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Recommendation ITU-T G.8032/Y.1344

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Recommendation ITU-T G.8032/Y.1344

Ethernet ring protection switching

Summary

Recommendation ITU-T G.8032/Y.1344 defines the automatic protection switching (APS) protocol and protection switching mechanisms for Ethernet layer network (ETH) ring topologies. Included are details pertaining to Ethernet ring protection characteristics, architectures and the ring APS (R-APS) protocol.

History

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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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Ethernet ring protection switching

1 Scope

This Recommendation defines the automatic protection switching (APS) protocol and protection switching mechanisms for Ethernet layer network (ETH) ring topologies. The protection protocol defined in this Recommendation enables protected point-to-point, point-to-multipoint and multipoint-to-multipoint connectivity within a ring or interconnected rings, called "multi-ring/ladder network" topology.

The ETH ring maps to the physical layer ring structure. Protection schemes for the other layers, including the Ethernet physical layer network (ETY), are out of the scope of this Recommendation.

2 References

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

[ITU-T G.805]	Recommendation ITU-T G.805 (2000), *Generic functional architecture of transport networks*.
[ITU-T G.806]	Recommendation ITU-T G.806 (2012), *Characteristics of transport equipment – Description methodology and generic functionality*.
[ITU-T G.808.1]	Recommendation ITU-T G.808.1 (2014), *Generic protection switching – Linear trail and subnetwork protection*.
[ITU-T G.809]	Recommendation ITU-T G.809 (2003), *Functional architecture of connectionless layer networks*.
[ITU-T G.870]	Recommendation ITU-T G.870/Y.1352 (2012), *Terms and definitions for optical transport networks (OTN)*.
[ITU-T G.8001]	Recommendation ITU-T G.8001/Y.1354 (2013), *Terms and definitions for Ethernet frames over transport*.
[ITU-T G.8010]	Recommendation ITU-T G.8010/Y.1306 (2004), *Architecture of Ethernet layer networks*.
[ITU-T G.8013]	Recommendation ITU-T G.8013/Y.1731 (2013), *Operation, administration and management (OAM) functions and mechanisms for Ethernet based networks*.
[ITU-T G.8021]	Recommendation ITU-T G.8021/Y.1341 (2015), *Characteristics of Ethernet transport network equipment functional blocks*.
[IEEE 802.1Q]	IEEE Std 802.1Q (2014), *IEEE standard for local and metropolitan area networks: Media access control (MAC) bridges and virtual bridged local area networks*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

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

   a)   adapted information

   b)   characteristic information

   c)   link

   d)   tandem connection

   e)   trail

3.1.2 Terms defined in [ITU-T G.806]:

   a)   defect

   b)   failure

   c)   server signal fail (SSF)

   d)   signal degrade (SD)

   e)   signal fail (SF)

   f)   trail signal fail (TSF)

3.1.3 Terms defined in [ITU-T G.808.1]:

   a)   transfer time (T_t)

3.1.4 Terms defined in [ITU-T G.809]:

   a)   adaptation

   b)   flow

   c)   layer network

   d)   network

   e)   port

   f)   transport

   g)   transport entity

3.1.5 Terms defined in [ITU-T G.870]:

   a)   hold-off time

   b)   non-revertive (protection) operation

   c)   protected domain

   d)   protection

   e)   protection transport entity

   f)   revertive (protection) operation

   g)   signal

   h)   switch

   i)   switching time

   j)   wait-to-restore time

   k)   working transport entity

3.1.6   Terms defined in [ITU-T G.8001]:

   a) ERP instance

   b) Ethernet ring

   c) Ethernet ring node

   d) interconnection node

   e) maintenance entity (ME)

   f) maintenance entity group (MEG)

   g) major ring

   h) MEG end point (MEP)

   i) R-APS virtual channel

   j) ring MEL

   k) ring protection link (RPL)

   l) RPL neighbour node

   m) RPL owner node

   n) sub-ring

   o) sub-ring link

   p) wait to block timer

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Adapted Information
APS	Automatic Protection Switching
BPR	Blocked Port Reference
CCM	Continuity Check Message
CI	Characteristic Information
DNF	Do Not Flush
E-LAN	Ethernet LAN
EPL	Ethernet Private Line
ERP	Ethernet Ring Protection
ETH	Ethernet layer network
ETHDi	Ethernet MAC layer network Diagnostic function within MIP
ETY	Ethernet physical layer network
EVPL	Ethernet Virtual Private Line
FDB	Filtering Database
FF	Flow Forwarding
FOP-PM	Failure Of Protocol – Provisioning Mismatch
FOP-TO	Failure Of Protocol – Time Out

