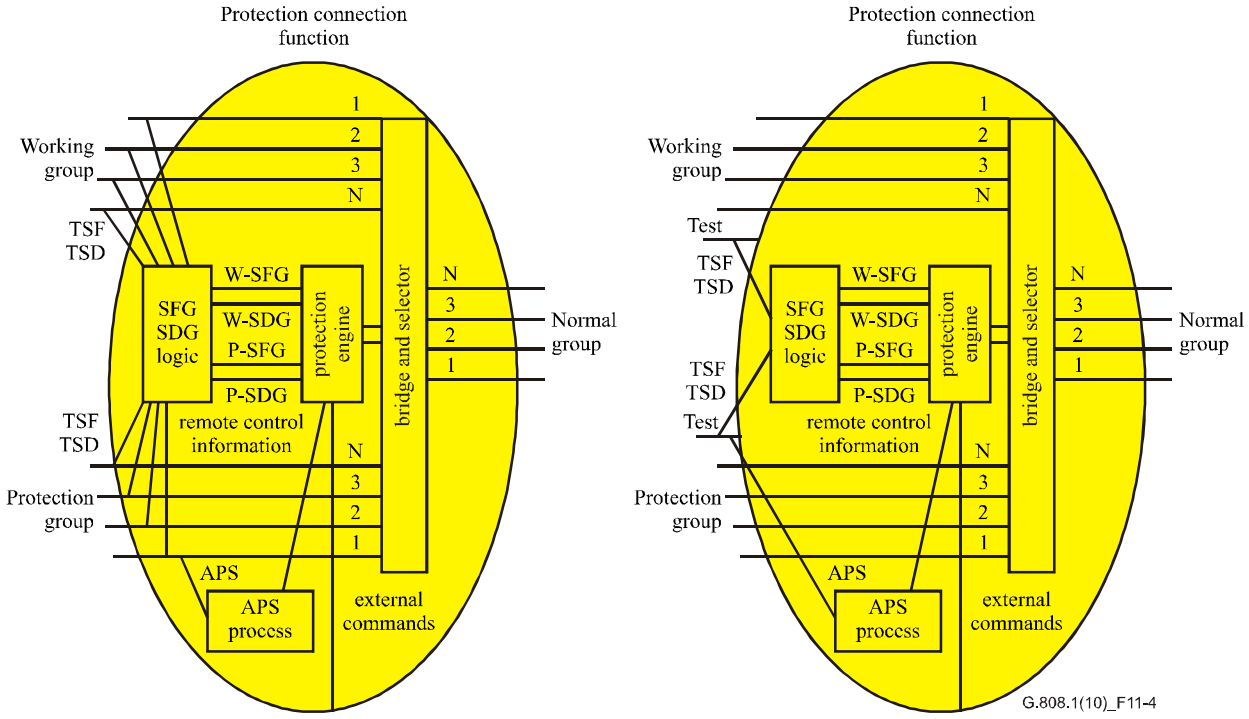


Figure 11-4 – SFG/SDG logic within the group protection process

As a result of the large number of tributary slots in some transmission technologies (e.g., ATM), extra tributary slots in the working and protection server layer signals can be allocated to transport test signals via test transport entities (Figures 11-5 and 11-6). These test signals (one per working, one per protection) can be used instead of the SFG, SDG information as described above. The APS signal is transported via the test protection transport entity.

The SFG/SDG logic operates now as follows:

- W-SFG = Wt-TSF
  P-SFG = Pt-TSF;
- W-SDG = Wt-TSD
  P-SDG = Pt-TSD.

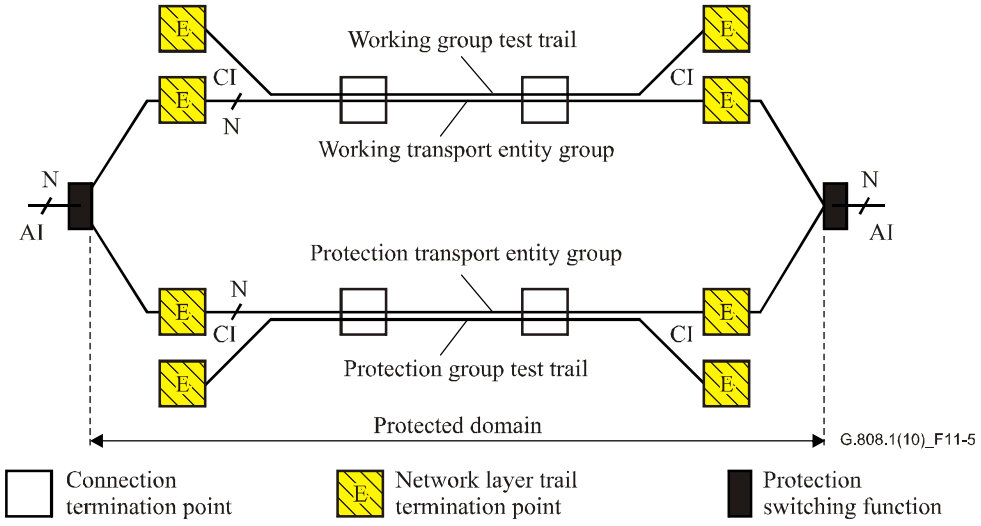


Figure 11-5 – Generic concept of group trail/T protection

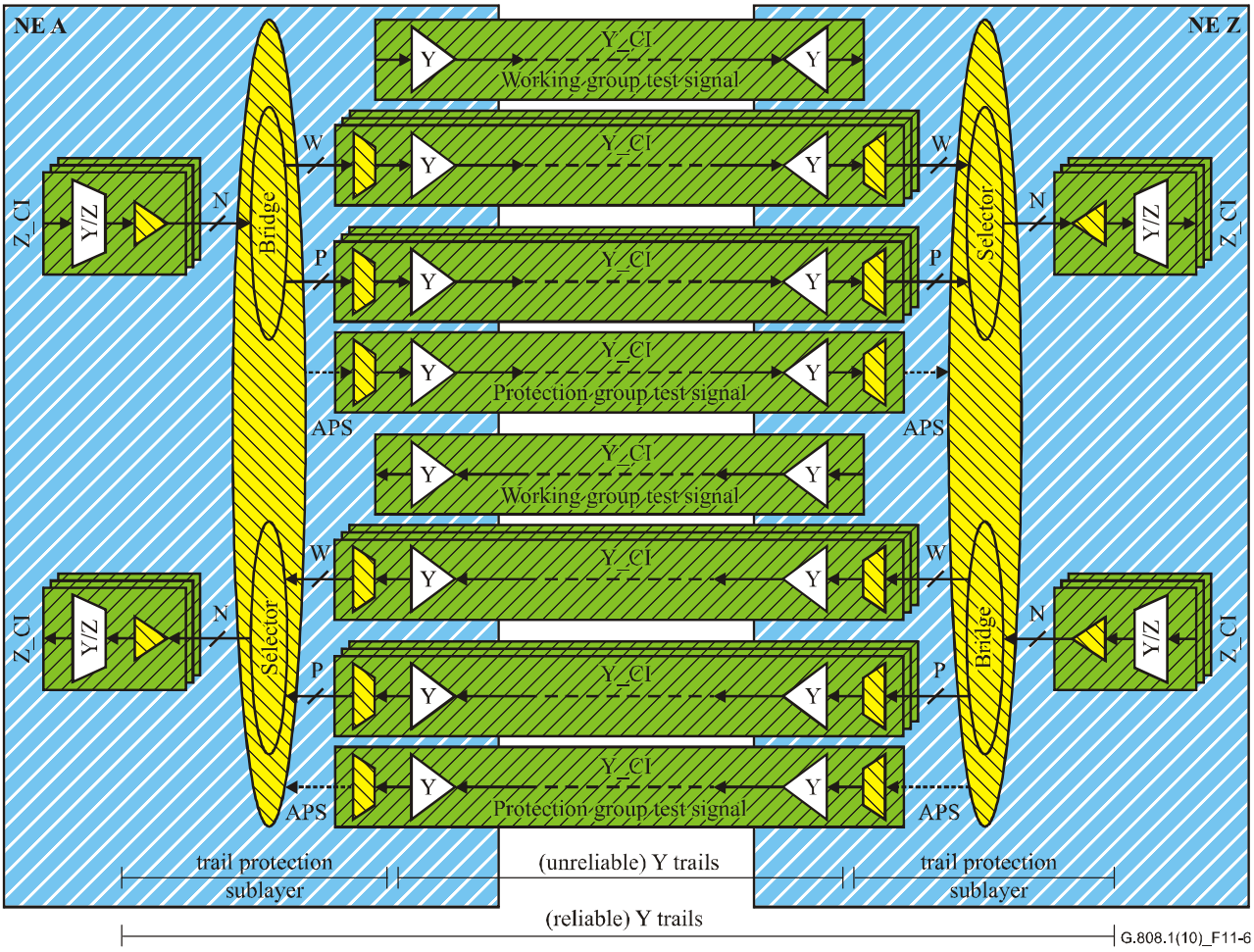


Figure 11-6 – 1+1/1:1 Group trail/T protection functional model

11.2 SNC protection

Subnetwork connection protection is the protection class used to protect a portion of a trail (e.g., that portion where two separate routes are available) within an operator's network or multiple operators' networks.

The subnetwork connection that is protected can be between two connection points (CPs) (Figure 11-7), between a CP and a termination connection point (TCP) (Figure 11-8), or the full end-to-end network connection between two TCPs (Figure 11-9).

As subnetwork connection protection is a dedicated protection mechanism, it can be used on any physical structure (i.e., meshed, rings, or mixed), and there is no fundamental limitation on the number of NEs within the subnetwork connection. It may be applied at any layer in a layered network.

SNC protection operates in all combinations of protection architectures, switching and operation.

SNCP can be further split into subclasses that represent the defect conditions that contribute to SF/SD:

1) Inherent: the server layer's trail termination and adaptation functions are used to determine the SF/SD condition. It supports detection of server layer defect conditions only.

2) Non-intrusive: non-intrusive monitoring functions are deployed to determine the SF/SD condition.

   a) End-to-end: Detection of server layer defect conditions, continuity/connectivity defect conditions in the layer network, and error degradation conditions in the layer network. The end-to-end overhead/OAM is used.

   b) Sublayer: Detection of server layer defect conditions, continuity/connectivity defect conditions in the layer network, and error degradation conditions in the layer network. The sublayer overhead/OAM is used.

3) Sublayer: Tandem connection/segment sublayer functions are deployed to determine the SF/SD condition. It supports detection of server layer defect conditions, continuity/connectivity defect conditions in the layer network, and error degradation conditions in the layer network. The sublayer overhead/OAM is used.

In general, SNC protection requires the creation of sublayer trails (tandem connections, segments) on the working and protection transport entities to distinguish a fault or degradation occurring "in front of" from "within" the protected domain. When the sublayer trail includes a single server layer trail, that server layer trail can be used instead (providing inherent monitoring). If a sublayer trail cannot be created, or a single server layer trail is not available between the ingress and egress points of the protected domain, SNC protection can be realized by means of dual feeding the normal traffic signal to both working and protection transport entities, non-intrusive monitoring both copies of the signal at the egress point and comparing the SF/SD status obtained from both monitors. If the fault or degradation occurred in front of the protected domain, both working and protection monitors will discover the impairment and a switch action will not be performed. Otherwise, only one of the two monitors will detect a SF/SD condition and, with a switch action, the traffic flow can be restored.

NOTE 1 – For SDH, due to the treatment of AU/TU pointers during server layer TSF conditions, 1+1 SNC/I can be deployed instead of 1+1 SNC/N if server layer defects are to be protected only.

For the case of SNC protection, the characteristic information (CI) (i.e., payload and its layer overhead) is protected. See Figures 11-7 to 11-10.

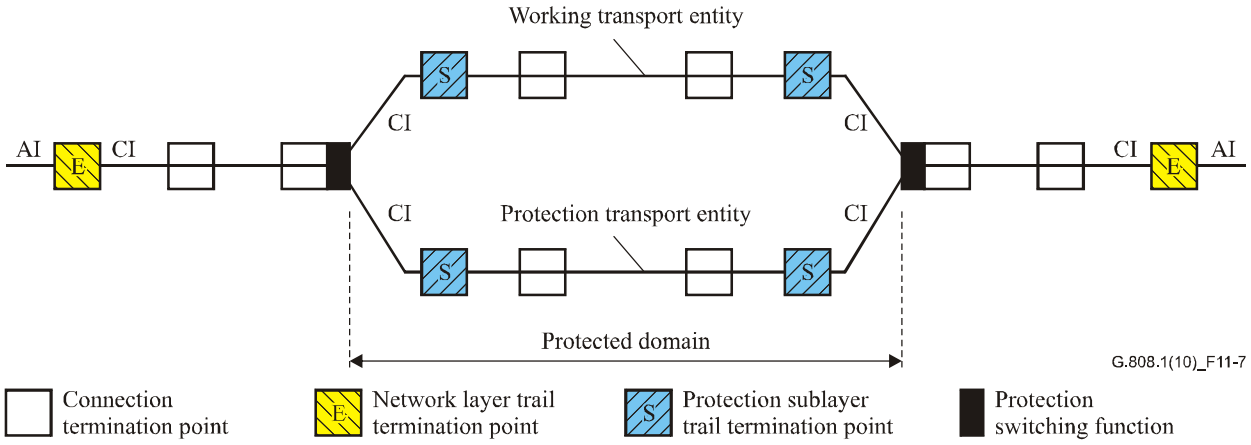


Figure 11-7 – SNC/S protection example 1

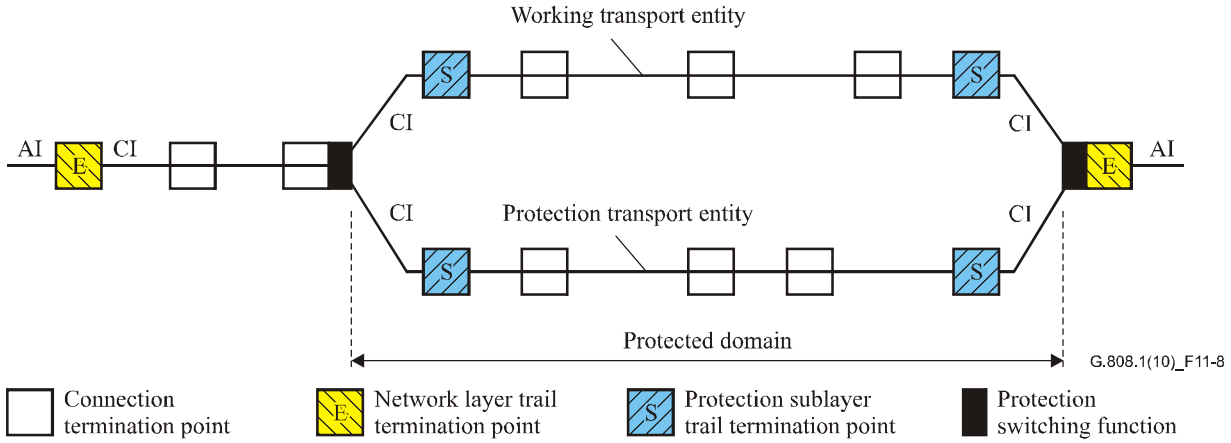


Figure 11-8 – SNC/S protection example 2

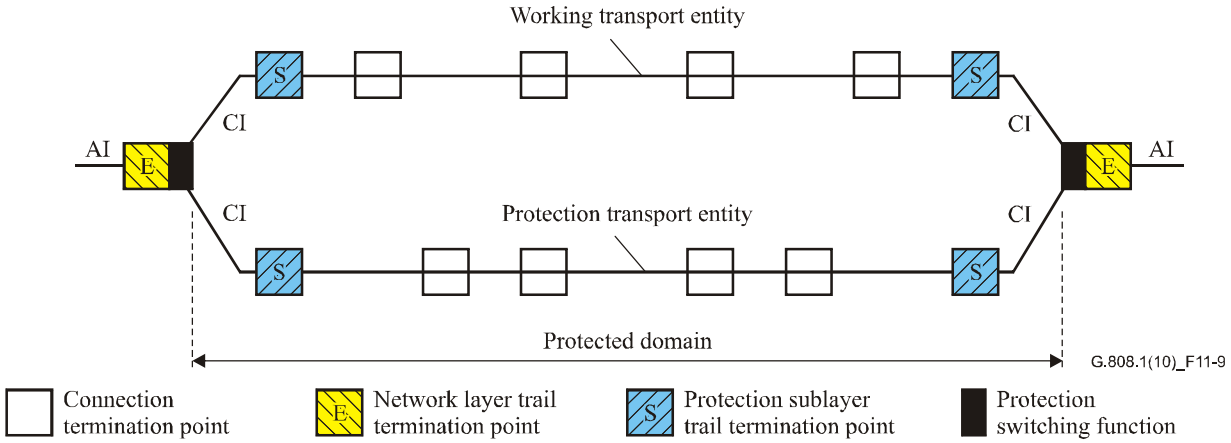


Figure 11-9 – SNC/S protection example 3

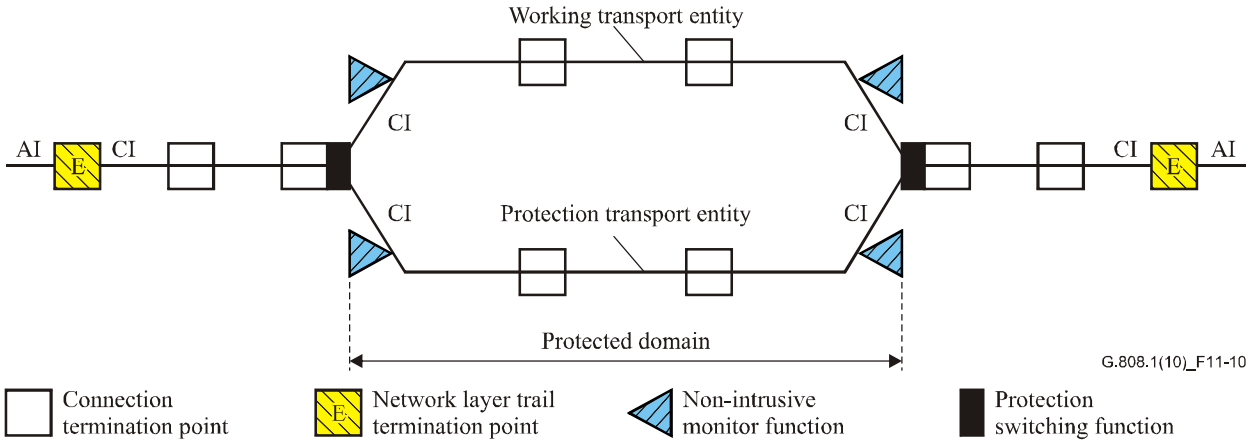


Figure 11-10 – 1+1 SNC/N protection

SNC protection supports network architectures, which make use of cascaded protected subnetworks. Such network architectures are able to restore traffic for the case of multiple faults (one fault per protected subnetwork); refer to Figure 11-11.

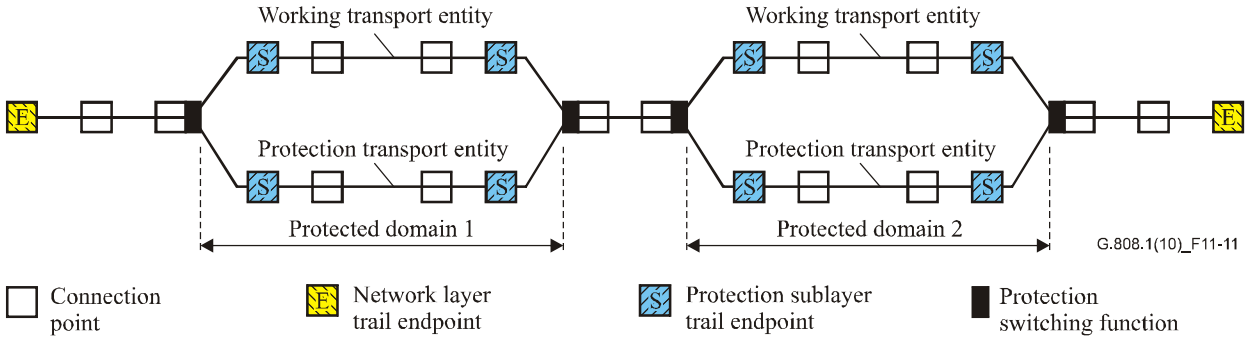


Figure 11-11 – Cascaded SNC/S protection

The fault tolerance (and reliability) of the cascaded SNC protected subnetworks is increased when the interconnection between the subnetworks is duplicated (Figure 11-12), removing the single point of failure.