FP	Flow Point
FS	Forced Switch
GFP	Generic Framing Procedure
ID	Identification
MAC	Media Access Control
MEG	Maintenance Entity Group
MEL	Maintenance Entity group Level
MEP	Maintenance entity group End Point
MI	Management Information
MPLS	Multiprotocol Label Switching
MS	Manual Switch
NR	No Request
OAM	Operation, Administration and Maintenance
OUI	Organizationally Unique Identifier
PDU	Protocol Data Unit
R-APS	Ring APS
RB	RPL Blocked
RPL	Ring Protection Link
SD	Signal Degrade
SDH VC	Synchronous Digital Hierarchy Virtual Circuit
SF	Signal Fail
SSF	Server Signal Fail
STP	Spanning Tree Protocol
TCM	Tandem Connection Monitoring
TLV	Type, Length and Value
Tx	Transmit
VID	VLAN Identifier
VLAN	Virtual Local Area Network
VPLS	Virtual Private Local Area Network Service
WTB	Wait To Block
WTR	Wait To Restore

5 Conventions

5.1 Representation of octets

Octets are represented as defined in [ITU-T G.8013].

When consecutive octets are used to represent a binary number, the lowest octet number has the most significant value. The bits in an octet are numbered from 1 to 8, where 1 is the least significant bit and 8 is the most significant bit.

6   Introduction

This Recommendation specifies protection switching mechanisms and a protocol for Ethernet layer network (ETH) rings. Ethernet rings can provide wide-area multipoint connectivity more economically due to their reduced number of links. The mechanisms and protocol defined in this Recommendation achieve highly reliable and stable protection; and never form loops, which would fatally affect network operation and service availability.

Each Ethernet ring node is connected to adjacent Ethernet ring nodes participating in the same Ethernet ring, using two independent links. A ring link is bounded by two adjacent Ethernet ring nodes and a port for a ring link is called a ring port. The minimum number of Ethernet ring nodes in an Ethernet ring is two.

The fundamentals of this ring protection switching architecture are:

a)   the principle of loop avoidance; and

b)   the utilization of learning, forwarding and filtering database (FDB) mechanisms defined in the Ethernet flow forwarding function (ETH_FF [ITU-T G.8021]).

Loop avoidance in an Ethernet ring is achieved by guaranteeing that, at any time, traffic may flow on all but one of the ring links. This particular link is called the ring protection link (RPL) and under normal conditions this ring link is blocked, i.e., not used for service traffic. One designated Ethernet ring node, the RPL owner node, is responsible for blocking traffic at one end of the RPL. Under an Ethernet ring failure condition, the RPL owner node is responsible for unblocking its end of the RPL, unless the RPL has failed, allowing the RPL to be used for traffic. The other Ethernet ring node adjacent to the RPL, the RPL neighbour node, may also participate in blocking or unblocking its end of the RPL.

The occurrence of an Ethernet ring failure event results in protection switching of the traffic. This is achieved under the control of the ETH_FF functions on all Ethernet ring nodes.

An APS protocol is used to coordinate the protection actions over the ring.

The Ethernet rings could support a multi-ring or ladder network that consists of conjoined Ethernet rings by one or more interconnection points. The protection switching mechanisms and protocol defined in this Recommendation shall be applicable for a multi-ring/ladder network, if the following principles are adhered to:

1)   R-APS channels are not shared across Ethernet ring interconnections;

2)   on each ring port, each traffic channel and each R-APS channel are controlled (e.g., for blocking or flushing) by the Ethernet ring protection (ERP) control process of only one Ethernet ring;

3)   each major ring or sub-ring must have its own RPL.

7   Ring protection characteristics

7.1   Monitoring methods and conditions

Ring protection switching occurs based on the detection of defects on the transport entity of each ring link. The defects are defined within the equipment Recommendation [ITU-T G.8021]. For the purpose of the protection switching process, a transport entity, within the protected domain, has a condition of either failed [i.e., signal fail (SF)] or non-failed (OK).

ERP may adopt any of the following monitoring methods:

> Inherent – The fault condition status of each ring link connection is derived from the status of the underlying server layer trail.

> Sub-layer – Each ring link is monitored using tandem connection monitoring (TCM).

> Test trail – Defects are detected using an extra test trail, i.e., an extra test trail is set up along each ring link.

The protection switching is agnostic to the monitoring method used, as long as it can be given (OK or SF) information regarding the transport entity of each ring link.

7.2 Ethernet traffic and bandwidth consideration

It is desirable that ring bandwidth accommodates all traffic that is protected, regardless of the ring protection switching state. Being different from linear protection, ERP does not separate working and protection transport entities, but reconfigures the transport entity during protection switching. Therefore care should be taken that ring link capacity can continue to support all ring APS (R-APS) and service traffic that is protected after protection switching.