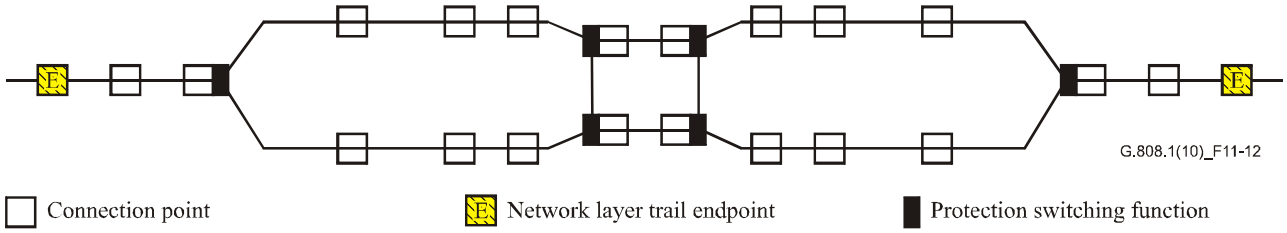


Figure 11-12 – Cascaded 1+1 SNC protection with fault tolerant subnetwork interconnects

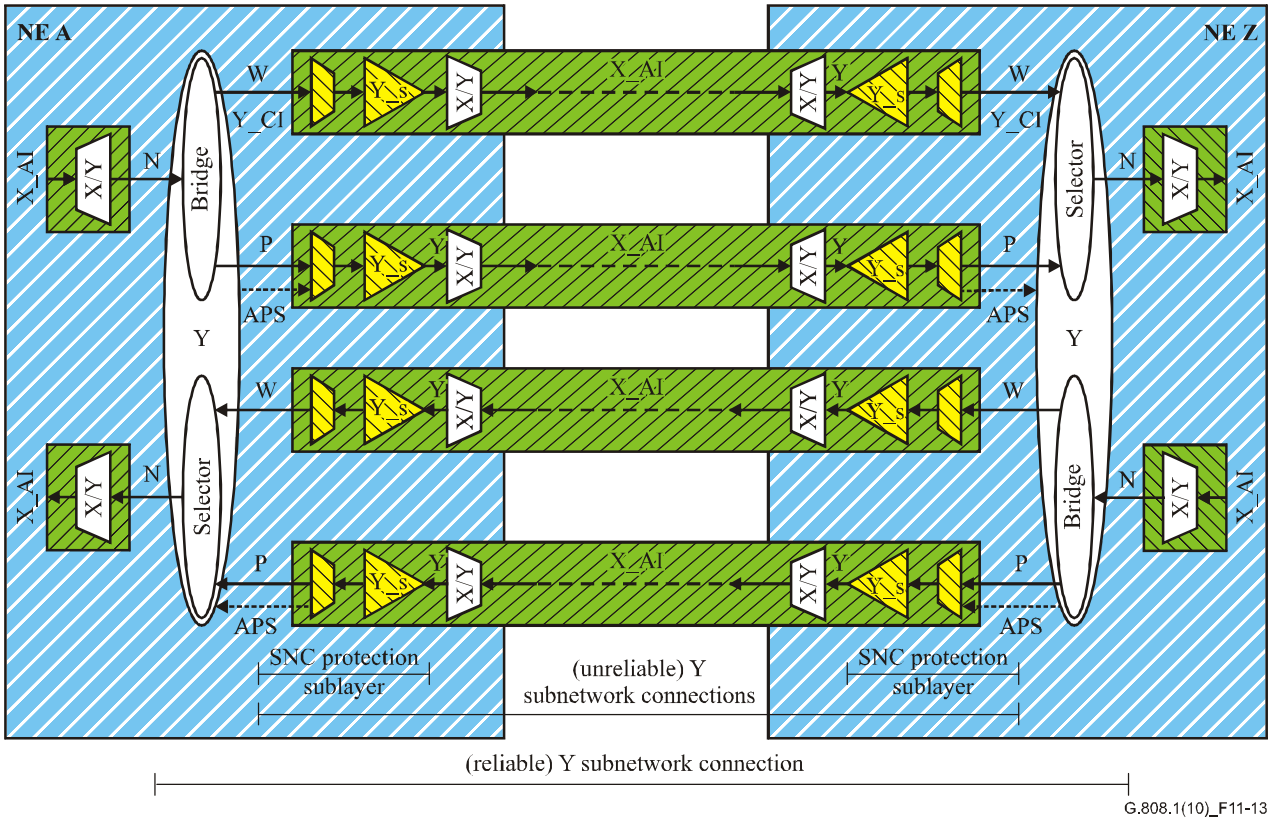
NOTE 2 – For the case of an 1:1, m:n, or $(1:1)^n$ architecture in ATM, the protection subnetwork connection(s) should contain a signal that allows accurate monitoring of its status. In normal conditions, in which the normal traffic signal is transported via the working SNC, there is no signal to be transported via protection. If the CC is inactive, such protection SNC will not transport any information under normal fault-free conditions. When a fault occurs, AIS cells are inserted. When the fault is present for a short period only (e.g., due to a "physical layer protection action"), the AIS defect detector at the protection segment endpoint will detect the AIS defect condition for 2 to 3 seconds according to the ITU-T I.610-defined AIS state definition. With the CC activated, the AIS defect condition will clear on the receipt of a CC cell, i.e., within a period of 1 second after the traffic interruption was cleared.

11.2.1 Individual SNC protection

11.2.1.1 1+1, 1:n, m:n, $(1:1)^n$ SNC/S

Figure 11-13 illustrates the case of 1+1 SNC/S protection and 1:1 SNC/S protection without extra traffic between ingress and egress of the protected domain between NEs A and Z. Two independent sublayer trails exist, which act as working and protection transport entities for the (protected) normal traffic signal. The sublayer TT functions generate/insert and monitor/extract the sublayer overhead/OAM information to determine the status of the working and protection transport entities. APS information is transported over the protection SNC, except for the case of 1+1 unidirectional switching.

The cases of 1:n, m:n and $(1:1)^n$ architectures with/without extra traffic are extensions of the 1+1/1:1 architecture, in accordance with the architecture type descriptions in clause 7.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

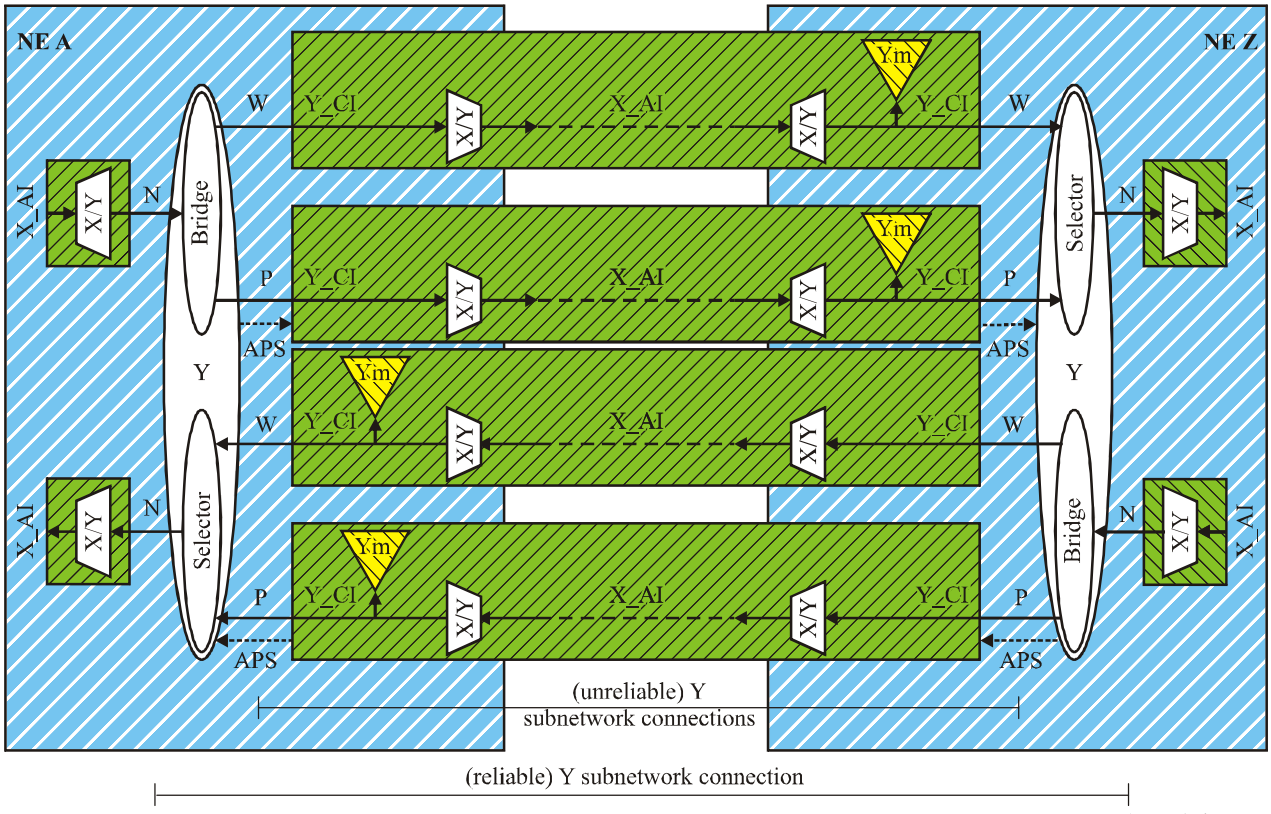
Figure 11-13 – 1+1/1:1 SNC/S protection functional model

NOTE – The sublayer trail termination functions (e.g., tandem connection/segment termination functions) are used for administrative purposes (to monitor the quality of service of the transport through the administrative network domain) and for protection purposes. For protection purposes, the location of the sublayer trail terminations is as indicated in the SNC/S figures. For administrative purposes, the optimum location is at the other side of the connection function.

11.2.1.2 1+1 SNC/N

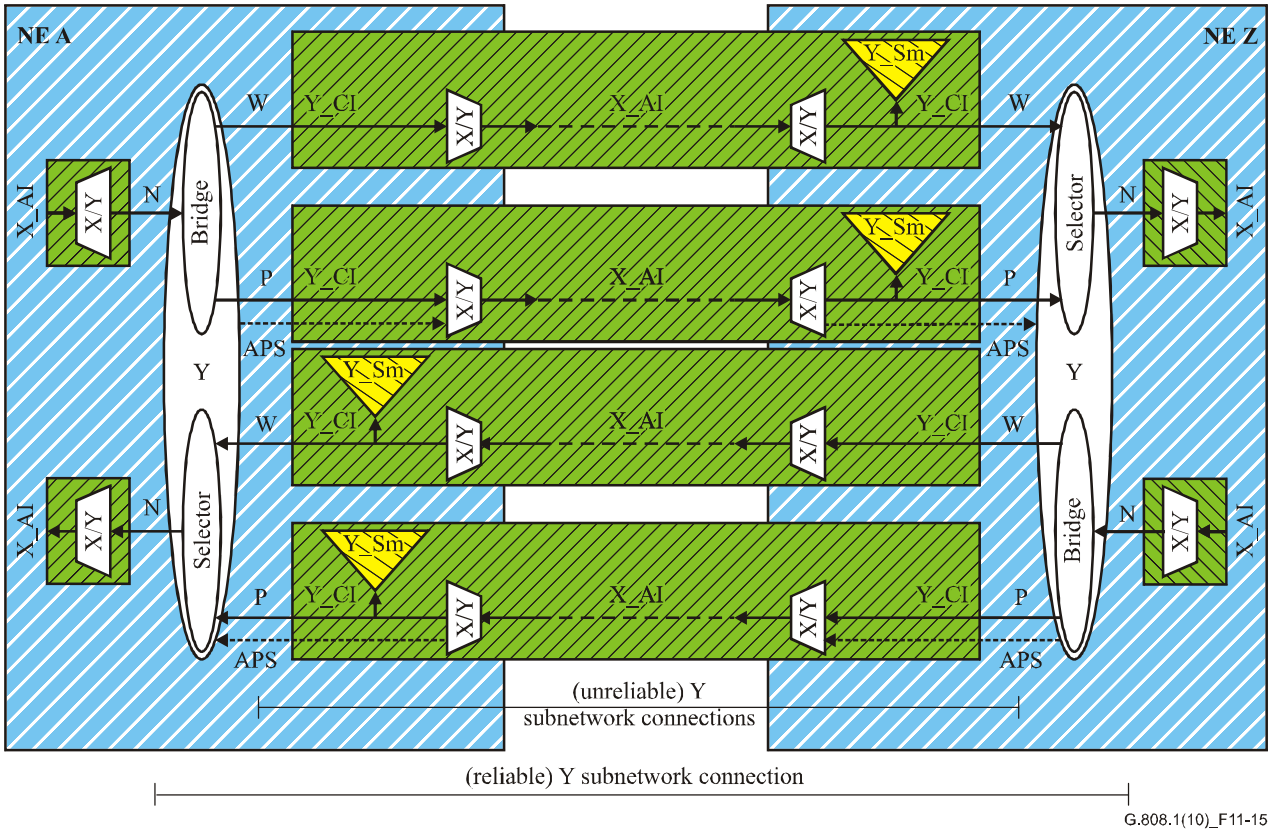
For the case of 1+1 SNC protection, a reduced complexity scheme is defined: SNC/N.

Figures 11-14 and 11-15 illustrate the case of 1+1 SNC/N protection between ingress and egress of the protected domain between NEs A and Z. Two independent subnetwork connections exist, which act as working and protection transport entities for the (protected) normal traffic signal. The non-intrusive monitoring (NIM) functions (Ym_TT_Sk, Y_Sm_TT_Sk) monitor the end-to-end (SNC/Ne) or sublayer (SNC/Ns) overhead/OAM information to determine the status of the working and protection transport entities. APS information is transported over the protection SNC, except for the case of 1+1 unidirectional switching.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-14 – 1+1 SNC/Ne protection functional model



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-15 – 1+1 SNC/Ns protection functional model

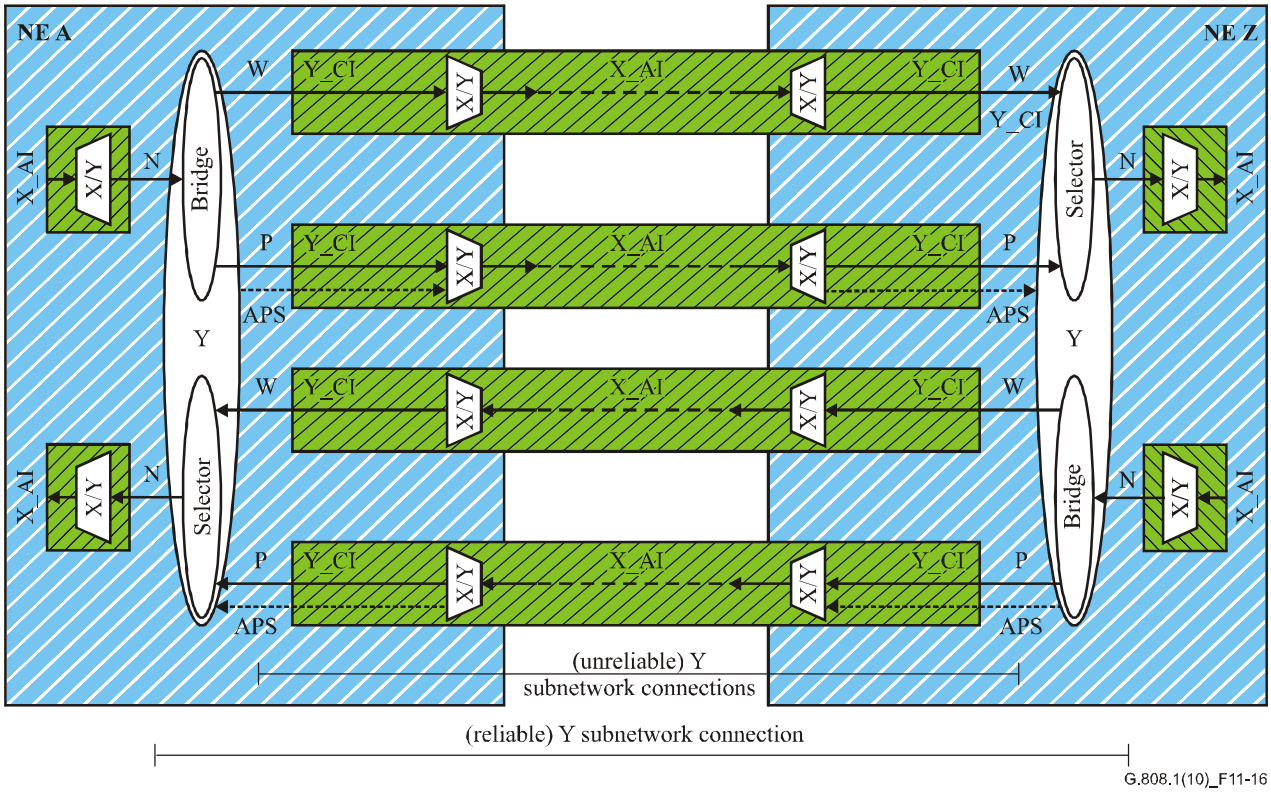
11.2.1.3 1+1/1:n SNC/I

For the case of 1+1/1:n SNC protection, another reduced complexity scheme is: SNC/I.

Figure 11-16 illustrates the case of 1+1/1:1 SNC/I protection between ingress and egress of the protected domain between NEs A and Z. Two independent subnetwork connections exist, which act as working and protection transport entities for the (protected) normal traffic signal. The X/Y adaptation functions monitor the server layer's adapted information for signal fail, to determine the status of the working and protection transport entities. APS information is transported over the protection SNC, except for the case of 1+1 unidirectional switching.

In general SNC/I protection is a protection scheme for a single link connection (spanning one server layer trail only) as the adaptation functions derive their SSF and SSD conditions from the server layer trail's TSF/TSD. The TSF status is forwarded as a client layer AIS/FDI maintenance signal and is not visible as such at downstream adaptation functions. The TSD information is not forwarded.

An exception exists for SDH VC-n SNC/I protection; SNC/I is able to protect a serial compound link connection as the AIS maintenance signal is detected in every adaptation function downstream of the insertion point.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-16 – 1+1/1:1 SNC/I protection functional model

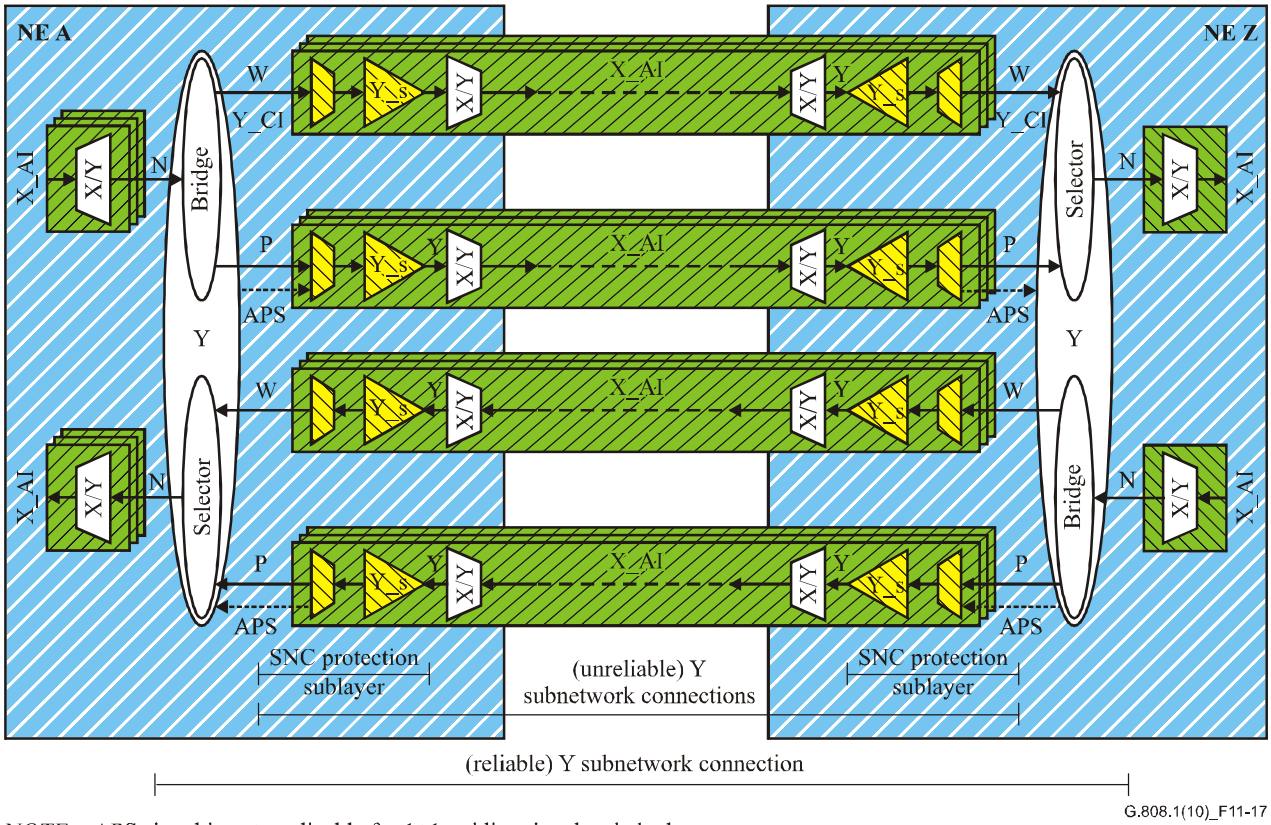
11.3 Subnetwork connection group (SNCG) protection

11.3.1 1+1/1:1 SNCG/S protection

Figure 11-17 illustrates the case of 1+1/1:1 SNCG/S protection between NEs A and Z. In this example, two times three parallel independent sublayer trail monitored subnetwork connections exist, which act as working and protection transport entity groups for the three (protected) normal traffic signals. The three parallel normal traffic signals in the group are protected jointly by the layer's connection function. The sublayer TT functions generate/insert and monitor/extract the sublayer overhead/OAM information to determine the status of the working and protection transport

entities. APS information is transported over one of the protection SNCs, except for the case of 1+1 unidirectional switching.

The cases of 1:n, m:n and $(1:1)^n$ architectures with/without extra traffic are extensions of the 1+1/1:1 architecture, in accordance with the architecture type descriptions in clause 7.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-17 – 1+1/1:1 Group SNC/S protection functional model

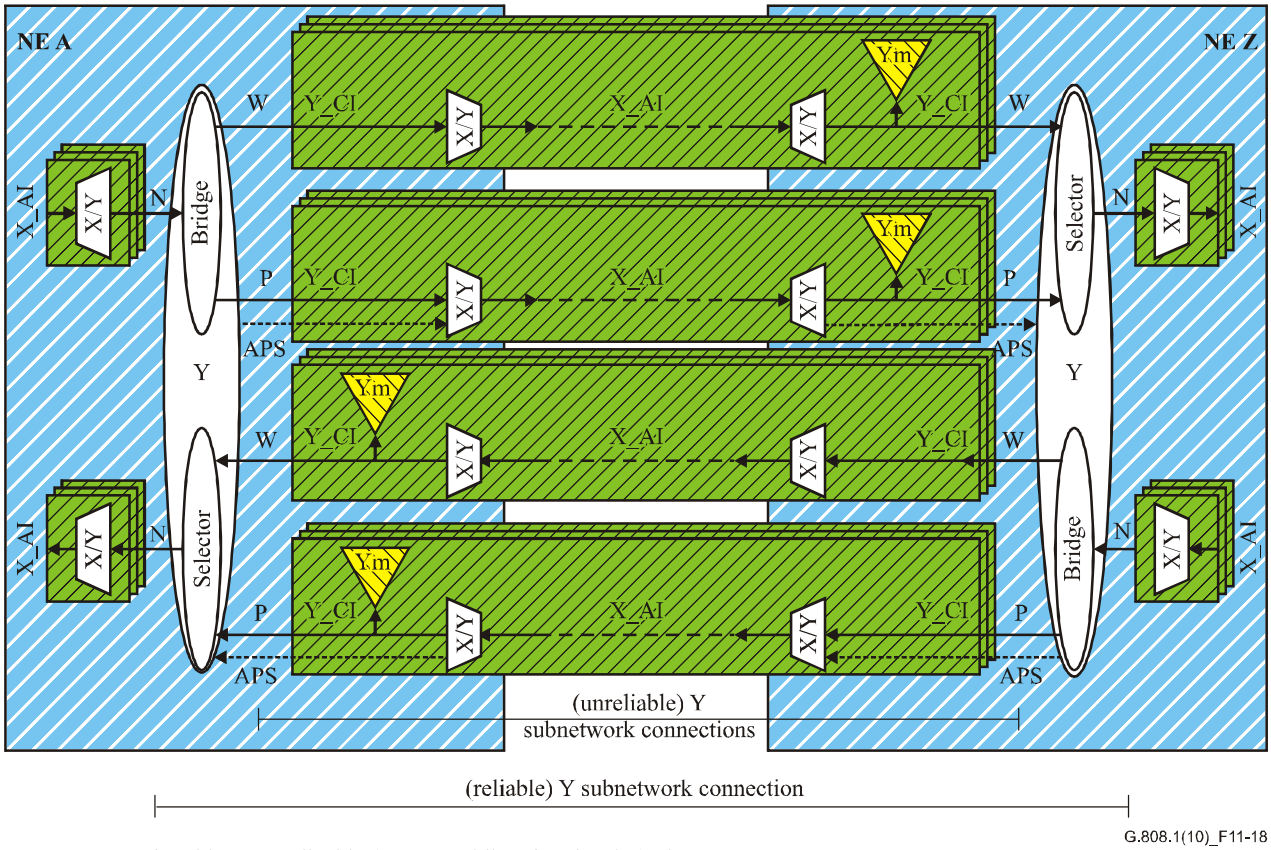
Figure 11-4 presents additional detail of this protection connection function's processes. Specific for group protection is the SFG/SDG logic process. This process "merges" the three individual trail signal fail (TSF) signals into a single SF group (SFG) and the individual trail signal degrade (TSD) signals into a single SD group (SDG).

The SNC/S SFG/SDG logic may operate in different modes:

- W-SFG = W1-TSF or W2-TSF or W3-TSF; P-SFG = P1-TSF or P2-TSF or P3-TSF;
- W-SFG = W1-TSF; P-SFG = P1-TSF;
- W-SFG = X% of the Wi-TSF signals are active; P-SFG = X% of the Pi-TSF signals are active;
- idem for SDG.

11.3.2 1+1 SNCG/N protection

Figure 11-18 illustrates the case of 1+1 SNCG/N protection between NEs A and Z. In this example, two times three parallel independent subnetwork connections exist, which act as working and protection transport entity groups for the three (protected) normal traffic signals. The three parallel normal traffic signals in the group are protected jointly by the layer's connection function. The NIM functions monitor the end-to-end (SNC/Ne) or sublayer (SNC/Ns) overhead/OAM information to determine the status of the working and protection transport entities. APS information is transported over one of the protection SNCs, except for the case of 1+1 unidirectional switching.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-18 – 1+1 group SNC/Ne protection functional model

Figure 11-4 presents additional detail of this protection connection function's processes. Specific for group 1+1 SNC/N protection is the SFG/SDG logic process. This process "merges" the three individual trail signal fail (TSF) signals into a single SF group (SFG) and the individual trail signal degrade (TSD) signals into a single SD group (SDG).

The SNC/N SFG/SDG logic may operate in different modes:

- W-SFG = (W1-TSF and not P1-TSF) or (W2-TSF and not P2-TSF) or (W3-TSF and not P3-TSF);

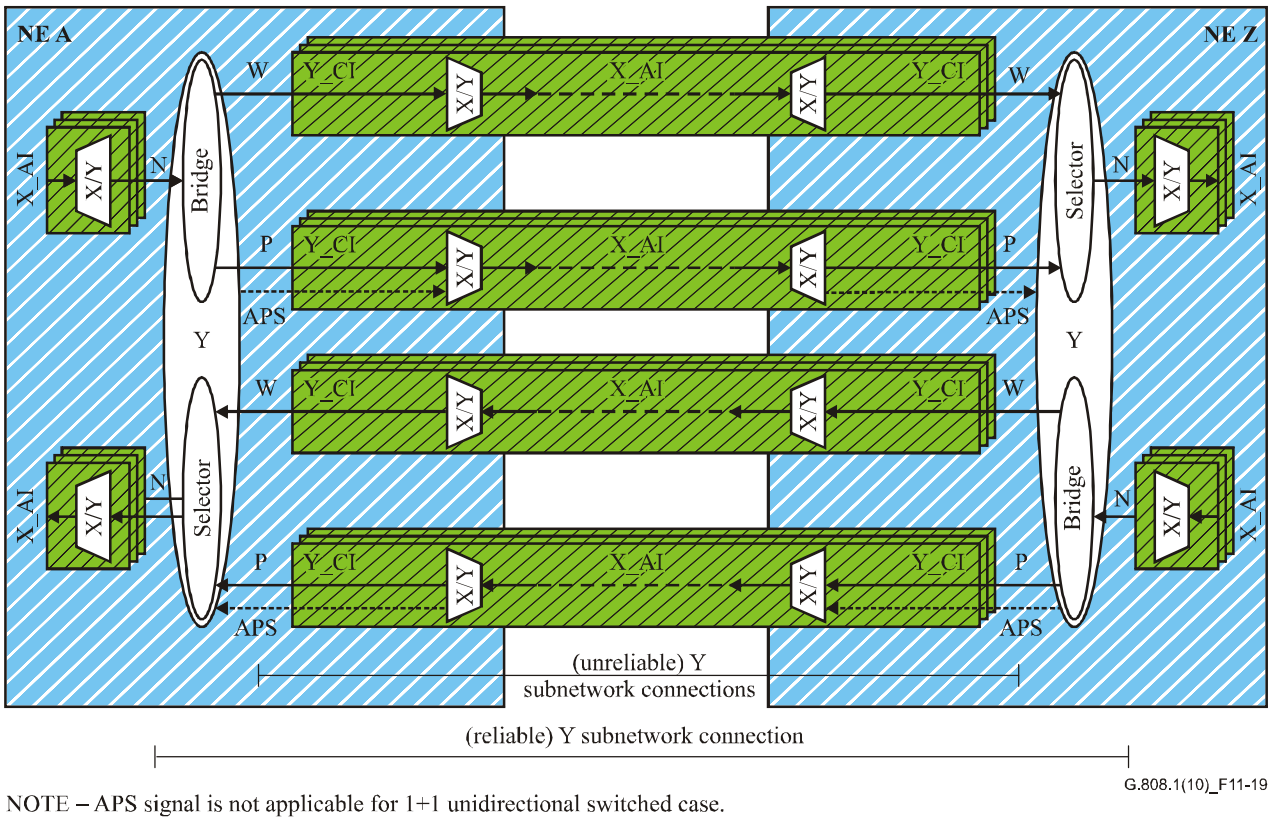
  P-SFG = (P1-TSF and not W1-TSF) or (P2-TSF and not W2-TSF) or (P3-TSF and not W3-TSF);
- W-SFG = (W1-TSF and not P1-TSF); P-SFG = (P1-TSF and not W1-TSF);
- W-SFG = X% of the (Wi-TSF and not Pi-TSF) signals are active; P-SFG = X% of the (Pi-TSF and not Wi-TSF) signals are active;
- idem for SDG.

For virtual concatenated SDH VC-n signals (VC-n-Xv), the group SF and SD conditions should be declared as soon as one of the X signals in the group is failed or degraded.

- W-SFG = W1-TSF or W2-TSF or W3-TSF; P-SFG = P1-TSF or P2-TSF or P3-TSF;
- idem for SDG.

11.3.3 1+1 SNCG/I protection

Figure 11-19 illustrates the case of 1+1 SNCG/I protection between NEs A and Z. In this example, two times three parallel independent subnetwork connections exist, which act as working and protection transport entity groups for the three (protected) normal traffic signals. The three parallel normal traffic signals in the group are protected jointly by the layer's connection function. The X/Y adaptation functions monitor the server layer's adapted information for signal fail, to determine the status of the working and protection transport entities. APS information is transported over one of the protection SNCs, except for the case of 1+1 unidirectional switching.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-19 – 1+1 Group SNC/I protection functional model

Figure 11-4 presents additional detail of this protection connection function's processes. Specific for 1+1 SNCG/I protection is the SFG logic process. This process "merges" the three individual server signal fail (SSF) signals into a single SF group (SFG).

The SNC/I SFG logic may operate in different modes:

- W-SFG = (W1-SSF and not P1-SSF) or (W2-SSF and not P2-SSF) or (W3-SSF and not P3-SSF);

  P-SFG = (P1-SSF and not W1-SSF) or (P2-SSF and not W2-SSF) or (P3-SSF and not W3-SSF);
- W-SFG = (W1-SSF and not P1-SSF); P-SFG = (P1-SSF and not W1-SSF);
- W-SFG = X% of the (Wi-SSF and not Pi-SSF) signals are active; P-SFG = X% of the (Pi-SSF and not Wi-SSF) signals are active.

For virtual concatenated SDH VC-n signals (VC-n-Xv), the group SF and SD conditions should be declared as soon as one of the X signals in the group is failed or degraded.

- W-SFG = W1-SSF or W2-SSF or W3-SSF; P-SFG = P1-SSF or P2-SSF or P3-SSF;
- idem for SDG.

11.3.4 1+1/1:1 group SNC/T protection (SNCG/T)

As a result of the large number of tributary slots in some transmission technologies (e.g., ATM), extra tributary slots in the working and protection server layer signals can be allocated to transport test signals via test transport entities (Figures 11-20 and 11-22). These test signals (one per working, one per protection) can be used instead of the SFG, SDG information as described above. The APS signal is transported via the test protection transport entity.

The SFG/SDG logic operates now as follows:

- W-SFG = Wt-TSF;
  P-SFG = Pt-TSF;
- W-SDG = Wt-TSD;
  P-SDG = Pt-TSD.

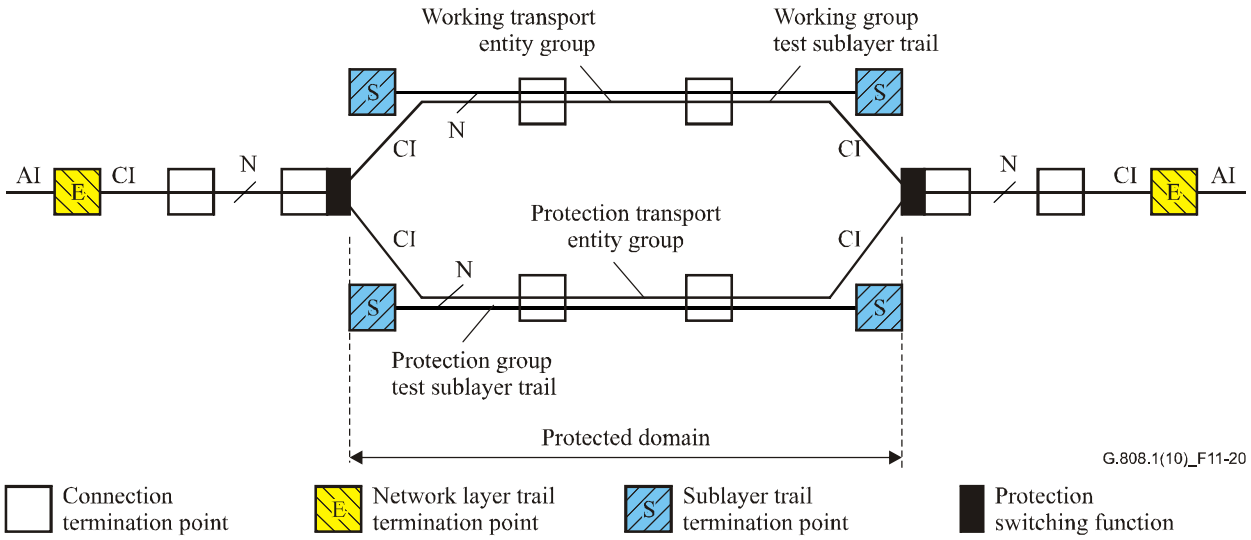


Figure 11-20 – 1:1 or 1+1 SNC/Ts group protection using sublayer trail terminations

SNCG/T protection can also use the end-to-end overhead/OAM to create an end-to-end layer network trail as a test trail (Figure 11-21). Equipment designs typically locate those layer termination functions at port units at the "other side" of the connection function; i.e., not readily available for group protection test trail purposes.

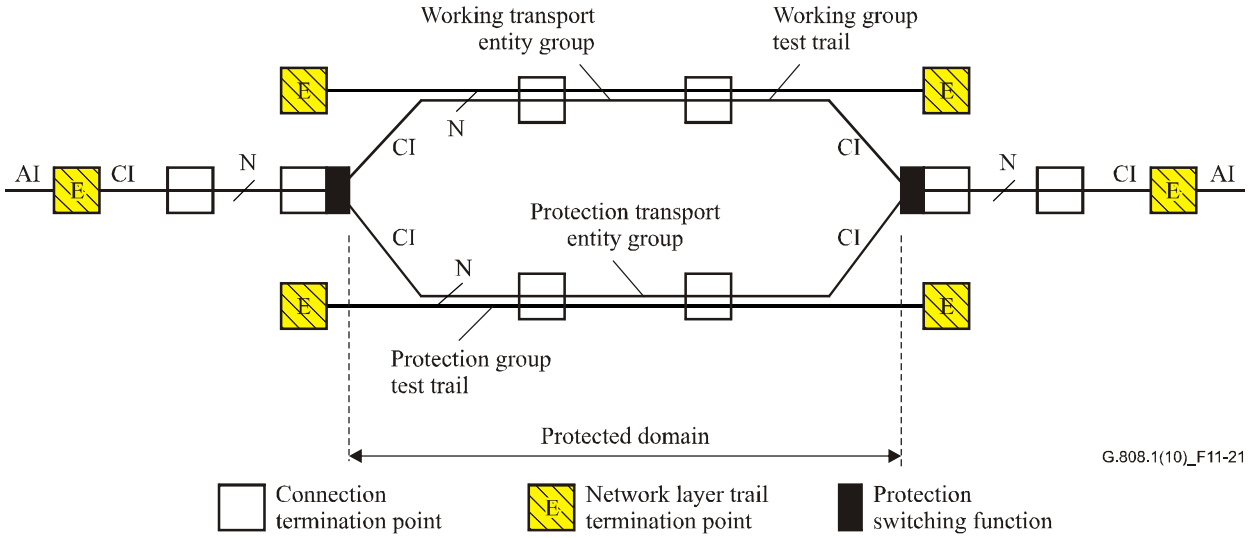
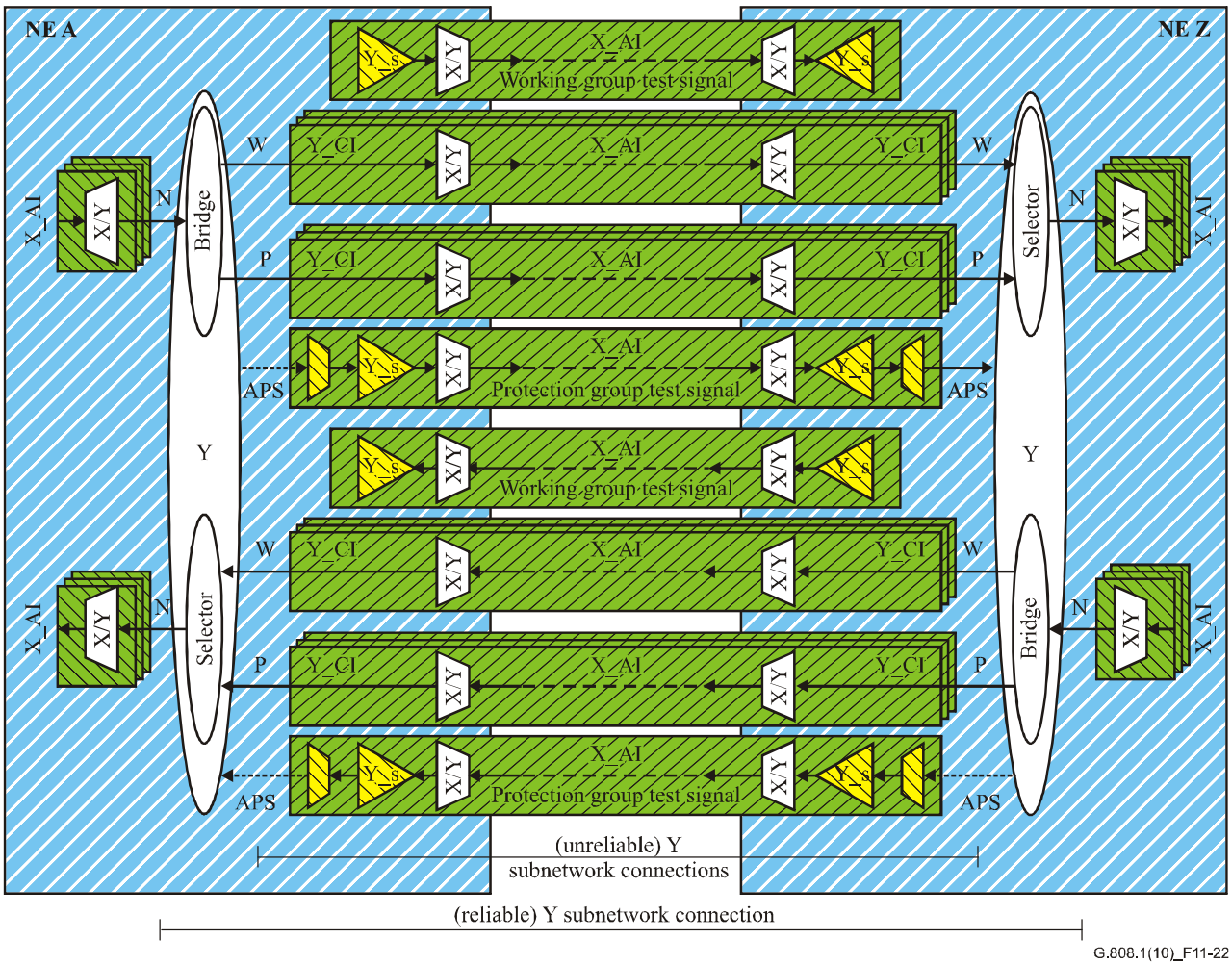