7.3 Ethernet ring protection switching performance

In an Ethernet ring, without congestion, with all Ethernet ring nodes in the idle state (i.e., no detected failure, no active automatic or external command and receiving only "NR, RB" R-APS messages), with less than 1 200 km of ring fibre circumference and fewer than 16 Ethernet ring nodes, the switch completion time (transfer time as defined in [ITU-T G.808.1]) for a failure on a ring link shall be less than 50 ms. On Ethernet rings, under all other conditions, the switch completion time may exceed 50 ms (the specific interval is under study), to allow time to negotiate and accommodate coexisting APS requests. If sub-rings with R-APS virtual channel are interconnected to a major ring, the R-APS messages of the sub-ring that are inserted into the R-APS virtual channel take on the performance characteristics (e.g., delay, jitter, packet drop probability) of the ring links and Ethernet ring nodes that it crosses over the interconnected Ethernet ring. In this case, if the R-APS channel and R-APS virtual channel exceed the number of Ethernet ring nodes or fibre circumference defined above, the protection switching of the sub-ring may exceed 50 ms.

NOTE – The inclusion of the completion of FDB flush operation within the transfer time is for further study.

8 Ring protection conditions and commands

This Recommendation supports the following conditions of the Ethernet ring:

Signal fail (SF) – When an SF condition is detected on a ring link and it is determined to be a "stable" failure, Ethernet ring nodes adjacent to the failed ring link initiate the protection switching mechanism described in this Recommendation.

No request (NR) – The condition when no local protection switching requests are active.

The following administrative commands are supported (as possible values for ETH_C_MI_RAPS_ExtCMD):

Forced switch (FS) – This command forces a block on the ring port where the command is issued.

Manual switch (MS) – In the absence of a failure or FS, this command forces a block on the ring port where the command is issued.

Clear – The Clear command, at the Ethernet ring node, is used for the following operations.

a) Clearing an active local administrative command (e.g., FS or MS).

b) Triggering reversion before the wait to restore (WTR) or wait to block (WTB) timer expires in the case of revertive operation.

c)   Triggering reversion in the case of non-revertive operation.

The following commands are for further study.

Lockout of protection – This command disables the protection group.

Replace the RPL – This command moves the RPL by blocking a different ring link and unblocking the RPL permanently.

Exercise signal – Exercise of the R-APS protocol. The signal is chosen so as not to modify the position of the blocked ring port.

9   Ring protection architectures

In the ring protection architecture defined in this Recommendation, protection switching is performed at all Ethernet ring nodes.

The ring protection architecture relies on the existence of an APS protocol to coordinate ring protection actions around an Ethernet ring.

9.1   Revertive and non-revertive switching

In revertive operation, after the condition(s) causing a switch has/have cleared, the traffic channel is restored to the working transport entity, i.e., blocked on the RPL. If a defect is cleared, the traffic channel reverts after the expiry of a WTR timer (see clause 10.1.4), which is used to avoid toggling protection states in the case of intermittent defects.

In non-revertive operation, the traffic channel continues to use the RPL, if it has not failed, after a switch condition has cleared.

Since in ERP the working transport entity resources may be more optimized, in some cases it is desirable to revert to this working transport entity once all ring links are available. This is performed at the expense of an additional traffic interruption.

In some cases, there may be no advantage to revert to the working transport entities immediately. In this case, a second traffic interruption is avoided by not reverting protection switching.

9.2   Protection switching triggers

Protection switching shall be performed when:

a)   SF is declared on one of the ring links and the detected SF condition has a higher priority than any other local request or far-end request; or

b)   the received R-APS message requests to switch and it has a higher priority than any other local request; or

c)   initiated by operator control (e.g., FS, MS) if it has a higher priority than any other local request or far-end request.

9.2.1   Signal fail declaration conditions

SF is declared when an ETH trail SF condition is detected. ETH trail SF is specified in [ITU-T G.8021].

9.3   Protection switching models on a single Ethernet ring

Figure 9-1 depicts an example of the ERP switching model defined in this Recommendation. Other network scenarios are permissible. In this example, four Ethernet ring nodes are depicted.

If the Ethernet ring is in its normal condition, one Ethernet ring node adjacent to the RPL is configured as the RPL owner node and, in this example, another Ethernet ring node adjacent to the RPL is

configured as the RPL neighbour node. Both end nodes of the RPL are responsible for blocking the transmission and reception of traffic over the RPL when there is NR on the Ethernet ring.