Figure 11-21 – 1:1 or 1+1 SNC/Te group protection using layer network trail terminations

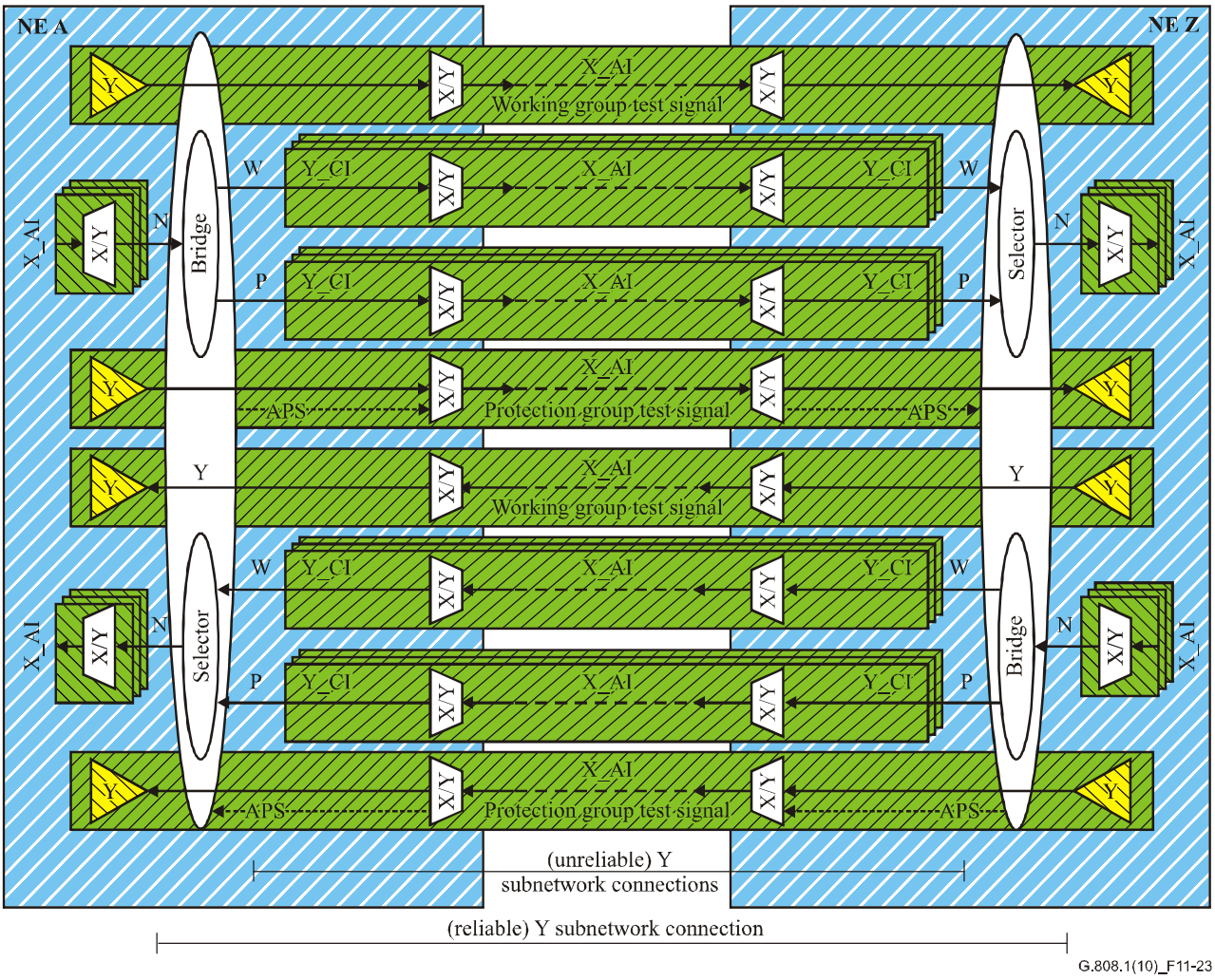


NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-22 – 1+1/1:1 Group SNC/Ts protection functional model using sublayer trail terminations

NOTE – For the case of ATM, the test (sublayer) trail should contain a test signal that has continuity check (CC) activated. If the CC is inactive, such a test (sublayer) trail would not transport any information under normal fault-free conditions. When a fault occurs, AIS cells are inserted. When the fault is present for a short

period only (e.g., due to a "physical layer protection action"), the AIS defect detector at the test (sublayer) trail endpoint will detect the AIS defect condition for 2 to 3 seconds according to the ITU-T I.610-defined AIS state definition. With the CC activated, the AIS defect condition will clear on the receipt of a CC cell, i.e., within a period of 1 second after the traffic interruption was cleared.



NOTE – APS signal is not applicable for 1+1 unidirectional switched case.

Figure 11-23 – 1+1/1:1 Group SNC/Te protection functional model using layer network trail terminations

11.3.5 1:1 compound link based group SNC/I protection (CL_SNCG/I)

Figure 11-24 illustrates the case of 1:1 compound link based SNC group protection with inherent monitoring (CL-SNCG/I) protection between NEs A and Z.

There are two links (0, 1) in layer network Y supported by two server layer trails (0, 1) in layer network X. These two links form a compound link with two component links.

There is a set of normal signals in layer network Y, which are divided into two subsets (Na, Nb) and a set of unprotected signals (U). The set of Na signals has its working link connections on Link 1 (Wa), and its protection link connections on Link 0 (Pa). The set of Nb signals has its working link connections on link 0 (Wb), and its protection link connections on Link 1 (Pb). The unprotected (U) signals are carried over links 0 and 1 (NUTa, NUTb). The network operator allocates the normal signals to either the Na, or Nb subset.

In packet transport networks, distribution of normal signals over both Link 0 and Link 1 may improve the performance observed by those normal signals (e.g., less frame/packet drop, lower latency) during fault free periods.

NOTE 1 – The Na subset may contain all normal signals. The Nb subset will then be empty. This configuration is very similar to the case in which the transport of the group of normal signals in layer network Y is protected by 1:1 trail protection in layer network X. Many implementations of trail protection protect the group of client layer signals and emulate the trail protection behaviour as described in Appendix III. Such emulation of trail protection adds complexity that is not present in this CL-SNCG/I protection.

NOTE 2 – In this example the server layer trails supporting the layer network Y component links are considered to belong to the same layer network X. This is not a requirement. These server layer trails may belong to different layer networks; e.g., X and W.

The layer X termination functions monitor the layer X characteristic information for signal fail and signal degrade, to determine the status of the layer Y component links and carried Wa, Wb, Pa and Pb link connections. APS information is transported over component link 0.

When layer X trail 0 detects a trail signal fail (TSF) or trail signal degrade (TSD) condition, then the CL-SNCG/I process in the Y connection function will switch the set of Nb signals to the set of Pb link connections. Vice versa, when layer X trail 1 detects a trail signal fail (TSF) or trail signal degrade (TSD) condition, then the CL-SNCG/I process in the Y connection function will switch the set of Na signals to the set of Pa link connections.

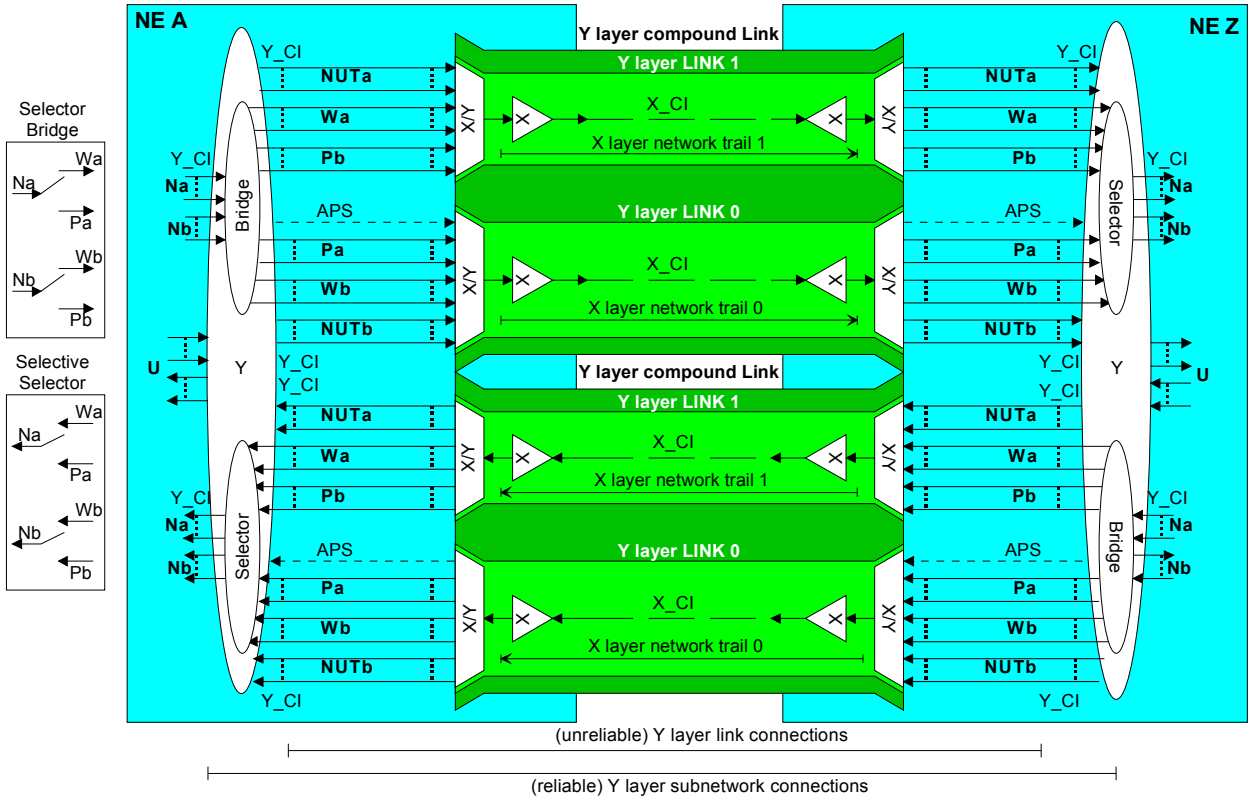


Figure 11-24 – 1:1 Compound link subnetwork connection group protection with inherent monitoring (CL-SNCG/I) functional model

11.3.6 Adaptive CL-SNCG/I

Figure 11-25 illustrates the case of compound link based adaptive compound link SNC group protection with inherent monitoring (ACL-SNCG/I) protection between NEs A and Z.

There are m+1 links (0, 1, .., m) in layer network Y supported by m+1 server layer trails (0, 1, .., m) in layer network X. These m+1 links form a compound link including m+1 component links.

There is a set of normal signals Ni (i=1, 2, .., n) in layer network Y that are transported via the compound link. The distribution of the set of normal signals over the m+1 component links is controlled by the ACL-SNCG/I connection manager process on the basis of the status of the egress component links, bandwidth (i.e., CIR/EIR) of the component links, bandwidth (CIR/EIR) of the normal signals, priority of the normal signals and external commands.

Each of the component links (Link j (j=0, .., m)) supports a link connection for each of the normal signals Ni (i=1, 2, .., n). This link connection is identified as LjCi (see Figure 11-25). The distributor connects each Ni signal with exactly one of the LjCi link connections in the component link.

The distribution decision is made at the head end and is not communicated to the tail end. The collector process at the tail end merges the traffic from all L0Ci to LmCi and applies this to output Ni (i=1, 2, .., n).

For the case in which Link j experiences a signal fail or signal degrade condition, AIS is inserted towards each layer Y connection point. As long as at least one component link is not experiencing a signal fail/degrade condition, traffic for Ni will be carried over a non-failed component link and AIS should not be present in the signal. The collector process will block such AIS or other unexpected frames from a failed component link under control of the link's trail signal fail (TSFj) or signal degrade (TSDj) indication. When all component links have failed, AIS generated by the last component link endpoint will be passed through the collector process towards the Ni output ports.

For the case in which one or more component links have failed, the remaining available bandwidth of the compound link may be less than the bandwidth of the set of normal signals. The distribution process will now block forwarding a subset of the normal signals, i.e., those with lowest priority, so as not to exceed the available capacity on the compound link. The distribution process will insert AIS in those blocked normal signals and transport them over their link connections on the available component links to suppress downstream continuity alarms.

The layer X termination functions monitor the layer X characteristic information for signal fail and signal degrade, to determine the status of the layer Y component links.

The signal fail/signal degrade status of each component link is known at the tail end, while it is used at the head end by the distribution process. The tail end uses the ACL-APS OAM to send the status to the head end. The head end sends this ACL-APS OAM in all layer X trails, the tail end reads this ACL-APS OAM from one of the operational (non-failed) layer X trails.

The operator may temporarily disable one or more component links in the compound link; e.g., for maintenance purposes. The operator may increase the set of component links in the compound link. The operator may permanently decrease the set of component links in the compound link.

NOTE – In this example the server layer trails supporting the layer network Y component links are considered to belong to the same layer network X. This is not a requirement. These server layer trails may belong to different layer networks; e.g., V, W and X.

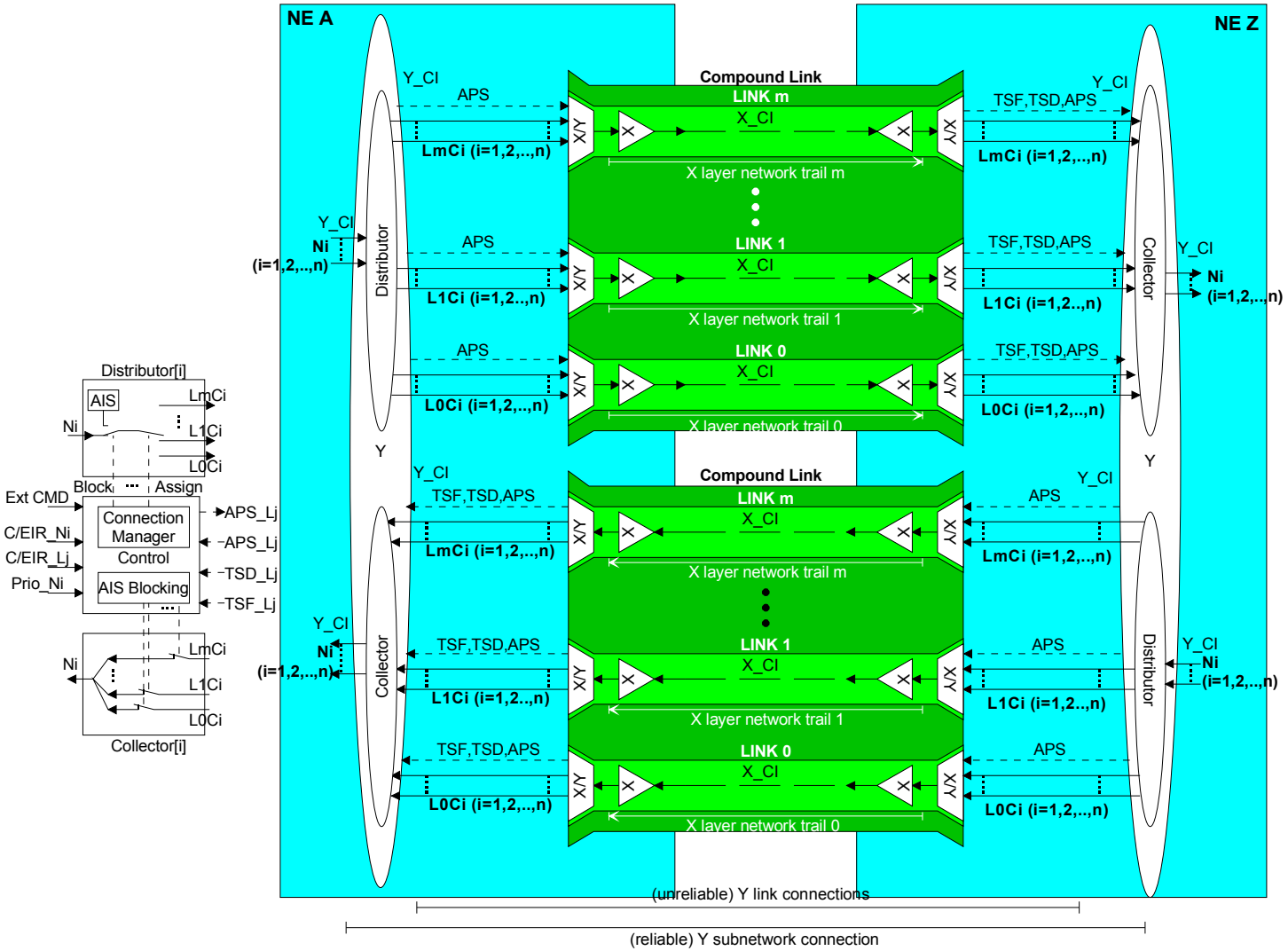


Figure 11-25 – Adaptive compound link SNC group protection with inherent monitoring (A-SNCG/I) functional model

12 Survivability of inverse multiplexed link connections (SIM)

Transport methodologies are available that support inverse multiplexing. Inverse multiplexing can be used to transport a client signal by distributing the payload and transfer the fragments over a number of individual trails through the network. The individual fragment trails can be considered being members of an inverse multiplexed group (IMG).

Inverse multiplexing schemes that provide accommodation to network faults (e.g., virtual concatenation with LCAS) can be used to offer survivability to a P-X signal trail across an entire operator's network or across multiple operator networks. It is an end-to-end survivability architecture that can be used in different network topologies, e.g., meshed networks, ring networks, etc. As it is a dedicated survivability mechanism, there is no fundamental limitation on the number of NEs within the trails.

SIM will operate in all combinations of protection architectures, switching and operation.

SIM generically protects against faults in the server layer, and connectivity faults and performance degradations in the client layer.

SIM protects the adapted information (AI) (i.e., the total payload of the network layer's individual characteristic information (CI)). See Figure 12-1.

The accommodation consists of removing the fractional payload transported by any member of the IMG that experiences a transport entity fault condition. The result is a reduced AI payload size.

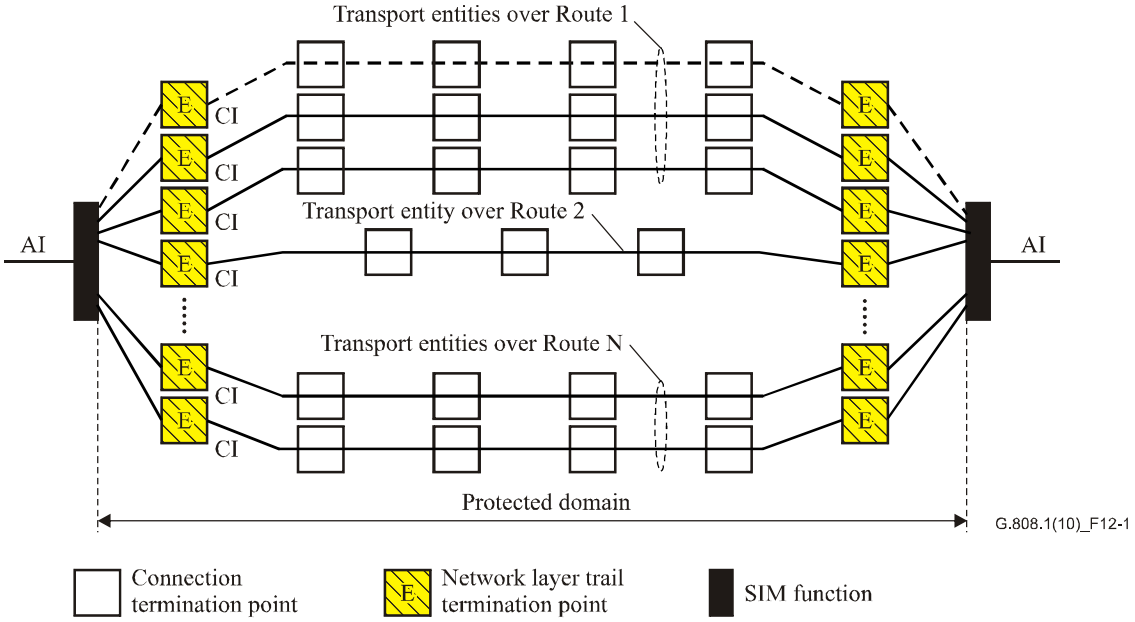


Figure 12-1 – Generic concept of survivability of inverse multiplexed trail

The AI is transported using a IMG with X members, distributed over N routes, where:

- N = Number of routes ($1 \leq N \leq X$) each containing one or more network connections within the IMG.
- X = Number of members in the IMG required to transport the client's bandwidth AI + extra/protection capacity Z ($X \geq 1$, $Z \geq 0$).
- B = Total bandwidth of the X + Z members in the group. $B = \sum_{i}^{X+Z} B_i$.

- B_{ACT} = Actual transported payload ($0 \leq B_{ACT} \leq B$); due to failure of one or more of the member trails, the bandwidth of one or more members in the IMG will not be used to transport the AI.

SIM is independent of protection at the server layers.

12.1 SIM functional model

Figure 12-2 illustrates the case of SIM for transport between NEs A and Z. Multiple independent trails (in layer network Y) are used as transport entities for the normal (payload) traffic signal Z_CI. The X trail termination functions Y_TT generate/insert and monitor/extract the end-to-end overhead information to determine the status of the individual transport entities. The inverse multiplexing adaptation functions Y-Xv/Y-X_A generate/insert and monitor/extract the end-to-end inverse multiplexing overhead information to determine and align the status of the X members in the IMG.

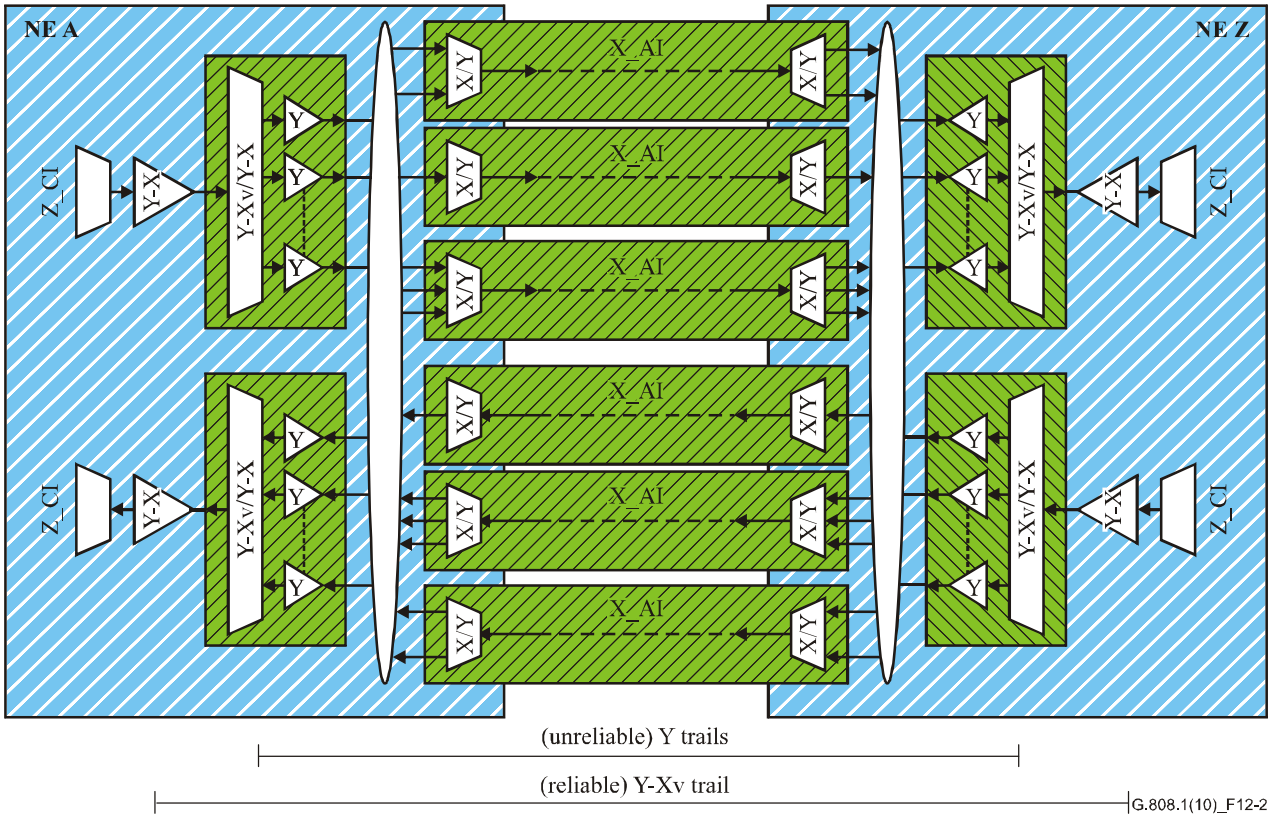


Figure 12-2 – SIM functional model

The inverse multiplexing adaptation functions Y-Xv/Y-X_A distribute/collect the transported payload using the X_{ACT} available layer network Y trails out of the X provisioned layer network Y trails.

13 Protection switching performance

The protection switching temporal model derived from [ITU-T M.495] is illustrated in Figure 13-1. Model parameters are defined as follows.

13.1 detection time, T_1: Time interval between the occurrence of a network impairment and the detection of a signal fail (SF) or signal degrade (SD) triggered by that network impairment.

13.2 hold-off time, T_2: Time interval after the detection of a SF or SD and its confirmation as a condition requiring the protection switching procedure.

NOTE – [ITU-T M.495] identifies time T_2 as the "waiting time".

13.3 protection switching operations time, T_3: Time interval between the confirmation of a SF or SD and completion of the processing and transmission of the control signals required to effect protection switching.

13.4 protection switching transfer time, T_4: Time interval between completion of the processing and transmission of the control signals required to effect protection switching and the completion of protection switching operations.

13.5 recovery time, T_5: Time interval between the completion of protection switching operations and the full restoration of protected traffic.

NOTE – This may include the verification of switching operations, resynchronization of digital transmission, etc.

13.6 confirmation time, T_c: The time from the occurrence of the network impairment to the instant when the triggered SF or SD is confirmed as requiring protection switching operations: $T_c = T_1 + T_2$.

13.7 transfer time, T_t: The time interval after the confirmation that a SF or SD requires protection switching operations to the completion of the protection switching operations: $T_t = T_3 + T_4$.

13.8 protected traffic restoration time, T_r: The time from the occurrence of the network impairment to the restoration of protected traffic:

$$T_r = T_1 + T_2 + T_3 + T_4 + T_5 = T_c + T_t + T_5.$$

NOTE – An apparent network impairment might be detected by an equipment and not confirmed after confirmation operations. In this case, only times T_1 and T_2 are relevant.

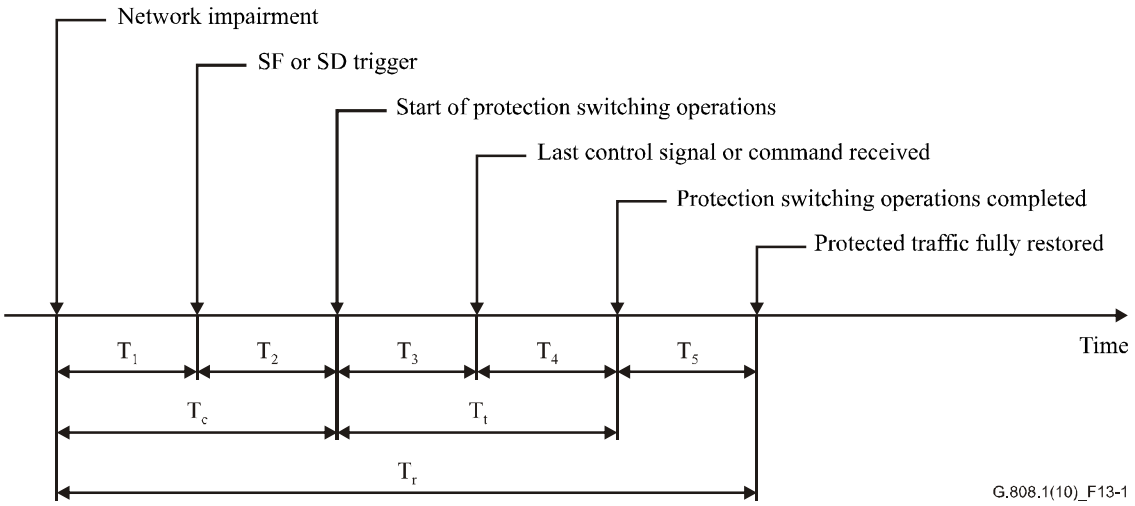


Figure 13-1 – Protection switching temporal model

14 Hold-off timer

Hold-off timers are intended to operate when a signal is protected by means of nested protection. They allow an inner protection group to restore the traffic before the outer protection group tries to do so, in order to limit the number of switch actions.

Hold-off timers are also applied in 1+1 SNC/N and SNC/I protection types to prevent too early switching due to the differential delay difference between the short and long route.

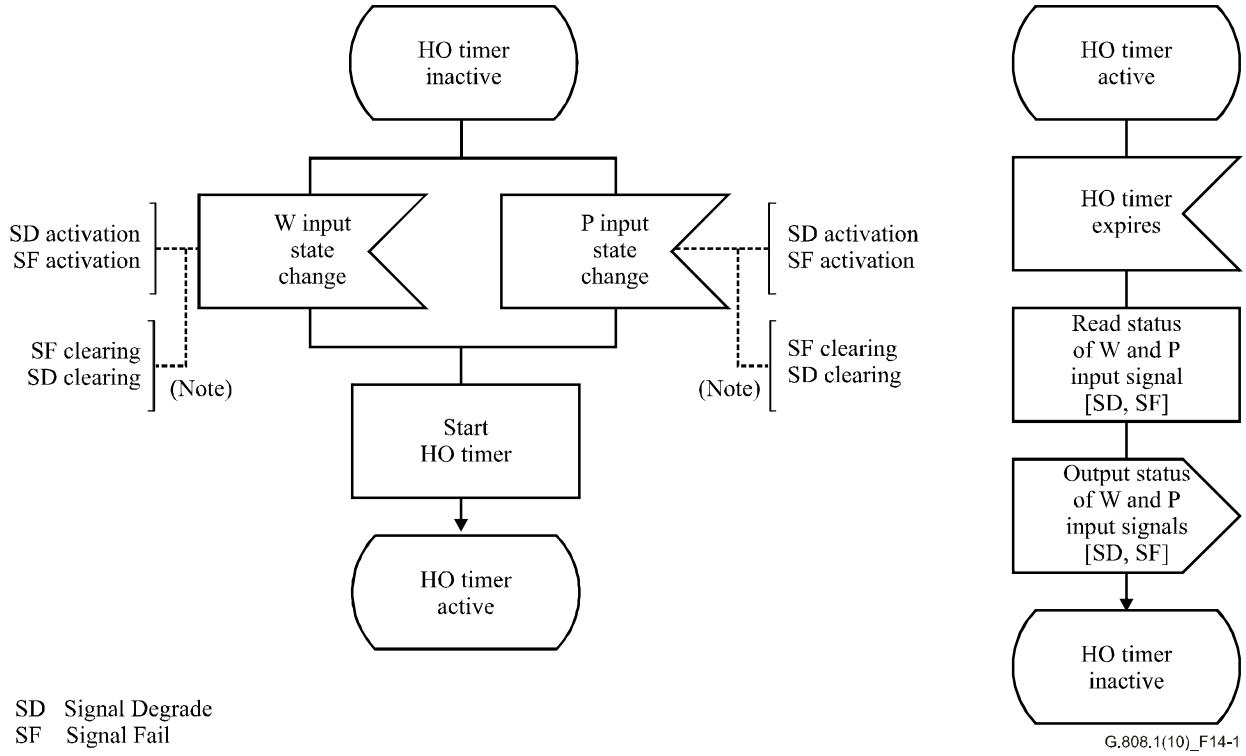
Each protection selector may have one hold-off timer.

A hold-off timer is started when one or more of the SF or SD conditions in the protection group become active, and runs for a non-resettable period which is provisionable from 0 to 10 seconds in steps of X ms. X is 100 ms (SDH, OTN) or 500 ms (ATM).

During this period, the modified SF/SD statuses are not passed to the protection switching process.

When the timer expires, the SF/SD status of all signals is read and passed through to the protection switching process. The protection switching process will react on the new SF/SD status at this point.

NOTE – An SF/SD condition does not have to be present for the entire duration of the hold-off period, only the state at the expiry of the hold-off timer is relevant. Further, the SF/SD condition that triggers the hold-off timer does not need to be of the same one as the one at the expiry of the hold-off period.



NOTE – The use of SF/SD clearing events as triggers for the start of the hold-off timer is not mandatory, but is recommended in order to prevent unnecessary protection switches that can otherwise occur under certain circumstances.

Figure 14-1 – Hold-off timer operation

15 Wait-to-restore timer

In revertive mode of operation, to prevent frequent operation of the protection switch due to an intermittent defect (e.g., BER fluctuating around the SD threshold), a failed working transport entity must become fault-free (e.g., BER less than a restoration threshold). After the failed working transport entity meets this criterion, a fixed period of time shall elapse before a normal traffic signal uses it again. This period, called wait-to-restore (WTR) period, is of the order of 5-12 minutes and should be capable of being set. A SF or SD condition will override the WTR.

In revertive mode of operation, when the protection is no longer requested, i.e., the failed working transport entity is no longer in SD or SF condition (and assuming no other requesting transport entities), a local wait-to-restore state will be activated. Since this state becomes the highest in priority, it is indicated on the APS signal (if applicable), and maintains the normal traffic signal from the previously failed working transport entity on the protection transport entity. This state shall normally time out and become a no request null signal (or no request extra traffic signal, if

applicable). The wait-to-restore timer deactivates earlier when any request of higher priority pre-empts this state.

16 Automatic protection switching (APS) signal

An APS signal is used to synchronize the actions at the A and Z ends of the protected domain. Communicated are:

– request/state type;
– requested signal;
– bridged signal;
– protection configuration.

The request/state type information identifies the highest priority fault condition, external command or protection process state.

The requested and bridged signal information when transported in an n-bit field identify:

0	null signal;
1.. $2^n - 2$	normal traffic signal 1 to $2^n - 2$;
$2^n - 1$	extra traffic signal.

The protection configuration information identifies:

– use of an APS channel;
– protection architecture (1+1, 1:n);
– switching type (uni-, bidirectional);
– operation type (non-revertive, revertive).

The APS signal is transported via the APS channel. In principle, it is possible to allocate an APS channel on every transport entity. Allocation of this channel on a working transport entity, however, would not provide sufficient survivability; i.e., when the working transport entity would fail, communication between the two endpoints will fail as well, and protection is not possible. Therefore the APS channel is allocated to one or more protection transport entities.

17 Non-pre-emptible unprotected traffic (NUT)

Non-pre-emptible unprotected traffic is one of three traffic classes in (1:1) and $(1:1)^n$ protection schemes, the others being protected traffic and extra traffic. NUT has no protection associated with it, but cannot be dropped from the network to allow protection of other traffic.

Extra traffic or protection channel access allows the use of the protection entities for additional traffic during normal operation in (1:1) or $(1:1)^n$ architectures. When a protection switch occurs, this traffic is dropped. Extra traffic provides a cheaper service than either protected traffic or non-pre-emptible unprotected traffic. It is unrelated to the protected traffic, coming from a different customer and may be used, for example, to provide additional capacity in response to a major event.

18 Extra traffic (protection) transport entity overhead/OAM

For the case of $(1:1)^n$ SNC/S protection with extra traffic, the extra traffic (protection) transport entity does not require the addition of a sublayer trail termination. The extra traffic (protection) transport entity has a dedicated tributary slot within the aggregate signal, separate from the tributary slots of the protection transport entities used to carry a normal traffic signal.

The status of the extra traffic (protection) transport entity does not impact the protection switching operation and, as such, it is not required to monitor this transport entity.

19 External commands

The autonomous behaviour of the protection switch process on the fault conditions of its transport entities can be modified by means of external (switch) commands. That is, an external (switch) command issues an appropriate external request on to the protection process.

NOTE – Only one external (switch) command can be issued per protection group. External commands which are pre-empted or denied by other higher priority conditions, states or requests, are discarded.

External commands are defined to allow the following types of actions (refer to clause 3.1.9 for exact definitions of the external commands):

1) Configuration modifications and maintenance to be performed on the protection group or its transport entities:
   - **Lockout of protection** temporarily disables access to the protection transport entity for all signals;
   - **Forced Switch for signal #i** temporarily forces signal #i to be routed over the protection transport entity;
   - **Manual Switch for signal #i** temporarily routes signal #i over the protection transport entity, unless a fault condition (SF, SD) requires another signal to be routed over this transport entity.
2) Lockout signals from the protection process:
   - **Lockout of signal #i** temporarily disables access to the protection transport entity for the specific signal;
   - **Clear Lockout of signal #i**.
3) Freeze the protection process:
   - **Freeze** temporarily prevents any switch action to be taken and, as such, freezes the current state. Until the freeze is cleared, additional near-end external commands are rejected and fault condition changes and received APS messages are ignored.
   - **Clear Freeze**: When the freeze command is cleared, the state of the protection group is recomputed based on the fault conditions and received APS message.
4) Testing the protection process and APS channel between the two endpoints:
   - **Exercise** is a command to test if the APS communication is operating correctly. It is lower priority than any "real" switch request.