In Figure 9-1, Ethernet ring node D is the RPL owner node and Ethernet ring node A is the RPL neighbour node. Both Ethernet ring nodes are responsible for blocking the traffic channel on the RPL. Figure 9-1 presents the case when no failure is present on any ring link. In this case, the ETH characteristic information (ETH_CI [ITU-T G.8010]) traffic may be transferred over both ring links of any Ethernet ring node, except for the RPL on the Ethernet ring nodes where the RPL is blocked. In Figure 9-1, the traffic channel is shown as arrows being transmitted and received from the ring links. In Figures 9-1 to 9-3, only the ETH_FF function for a single virtual local area network (VLAN) is represented.
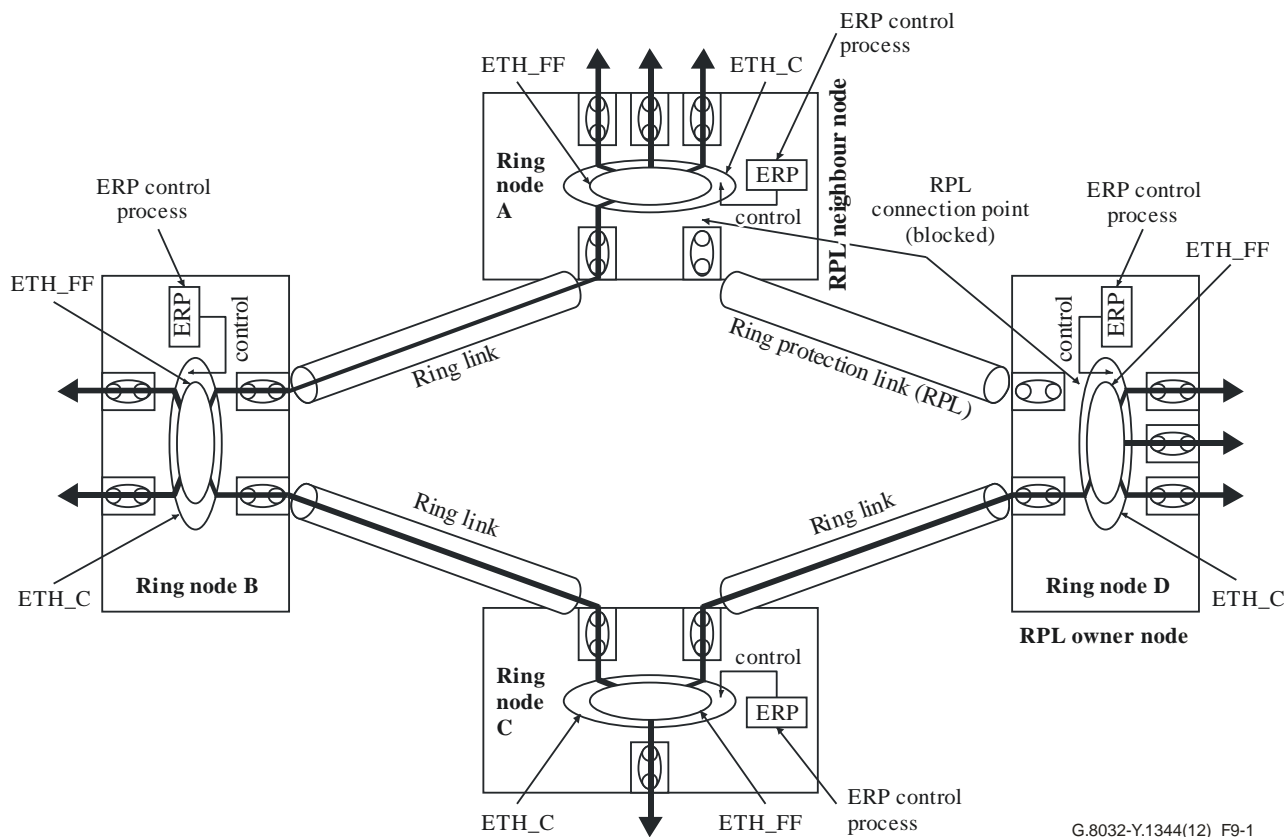
**Figure 9-1 – Ethernet ring protection switching architecture –
normal condition (single Ethernet ring)**

Figure 9-2 illustrates a situation where a protection switch has occurred due to an SF condition on one ring link. In this case, the traffic channel is blocked bidirectionally on the ports where the failure is detected and bidirectionally unblocked at the RPL connection point.