     It is only valid in bidirectional switching, since this is the only place where one can get a meaningful test by looking for a response. The Exercise command shall be issued with the same requested and bridged signal numbers of the NR, RR or DNR request that it replaces.
5) Clearing previous external (switch) command:
   - **Clear** clears all switch commands.

19.1 External commands for CL-SNC

For the compound link SNC group protection external commands are defined to allow the following types of actions:

1) Configuration modifications and maintenance to be performed on the protection group or its transport entities:
   - **Lockout of protection** temporarily disables access to link 0 for the normal signals (Na and Nb);
   - **Forced Switch for signal #i** temporarily forces signal #i (i=0: null signals, i=1: normal signals) to be routed over the link 0 topological component;

– **Manual Switch for signal #i** temporarily routes signal #i (i=0: null signals, i=1: normal signals) over the link 0 topological component, unless a fault condition (SF, SD) requires another signal group to be routed over this topological component.

2) Lockout signals from the protection process:
   – **Lockout of signal #i** temporarily disables access to link 0 for the specific signals;
   – **Clear Lockout of signal #i**.

3) Freeze the protection process:
   – **Freeze** temporarily prevents any switch action to be taken and, as such, freezes the current state. Until the freeze is cleared, additional near-end external commands are rejected and fault condition changes and received APS messages are ignored.
   – **Clear Freeze**: When the freeze command is cleared, the state of the protection group is recomputed based on the fault conditions and received APS message.

4) Testing the protection process and APS channel between the two endpoints:
   – **Exercise** is a command to test if the APS communication is operating correctly. It is lower priority than any "real" switch request.

5) Clearing previous external (switch) command:
   – **Clear** clears all switch commands.

19.2 External commands for ACL-SNC

For the adaptive compound link SNC group, protection external commands are defined to allow the following types of actions:

1) Configuration modifications and maintenance to be performed on the protection group or its transport entities:
   – **ADD** add a composite link to the ACL;
   – **REMOVE #i** removes a specific composite link (i) from the ACL;
   – **DO_NOT_USE #i** temporarily disables the use of composite link (i) from the ACL.

2) Lockout signals from the protection process:
   – **Lockout of signal #i** temporarily disables access to composite link (i) of the ACL;
   – **Clear Lockout of signal #i.**

3) Freeze the protection process:
   – **Freeze** temporarily prevents any protection switch action to be taken and, as such, freezes the current state. Until the freeze is cleared, additional near-end external commands are rejected and fault condition changes and received ACL-APS messages are ignored.
   – **Clear Freeze** recompute the state of the ACL protection group based on the fault conditions and received ACL-APS message.

4) Testing the protection process and ACL-APS channel between the two endpoints:
   – **Exercise** is a command to test if the APS communication is operating correctly. It is lower priority than any "real" switch request.

20 Protection switching process states

The following protection switching process states exist:

Do Not Revert normal traffic signal #i (DNR #i) – In non-revertive operation, this is used to maintain a normal traffic signal to be selected from the protection transport entity.

No Request (NR) – All normal traffic signals are selected from their corresponding working transport entities. The protection transport entity carries either the null signal, extra traffic, or a bridge of the single normal traffic signal in a 1+1 protection group.

Wait-to-Restore normal traffic signal #i (WtR) – In revertive operation, after the clearing of an SF or SD on working transport entity #i, maintains normal traffic signal #i as selected from the protection transport entity until a wait-to-restore timer expires. If the timer expires prior to any other event or command, the state will be changed to NR. This is used to prevent frequent operation of the selector in the case of intermittent failures.

21 Priority

Fault conditions, external commands and protection states are defined to have a relative priority with respect to each other. Priority is applied to these conditions/command/states locally at each endpoint and between the two endpoints.

Refer to the specific protection switching Recommendations for these priorities.

22 SF and SD trigger conditions

An SF condition is either a TSF or a SSF, which depends on the protection type.

Figure 22-1 illustrates the defect combination rules. SSF is given by adaptation function specific defects and AI_TSF. TSF is given by any defect of the layer network trail and CI_SSF.

An SF trigger condition is either directly detected by the trail termination function of the protected layer network, or it is passed through one or more layers according to the combination rules of specific defects, CI_SSF and AI_TSF.

TSD is the only SD trigger condition. It is issued on the detection of dDEG. TSD is always local to a trail termination function, i.e., it does not pass layer boundaries.

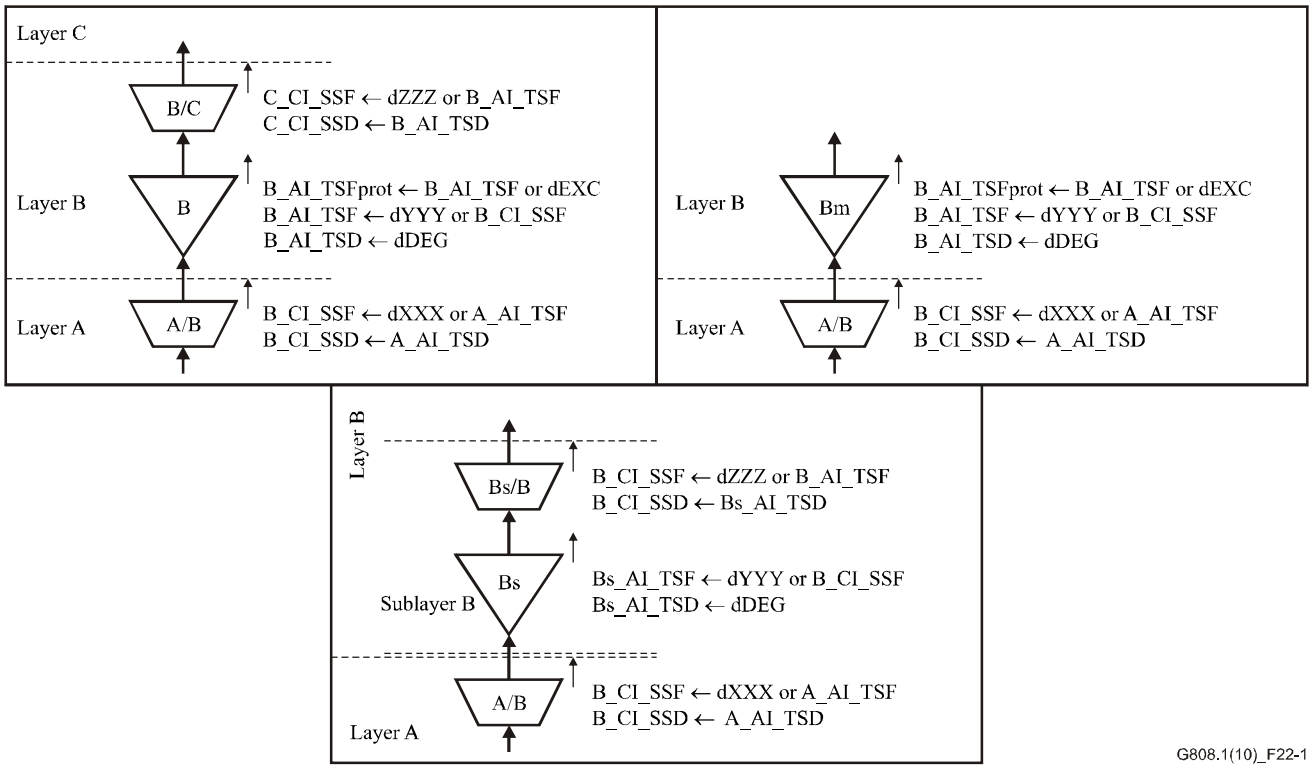


Figure 22-1 – Combination rules of defects

22.1 Overview of SF conditions

Table 2 presents an overview of defects that contribute to SF conditions in several transmission technologies. Refer to equipment Recommendations (e.g., [ITU-T G.783], [ITU-T G.798], [ITU-T I.732]) for specific SF specifications.

Table 2 – Overview of defects contributing to SF condition

	ATM	OTN	SDH
Continuity defects	LOC	LOS, LOS-P, LCK, LTC	LOS, LTC
Connectivity defects	None	TIM, OCI	TIM, UNEQ
Adaptation defects	LCD	MSIM, LOM, PLM, LOFLOM	LOF, LOM, LOP, PLM
Upstream server layer defects (Note 1)	AIS	FDI, FDI-P	AIS
Excessive errored Trail			EXC (Note 2)
Virtual concatenation defects (Note 3)		LOM, LOA	LOM, LOA
NOTE 1 – Any detected defect causes the generation of an AIS/FDI client layer signal that is transported downstream. Depending on the specific layer, AIS/FDI may be detected at an adaptation or a trail termination sink function. NOTE 2 – EXC does not contribute to TSF and, therefore, it is only a local trigger condition for the protected layer network (via TSFprot) and not for any client layer. NOTE 3 – The virtual concatenation defects are applicable for LCAS only.			

22.2 Overview of SD conditions

Table 3 presents an overview of defects that contribute to SD conditions in several transmission technologies. Refer to equipment Recommendations (e.g., [ITU-T G.783], [ITU-T G.798]) for specific SD specifications.

Table 3 – Overview of defects contributing to SD condition

	ATM	OTN	SDH
Digital degradations	None	DEG	DEG
Optical degradations	Not applicable	ffs (Note)	None
NOTE – Thresholds for optical degradations are for further study. Whether defects of the OTM overhead signal (OOS) contribute to the SD or not is for further study, since the OOS is not yet specified.			

NOTE – In the 1:1, 1:n, m:n and $(1:1)^n$ protection architectures of packet transport networks (PTN), the detection of SD on the standby entity cannot be based on the service frames, it can also not be based on the extra traffic because extra traffic can be added/dropped between the endpoints of the protection entity. Loss measurement (LM) is based on service frames, so it cannot be used in this case. However, by using a specific bridge at the source SD based protection can be achieved. Appendix VI describes the solution for supporting SD triggered protection in PTN.

23 Working and protection allocation

1+1 linear protection switching can be used as a protection application on a physical ring. As the ring is often part of a larger network, and only a portion of the trail traverses the ring, this application is normally used for subnetwork connection transport entities.

Bidirectional traffic can be engineered in two ways:

- The working transport entities for both directions may follow different physical paths, and the whole ring may be used. This is called unidirectional path switch ring (UPSR) and is shown in Figure 23-1. It is defined in SONET. In general, it can be used for SNC/I, SNC/N architectures. It should not be used for SNC/S architectures and trail protection architectures.

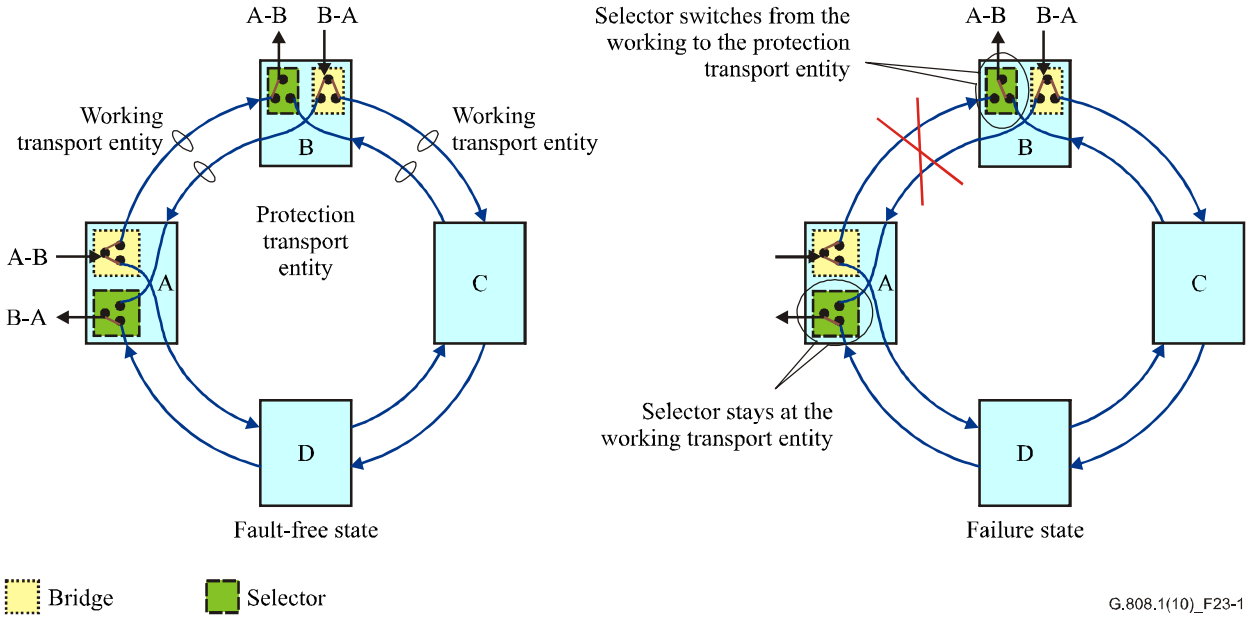


Figure 23-1 – Unidirectional path switch ring (UPSR)

- The working transport entities for both directions follow the same physical path, normally the shortest. The protection transport entities will use the other portion of the ring. This is shown in Figure 23-2 and is called subnetwork connection protection (SNCP). In a fault-free situation, this application minimizes the transfer delay and is the same for both directions. It is defined in SDH, OTN and ATM, and can be used in all protection architectures. Unidirectional path switched rings may be operated in this way as well.

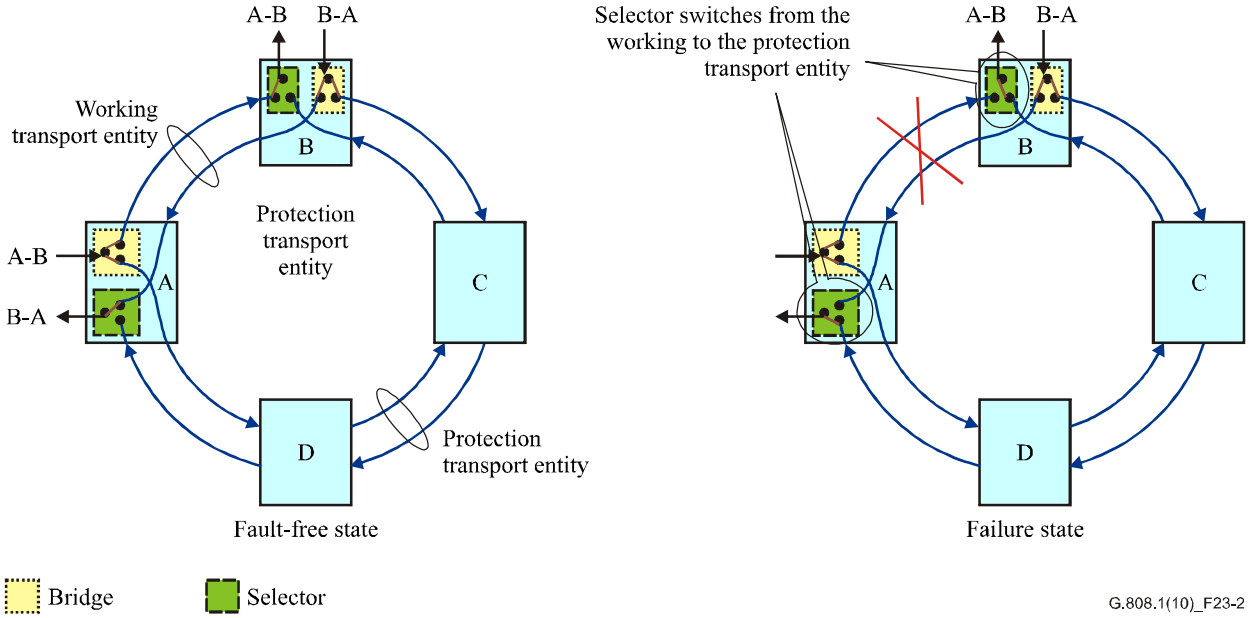


Figure 23-2 – Subnetwork connection protection (SNCP) ring

24 APS protocol

Generic definitions of APS protocol types are covered in clause 3.1.3. This clause addresses behavioural characteristics of the protocols and their applicability to the different protection architectures defined by this Recommendation. Exact details of the protocol coding schemes, and the identification of the overhead channels used for protocol transport, are defined by technology-specific protection switching Recommendations (e.g., [ITU-T G.841], [ITU-T G.873.1] and [ITU-T I.630]).

3-phase

– for all architecture types;

– prevents a misconnection to occur under all circumstances;

– operates a selector or bridge only after confirmation of priority.

2-phase

– for 1+1 and $(1:1)^n$ architectures;

– shorter protection switch time.

1-phase

– for 1+1 and $(1:1)^n$ architectures;

– shortest protection switch time;

– operates bridge/selector before priority is confirmed;

– more complex protocol.

NOTE – In the next figures the following notation is used for the exchanged APS signals: XX,y,z with XX = Request/State, y = Requested signal and z = Bridged signal.

24.1 1-phase

A means to align the two ends of the protected domain via the exchange of a single message (Z → A).

Applicable for $(1:1)^n$ and 1+1 architectures.

The bridge/selector at Z are operated before it is known if Z's condition has priority over the condition at A.

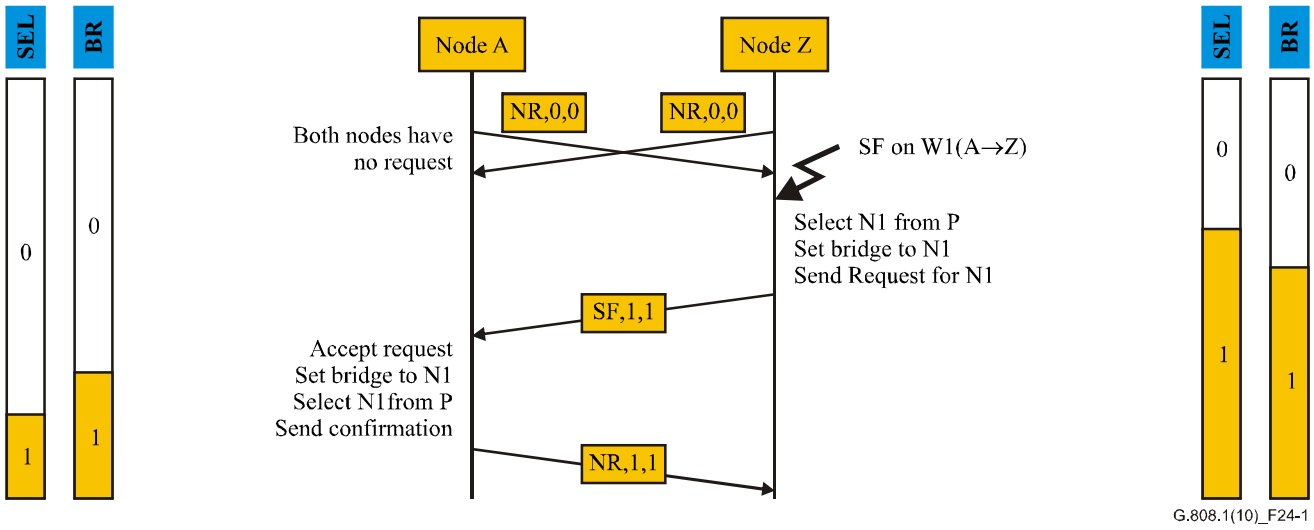


Figure 24-1 – 1-phase protocol example

24.2 2-phase

A means to align the two ends of the protected domain via the exchange of two messages (Z → A, A → Z).

Applicable for $(1:1)^n$ architecture and 1+1 architecture.

For the case of 1+1 architecture with its permanent bridge, Z does not perform any switch action until A confirms the priority of the condition at Z. When A confirms the priority, it operates the selector. On receipt of confirmation, Z operates its selector. See Figure 24-2.

For case of $(1:1)^n$ architecture, Z signals the switch condition to A and operates the bridge. When A confirms the priority of the condition at Z, it operates the selector and bridge. On receipt of confirmation, Z operates its selector. See Figure 24-3.