In revertive operation, when the failure is recovered, the traffic channel resumes the use of the recovered ring link only after the traffic channel has been blocked on the RPL. On the other hand, in non-revertive operation, the traffic channel remains blocked on the recovered ring link and unblocked on the RPL even if the failure is recovered.
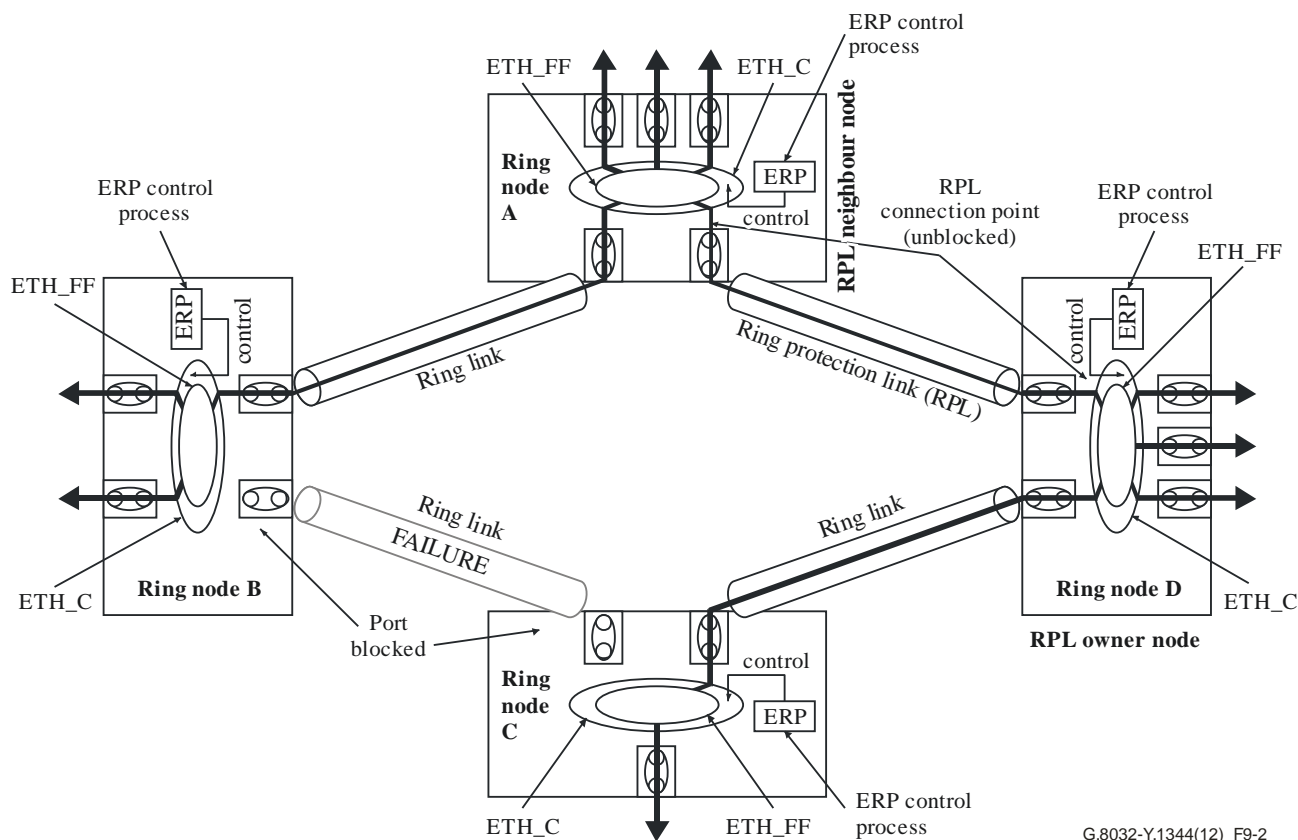
**Figure 9-2 – Ethernet ring protection switching architecture –
signal fail condition on one ring link (single Ethernet ring)**

A model of the functionality of an Ethernet ring node is presented in Figures 9-3 and 9-4.

The ERP control process is instantiated to protect normal traffic over an Ethernet ring. Each instantiated ETH_FF function determines the specific output Ethernet flow point (ETH_FP [ITU-T G.8010]) over which the ETH_CI is transferred. The ETH_CI may be forwarded over any ETH_FP corresponding to ring links or to non-ring links.

The ERP control process controls the ETH_FF function to perform actions such as disabling forwarding over any ETH_FP corresponding to blocked ring links and flushing the FDB.