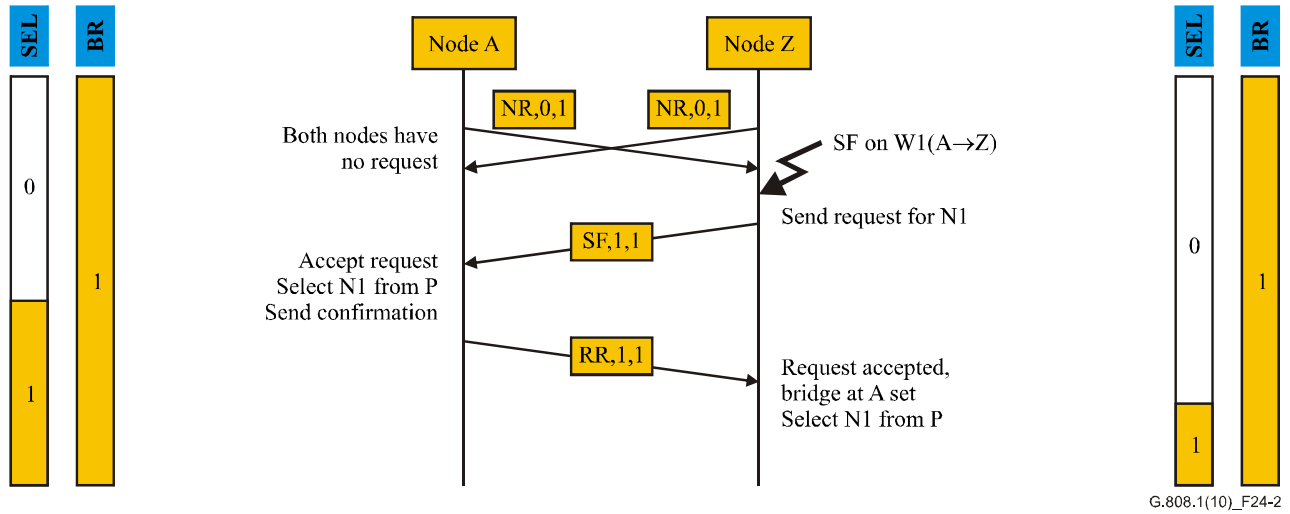


Figure 24-2 – 2-phase protocol example for 1+1 architecture

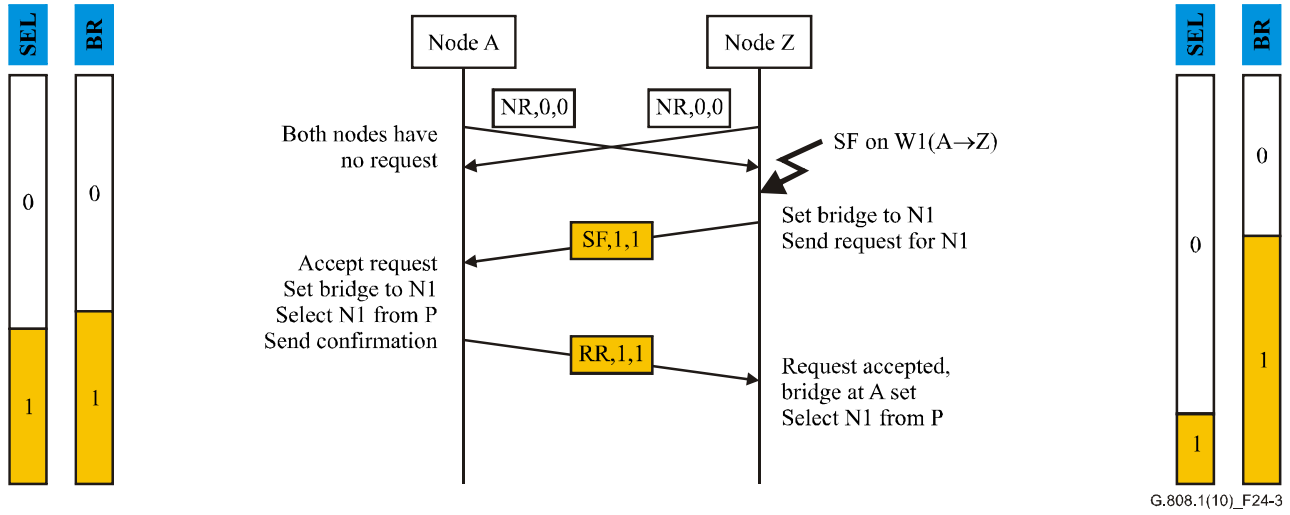


Figure 24-3 – 2-phase protocol example for $(1:1)^n$ architecture

24.3 3-phase

A means to align the two ends of the protected domain via the exchange of three messages (Z → A, A → Z, Z → A).

Applicable for 1:n and m:n architectures and for 1+1 architectures with its permanent bridges.

For case of 1:n, m:n architectures, Z does not perform any switch action until A confirms the priority of the condition at Z. When A confirms the priority, it operates the bridge. On receipt of confirmation, Z operates its selector and bridge, and indicates the bridge action to A. A finally operates the selector.

In the case of 1+1 architecture with its permanent bridges, selectors are operated only as described for case 1:n.

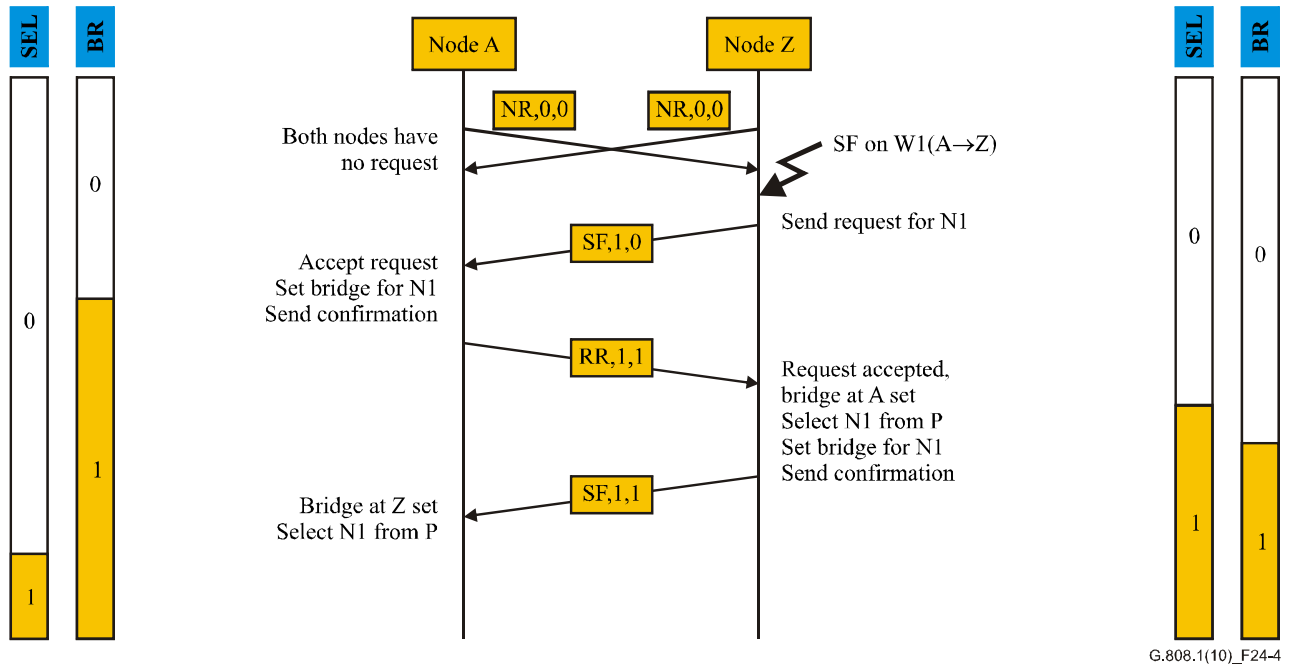


Figure 24-4 – 3-phase protocol example

Appendix I

Implementation of hold-off timer

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

An implementation of a hold-off timer may use a counter, which is decremented every X milliseconds. This quantization introduces an accuracy limitation in realizing the hold-off time. Figure I.1 presents two examples: it decrements actions every 10 ms [25 ms in the second example]. For a hold-off time of 100 ms, the hold-off counter can be loaded with a value of 10 [4 in the second example] at the moment of SF/SD occurrence, it decrements at the end of every 10 ms [25 ms in the second example] decrement period, and expires when reaching value 0. The hold-off time realized in this implementation is 95 ± 5 ms [82.5 ± 12.5 ms in the second example].

NOTE – For the case of a decrement period of 100 ms, the 100 ms hold-off time is actually 50 ± 50 ms; i.e., between 0 and 100 ms.

Instead of loading with a value of 10 [4 in the second example], the counter can be loaded with 11 [5 in the second example], realizing hold-off times of 105 ± 5 ms [112.5 ± 12.5 ms in the second example].

The accuracy of this type of hold-off timer is 0.5 times the decrement period.

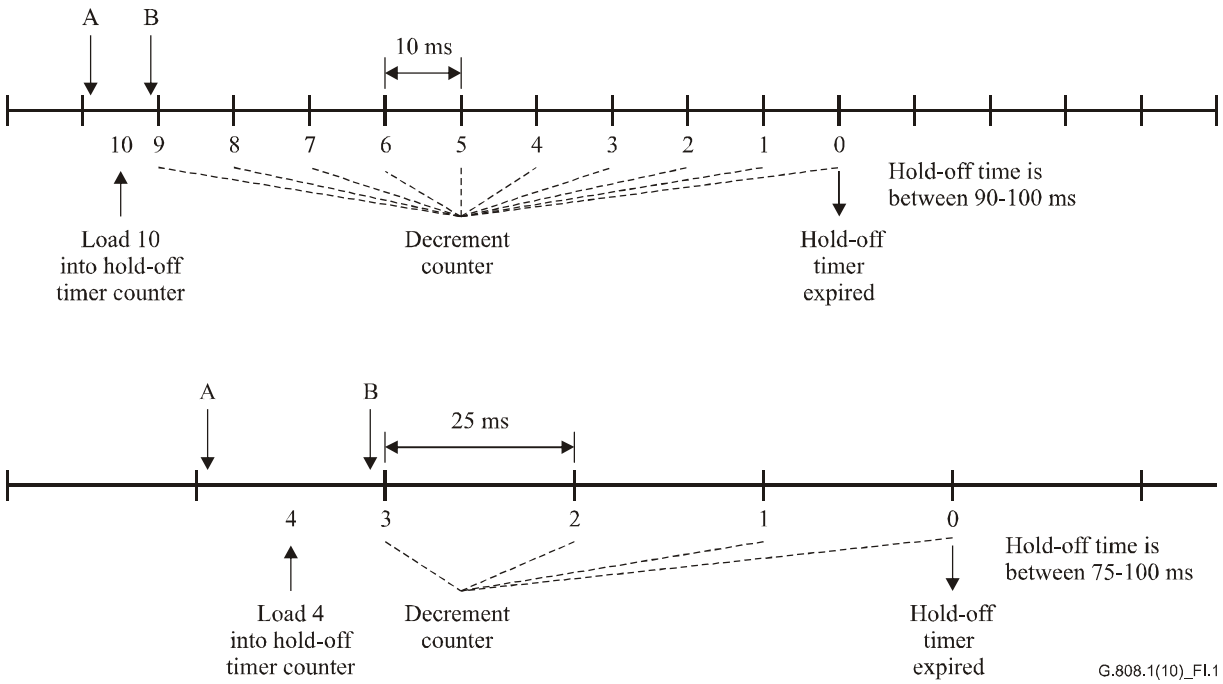


Figure I.1 – Hold-off timer accuracy

With a 10 ms decrement period, the effect of transfer delay differences between working and protection transport entities in 1+1 SNC/I and SNC/N protection can be compensated when a hold-off time of "0" is selected. When the hold-off timer is actually used (instead of disabled), and the counter is loaded with a value of "2", differential delays of 10 ms can be compensated. Refer to [ITU-T G.873.1].

Appendix II

Automatic conditions (SF, SD) in group SNC protection

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

In 1+1 SNC/N [and SNC/I] protection, SF and SD conditions for the group are the SFG and SDG SF and SD conditions that are the inputs for the SNC protection process. The logic that computes the SFG and SDG conditions operates as follows:

- Working SFG = (W-SF1 and not P-SF1) or (W-SF2 and not P-SF2) or etc.
- Protection SFG = (P-SF1 and not W-SF1) or (P-SF2 and not W-SF2) or etc.
- Working SDG = (W-SD1 and not P-SD1) or (W-SD2 and not P-SD2) or etc.
- Protection SDG = (P-SD1 and not W-SD1) or (P-SD2 and not W-SD2) or etc.

This definition of SFG and SDG allows differentiating between a fault occurring "in front of" or "within" the protected domain. A fault in front of the protected domain in a single signal will neither activate W-SFG [SDG] nor P-SFG [SDG], while in both the W-bundle and the P-bundle SF-i will be activated; the terms "(W-SF-i and not P-SF-i)" and "(P-SF-i and not W-SF-i)" will, however, be "false".

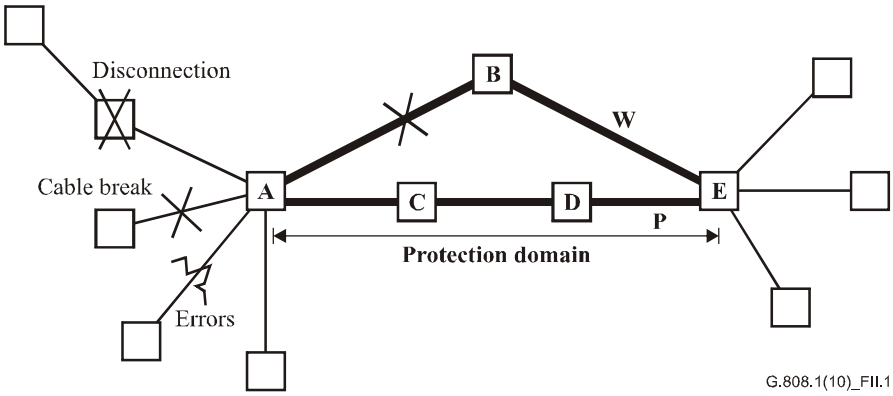


Figure II.1 – Example of fault within the protected domain

A fault between network elements (NE) A and B (Figure II.1) will cause W-SFG [or W-SDG] to be activated. If it is a server signal fault, all signals within the bundle will experience a SF condition. If it is a connectivity fault, a single signal may experience a SF condition. Both situations will cause W-SFG to be activated.

If, at the same time, e.g., a disconnection or cable break before NE A is present (impacting one of the signals in the group), W-SF-i and P-SF-i will be active. When the fault in the protection domain is a server fault, W-SFG will still be active, and P-SFG is inactive. In the other case (connectivity fault in the protection domain), the group will be switched if the failed signals in front of and within the protection domain are different.

NOTE – The special case where all signals have already failed before the protection domain results in inactive W-SFG and P-SFG. But this special case does not corrupt the operation of the protection process; there is nothing left to protect.

The errors/faults within the protected domain that cause AIS and DEG defects will do this on all members of the group at the same moment (assuming it is required that all signals within the group are transported in the same server signal). As such, the "ORing" of the individual SF and SD conditions can be used as a trigger.

With respect to a signal loss (e.g., loss of continuity, unequipped), or a connectivity (e.g., trace identifier mismatch) defect, this group behaviour might not be present. The signals are (in principle) individually cross-connected in each network element. As such, the ORing of the individual signals will initiate a protection switch for the group when only one (or a subset) of the signals has a signal loss defect condition. This is the consequence of the complexity reduction.

Appendix III

Implementation observations

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

In a technology, commonly available and in use today, SDH or other technology (e.g., ATM, OTN), NEs consist of "port units" (PU) and "switch units". The switch units perform the cross-connection/switching, the port units perform all necessary SDH (or PDH) overhead (and ATM OAM) processing.

For SDH VC-12 cross-connecting network elements (NE), a port unit will perform SOH, AU4 pointer, VC-4 POH and TU12 pointer processing (Figure III.1). The resulting SDH VC-12 signals are then handed off to the switch unit to be routed to their respective output port units.

It is possible to use the same port unit when the SDH VC-4 signal should not be terminated, but instead passed through as a VC-4 signal.

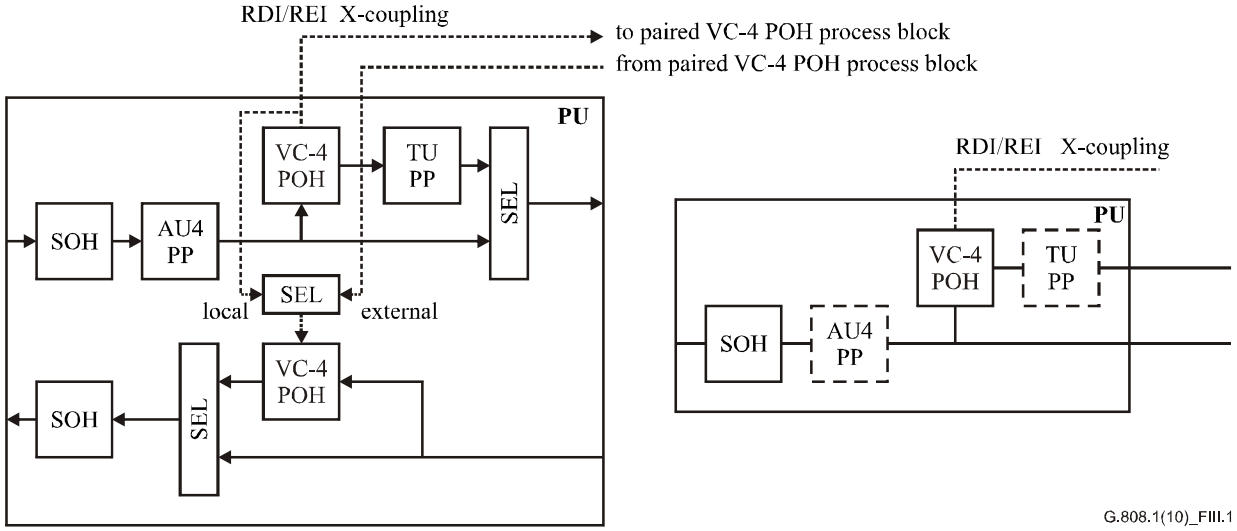


Figure III.1 – Port unit detailed view (left) and compressed view (right) (basic functionality only)

III.1 Analysis

Consider as an example the case of 1+1 MS protection (Figure III.2); two port units are used for this purpose, both with hardware performing SOH, AU PP, VC-4 POH and TU PP processing, while a protection switch is implemented at the switch unit by switching the total group of LOVC signals.

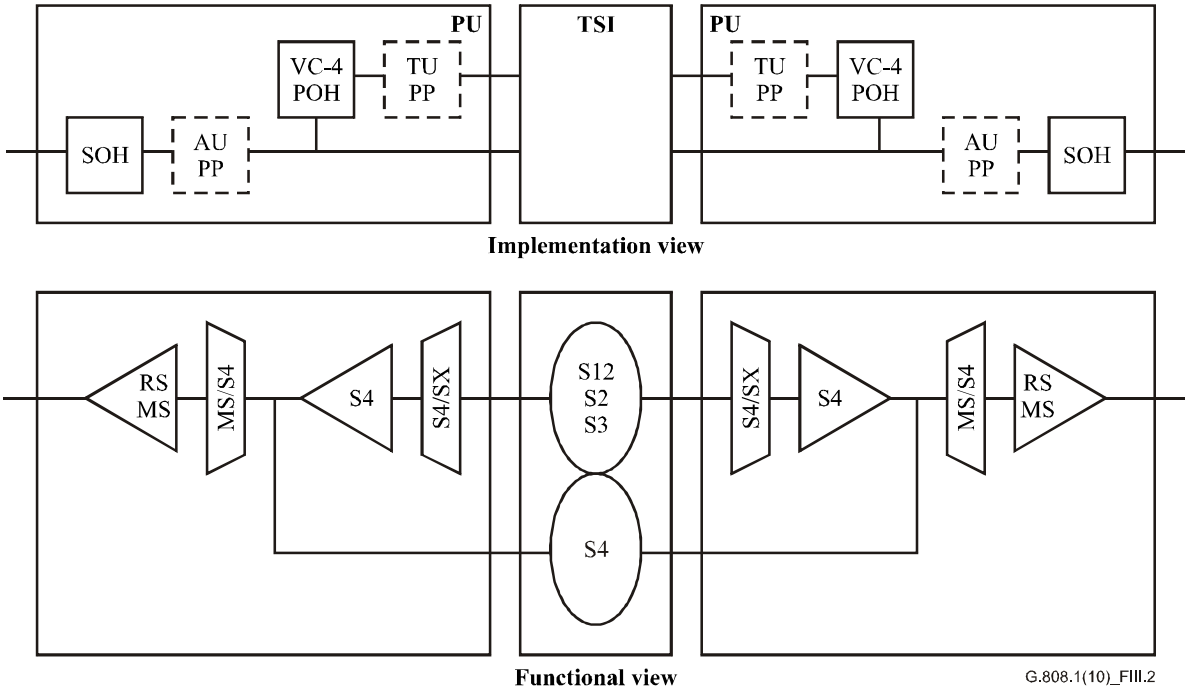


Figure III.2 – Mapping of implementation into functional view: Basic operation

According to the functional model, too much functionality is present (Figure III.3); i.e., SOH processing is expected to be present twice, while AU PP, VC-4 POH and TU PP processing should be present only once.