As an example, the ring links of each Ethernet ring node may be monitored by individually exchanging continuity check messages (CCMs) defined in [ITU-T G.8013] on the maintenance entity group end points (MEPs) illustrated in Figure 9-3.
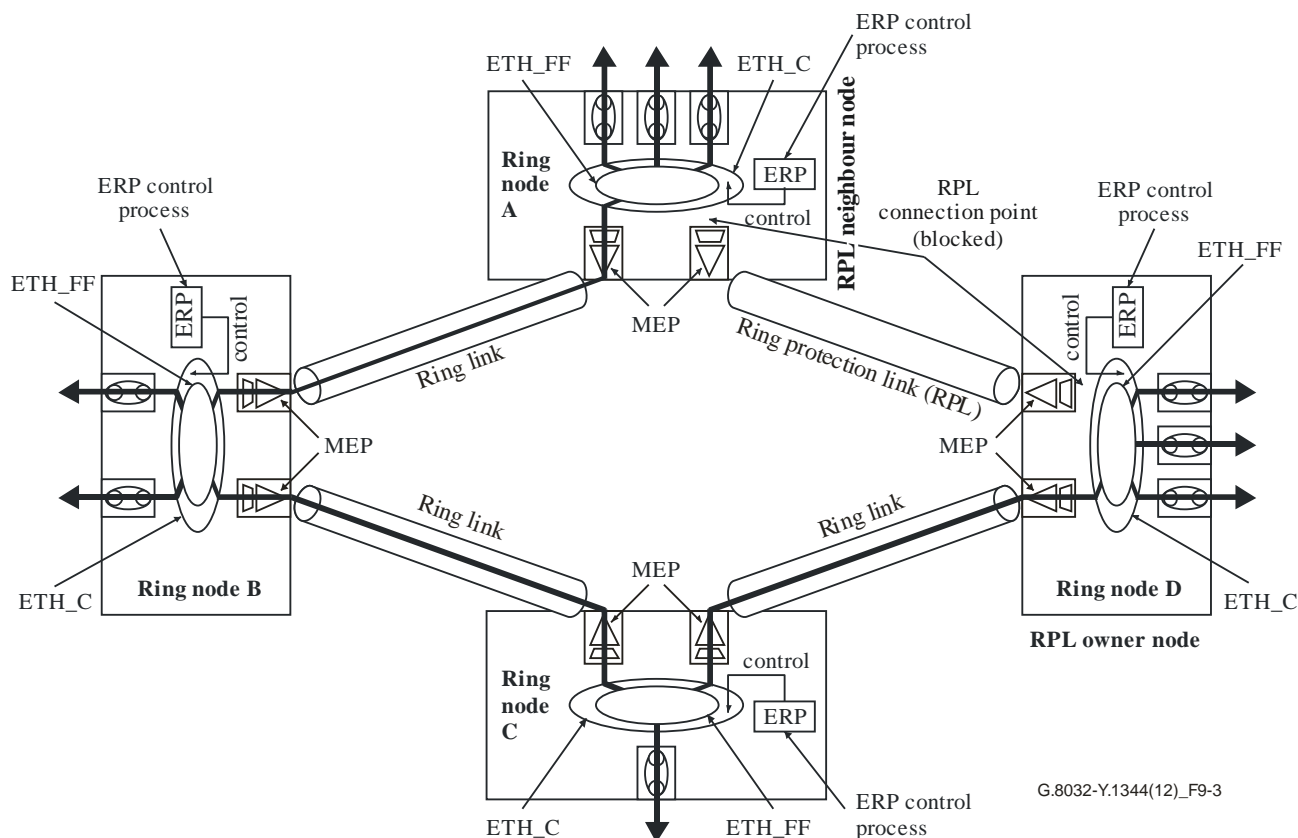
Figure 9-3 – MEPs in Ethernet ring protection switching architecture

Figure 9-4 represents the model of an Ethernet ring node. MEPs represented on each ring port are used for monitoring the ring link.

If an MEP detects a defect, which contributes to an SF defect condition, it informs the ERP control process that a failure condition has been detected. An ERP control function uses the Ethernet MAC characteristic information server signal fail (ETH_CI_SSF [ITU-T G.8021]) information, forwarded from the ETHx/ETH-m_A_Sk, to assert the SF condition of the ring link.

The ERP switching mechanism requires the R-APS protocol to coordinate the switching behaviour among all Ethernet ring nodes. The R-APS protocol communication is performed using R-APS messages. R-APS messages are transmitted and received during an ERP control process. The ETHDi/ETH adaptation function (ETHDi/ETH_A [ITU-T G.8021]) function in [ITU-T G.8021] extracts ETH_CI_RAPS information from a received R-APS message and sends the ETH_CI_RAPS information to the ERP control process. A received R-APS message is also forwarded to the ETH_FF. The ETHDi/ETH_A function also generates R-APS messages using the ETH_CI_RAPS information received from the ERP control process.