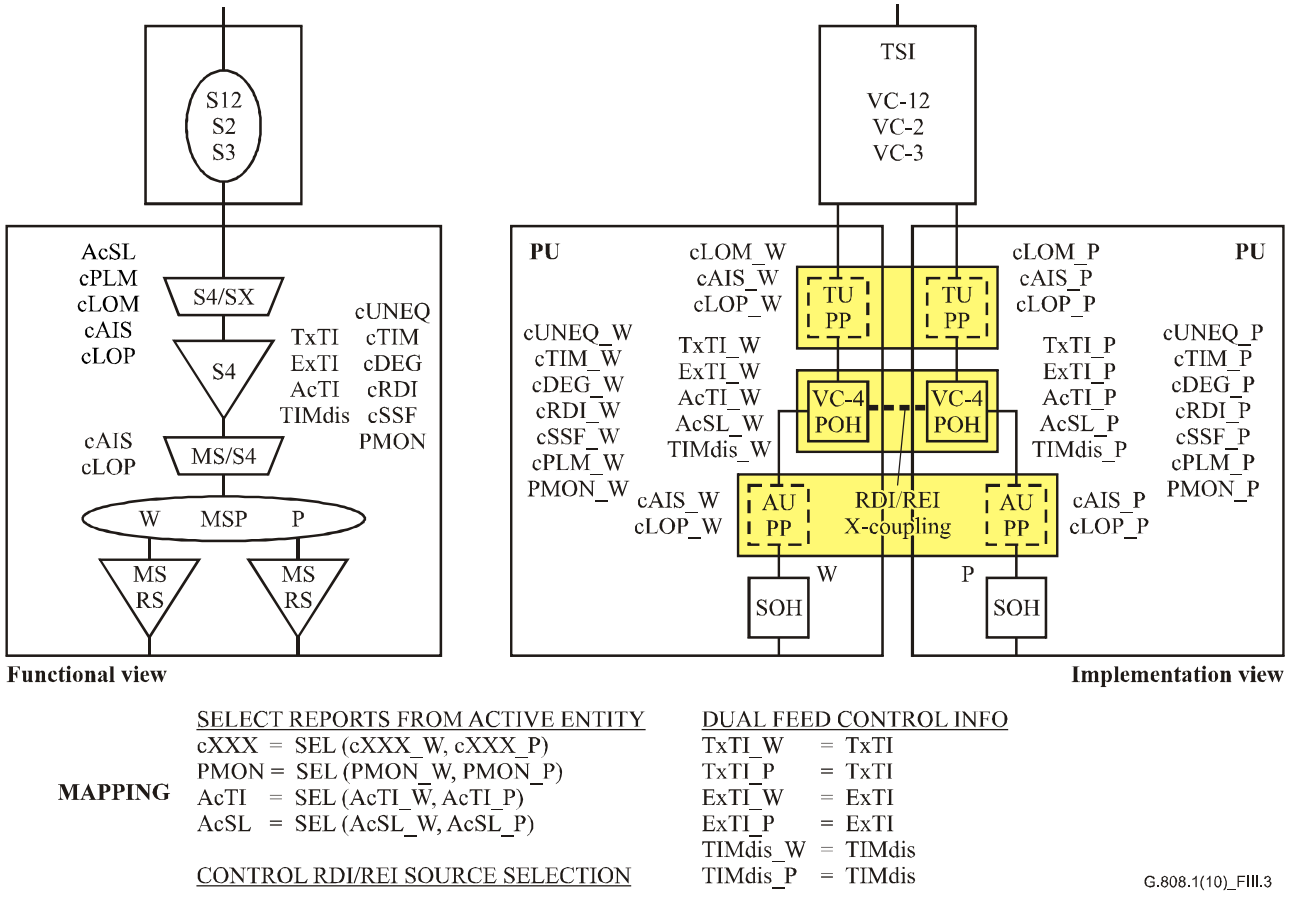


Figure III.3 – Mapping of implementation into a functional view: MS protection

With the software, an NE can present the expected functionality; it hides the standby AU PP, VC-4 POH and TU PP processes for the manager.

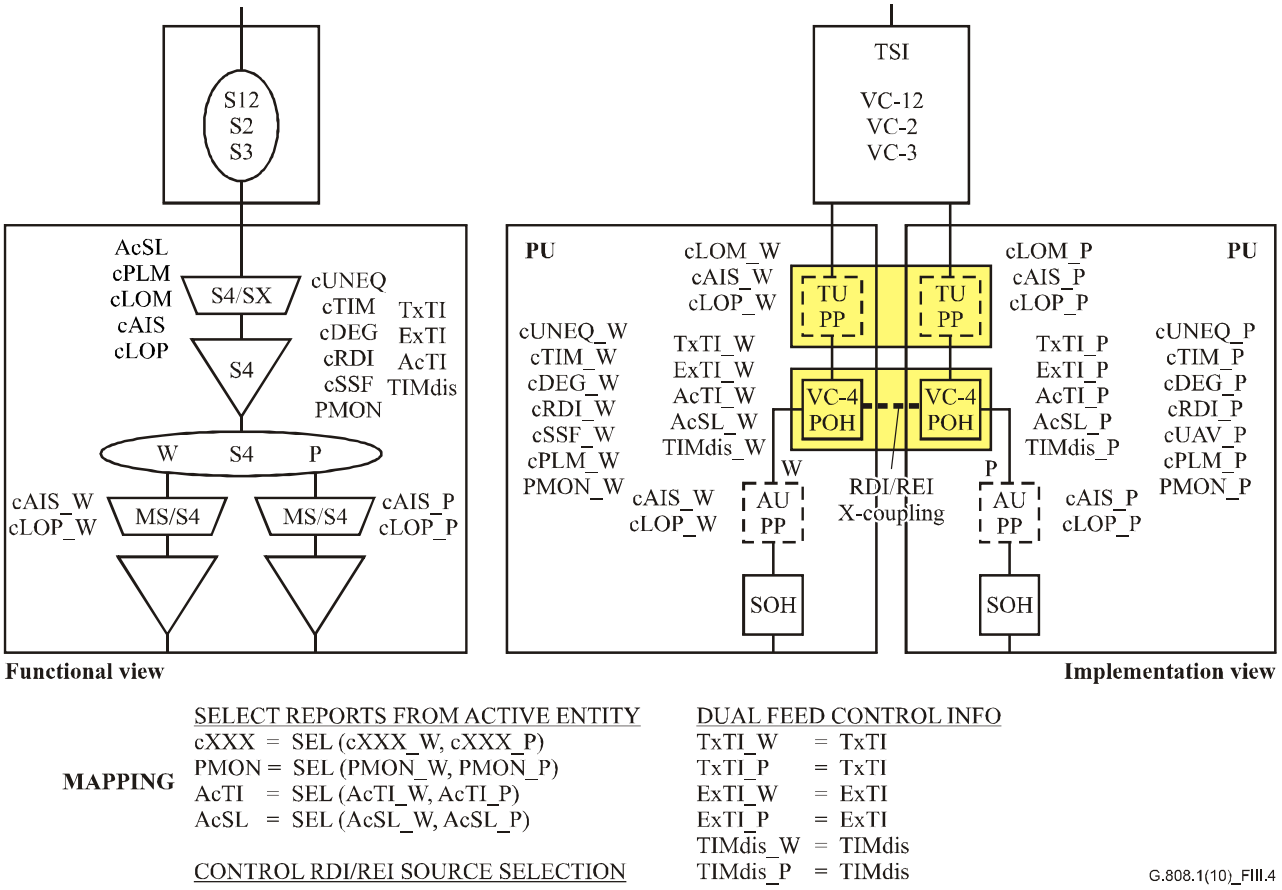
For the transmission interfaces, a masking is also required; the two STM-N interfaces are expected to output the same AU4(s), the same VC-4(s), and the same TU(s).

The most straightforward implementation will output "different" AU(s) and TU(s). The difference is the actual pointer value; these do not have to be the same in the working and protection STM-N signals.

The fact that the AU/TU pointer values might be different does not have any impact on network operation. That is, this "non-compliance" in the strict sense is without consequences: i.e., no compensation is required for this.

Such is not the case, however, for the VC-4 POH processing. Here it is necessary to make sure that the RDI and REI signals that are output via both STM-N interfaces are identical. That is, the VC-4 POH monitor process at the active STM-N port unit must forward its RI_RDI/RI_REI signals to the VC-4 POH generation processes on both (working and protection) port units.

Similarly, this is required when VC-4 SNC protection is selected instead of MS protection (Figure III.4).



MAPPING

SELECT REPORTS FROM ACTIVE ENTITY
cXXX = SEL (cXXX_W, cXXX_P)
PMON = SEL (PMON_W, PMON_P)
AcTI = SEL (AcTI_W, AcTI_P)
AcSL = SEL (AcSL_W, AcSL_P)

CONTROL RDI/REI SOURCE SELECTION

DUAL FEED CONTROL INFO
TxTI_W = TxTI
TxTI_P = TxTI
ExTI_W = ExTI
ExTI_P = ExTI
TIMdis_W = TIMdis
TIMdis_P = TIMdis

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Figure III.4 – Mapping of implementation into functional view: VC-4 SNC/I protection

In the case where RDI/REI X-coupling is not implemented, it will not be possible to add ITU-T G.826 performance monitoring to networks in which the above protection implementations are operational. Rec. ITU-T G.826 requires bidirectional (services based) performance monitoring to be supported. This requires that the far-end information be used. This far-end information must represent the error/defects detected in the signal path that is actually transporting the client information.

Unidirectional switching causes each end of the protection span to independently select between working and protection trail/SNC. If, in the direction A $\rightarrow$ Z, the working VC-4 SNC is selected and protection VC-4 SNC, in the direction Z $\rightarrow$ A the far-end information extracted at each end is inserted by the VC-4 POH generator on the standby port unit; i.e., the one that is not selected at this end. If it (now) uses its local RI_RDI/RI_REI signals (instead of its companion RI_RDI/RI_REI signals), the far-end would receive far-end information that is not related to the actually selected VC-4.

The bidirectional performance monitoring registers would (in this case) represent the wrong information; i.e., it cannot be used.

Of course, the same problem exists for the unidirectional (maintenance based) far-end registers.

For the case of a 64 kbit/s routing NE with STM-N interfaces, the same problem will be present at the VC-12 level.

NOTE – Figures III.3 and III.4 only represent the issue from the RDI/REI viewpoint. These figures do not show the tandem connection/segment termination or non-intrusive monitor functions that are required to control the protection switch.

Appendix IV

An example of $(1:1)^n$ protection

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

This appendix gives an example of $(1:1)^n$ protection switching (for n = 3) in an ATM network. In this case, there are three working entities which are diversely routed. They are protected by a single protection entity which, during normal operation, transports extra traffic. The protection entity must have sufficient bandwidth to transport the largest of the three normal traffic signals or the extra traffic signal. Each of the working entities is an ATM virtual path, whose size and virtual path identifier (VPI) are shown in Figure IV.1.

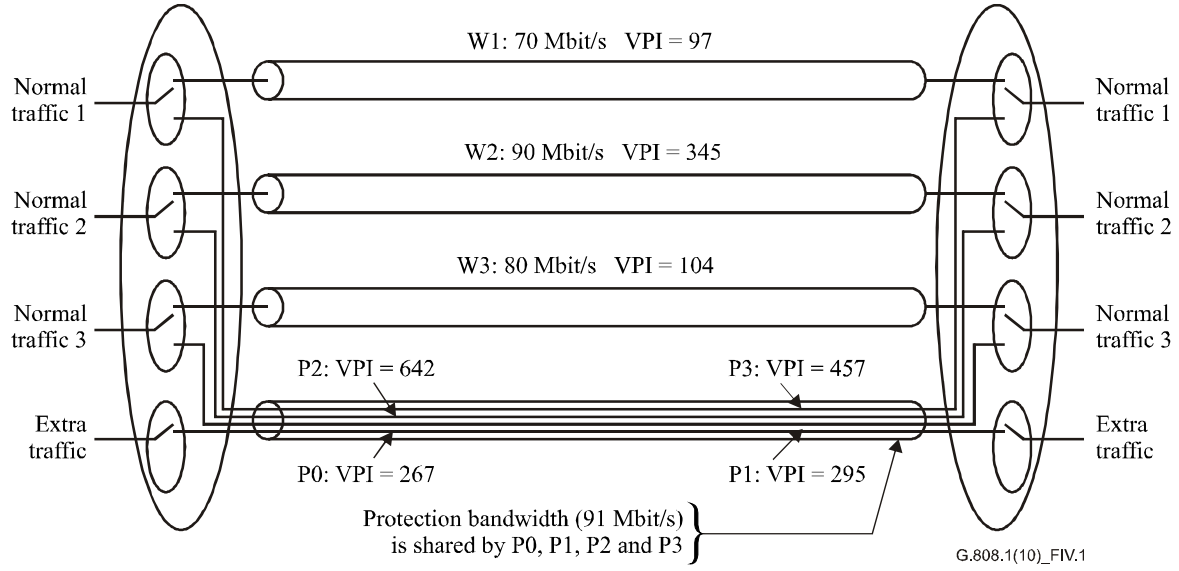

Figure IV.1 – An example of $(1:1)^n$ protection

In this example, 90 Mbit/s plus the OAM cells for P0 (includes VP-APS OAM), P1, P2 and P3 are required to provide protection switching. For unidirectional switching, a 1-phase protocol can be used because when a fault condition is detected: all that is needed is that a signal be sent from the Z end to the A end to initiate switching at the bridge. No misconnection can occur as the signal, which is on the protection entity, is uniquely identified by its VPI.

Appendix V

Examples of survivability of inverse multiplexed trails

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

V.1 Survivability offered by LCAS

Using the inverse multiplexing capability of VCAT + LCAS where Y = Y-Xv and Z = Y-Xc and the IMG is equivalent to a VCG, the following example is provided.

The AI is transported using a virtual concatenation group (VCG) with X members (VC_n_Xv, ODUk_Xv), distributed over N routes, where:

- All members belonging to the VCG have the same bandwidth.
- The bandwidth of the VCG is proportional to the number of active members.
- N = number of routes ($1 \leq N \leq X$) each containing one or more network connections within the VCG.
- X = number of members in the VCG required to transport the client's bandwidth AI + extra/protection capacity Z ($X \geq 1$, $Z \geq 0$).
- X_{ACT} = actual transported payload ($0 \leq X_{ACT} \leq X$); due to failure of one or more of the trails the bandwidth of one or more members in the VCG will not be used to transport the AI.

For the transport of a 10 Mbit/s signal a VC-12-5v is required. Five individual VC-12 trails are set up in this VCG, two are routed via route 1 and three VC-12 are routed via route 2 (Figure V.1). In this particular case, the survivable bandwidth is 2 × VC-12, or 40%, and the non-survivable bandwidth is 3 × VC-12, or 60%. When one extra VC-12 would have been provisioned (E = 1) routed via route 1, the survivable bandwidth would have been 3 × VC-12 or 60% and the unprotected bandwidth 2 × VC-12 or 40%.

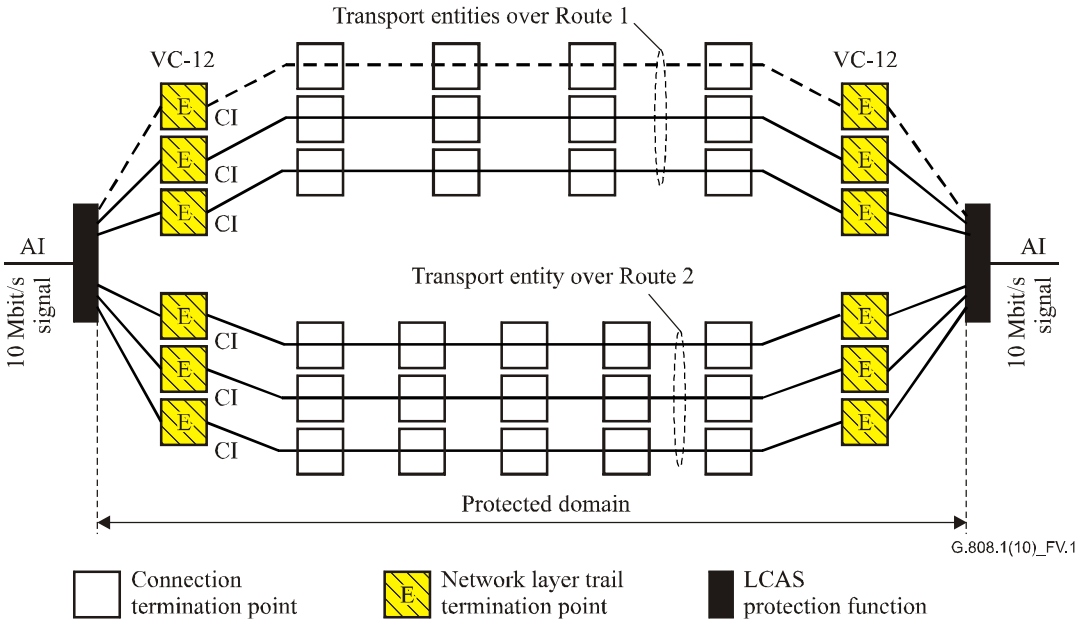

Figure V.1 – Example LCAS survivability for 10 Mbit/s signal over VC-12-(X + E)v (X = 5, E = 0, 1)

Appendix VI

Solution for SD triggered protection in PTN

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

NOTE 1 – The special SD behaviour described in this appendix is only required for the case of protection switching in packet transport layer networks (PTN).

The detection of SD (e.g., packet loss) is based on service packets. In 1+1 protection normal traffic is sent permanently on both working and protection entities. Therefore, the detection of SD and the clearing of SD on both working and protection entities can be based only on the characteristics of the original traffic.

However, in PTN with 1:1, 1:n, m:n and $(1:1)^n$ protection , there may be no end-to-end traffic on the standby transport entity, which makes the detection of SD based on LM impossible and consequently protection switch flapping may happen if no special measures are taken.

For this solution the detection of SD-W and SD-P is required and is used to prevent flapping.

Broadcast bridge for SD detection in SD-triggered protection

In the normal state, the normal traffic signal is bridged at the source only on the working transport entity and only the SD condition of the working transport entity can be evaluated. When SD is detected on the working transport entity, the sink end sends a SD-W indication to the source end, and the selector at the sink end switches to the protection transport entity. The bridge at the source end will then broadcast the normal traffic signal on both working and protection transport entities and the performance of both working and protection transport entities can be monitored. If SD is detected on the protection transport entity as well, i.e., SD-W and SD-P exist simultaneously, the sink end will remain selecting the normal traffic signal from the protection transport entity to avoid flapping between protection and working states.

The priority of SD-W and SD-P in the APS protocol is fixed as SD-W > SD-P to avoid flapping between protection and working states.

NOTE 2 – The SD-W based protection switch action described above is performed under the assumption that an SD condition on a transport entity is a rare condition, and it is thus unlikely that SD on the standby entity will co-exist with SD on the active entity.

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Printed in Switzerland
Geneva, 2010