R-APS messages are forwarded using an ETH_FF function for R-APS traffic, represented in Figure 9-4 as R-APS_FF. Traffic, other than R-APS traffic, is forwarded by use of other ETH_FF functions, represented in Figure 9-4 as Service_FF. R-APS messages use a dedicated VLAN. Only one traffic VLAN is depicted in Figure 9-4. More traffic VLANs could be supported using multiple Service_FFs.
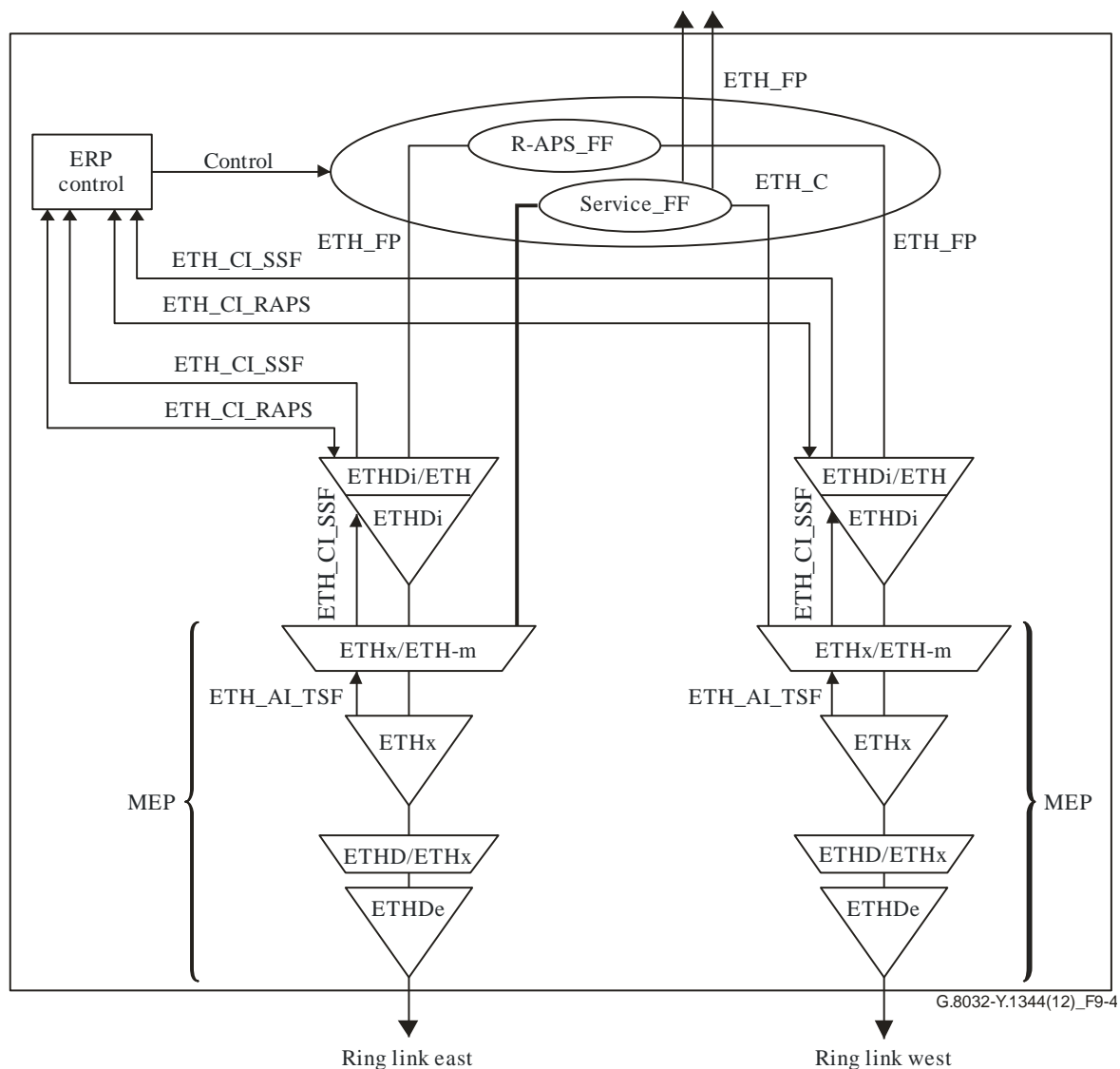
**Figure 9-4 – MEPs and R-APS insertion function in Ethernet ring node
(normal Ethernet ring node)**

9.4 Traffic channel blocking

Blocking traffic is supported by excluding the connection point from the ETH_FF functions for the one or more VLAN identifiers (VIDs) of the traffic channel controlled by the ERP instance. This is equivalent to VID filtering as defined in clause 8.13.10 of [IEEE 802.1Q]. This results in blocking the transmission and reception of traffic on one ring port. Each ERP instance shall only block or unblock the VIDs of the traffic channels of the set of VLANs assigned for protection by that ERP instance.

9.5 R-APS channel blocking

R-APS channel VLAN traffic forwarding is always blocked at the same ring ports where the traffic channel is blocked, except on sub-rings without an R-APS virtual channel (see clause 9.7.2). It is supported by excluding the connection point from the ETH_FF function for the VID of the R-APS traffic and is equivalent to performing VID filtering as defined in clause 8.13.10 of [IEEE 802.1Q]. This:

a)   only prevents R-APS messages received at one ring port from being forwarded to the other ring port;

b)   does not prevent R-APS messages, locally generated at the ERP control process, from being transmitted over both ring ports;

c)   allows R-APS messages received at each ring port to be delivered to the ERP control process. The ERP control process shall discard all received R-APS messages with a ring ID that does not match the configured ring ID of the current ERP instance.

Each ERP instance shall only block or unblock its R-APS channel. This is guaranteed by excluding the connection point from the ETH_FF for the VID of the R-APS traffic and is equivalent to performing group address filtering as defined in [IEEE 802.1Q].

On sub-rings without an R-APS virtual channel, the R-APS channel is never blocked on any of its sub-ring nodes. However, in this case, the R-APS channel is terminated at the interconnection nodes.

9.6   Filtering database flush

An FDB flush consists of removing MAC addresses learned on the ring ports of the protected Ethernet ring from the Ethernet ring node's FDB.

Each ERP instance may flush only the FDB for the VIDs of the traffic channels of the set of VLANs it is assigned to protect.
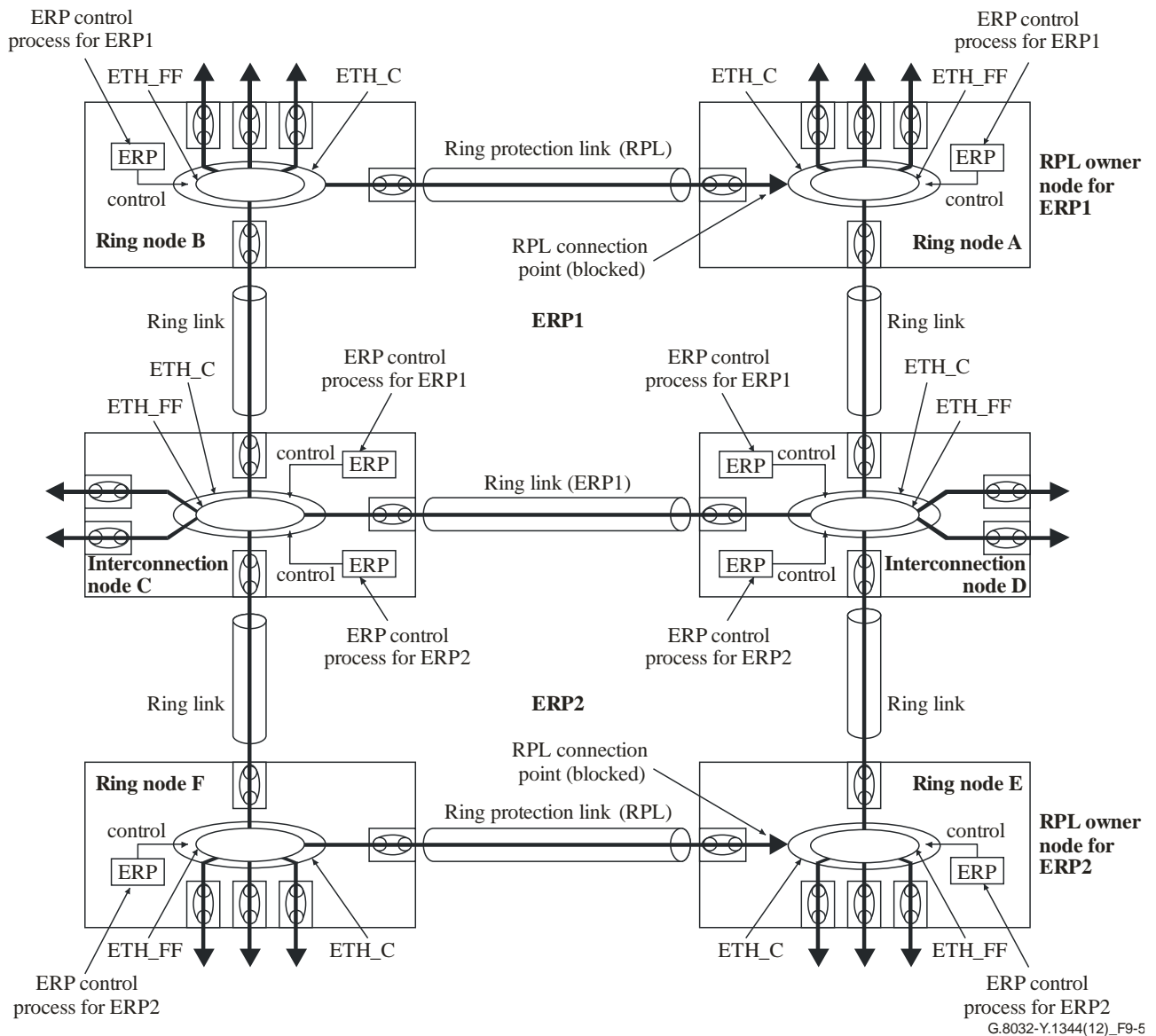
9.7   Ethernet ring protection switching models for interconnection

The ERP switching model for interconnection supports multi-ring/ladder topologies such as those illustrated in Appendix II.

Figure 9-5 depicts an example of the model on a multi-ring/ladder network defined in this Recommendation. If the multi-ring/ladder network is in its normal condition, the RPL owner node of each Ethernet ring blocks the transmission and reception of traffic over the RPL for that Ethernet ring. Figure 9-5 presents the configuration when no failure is present on any ring link.

In Figure 9-5 there are two interconnected Ethernet rings. Ethernet ring ERP1 is composed of Ethernet ring nodes A, B, C and D and the ring links between these Ethernet ring nodes. Ethernet ring ERP2 is composed of Ethernet ring nodes C, D, E and F and the ring links C-to-F, F-to-E, E-to-D. The ring link between D and C is used for traffic of Ethernet rings ERP1 and ERP2. On their own, ERP2 ring links do not form a closed loop. A closed loop may be formed by the ring links of ERP2 and the ring link between interconnection nodes that is controlled by ERP1. ERP2 is a sub-ring. Ethernet ring node A is the RPL owner node for ERP1. Ethernet ring node E is the RPL owner node for ERP2. These Ethernet ring nodes (A and E) are responsible for blocking the traffic channel on the RPL for ERP1 and ERP2 respectively. There is no restriction on which ring link on an Ethernet ring may be set as RPL. For example the RPL of ERP1 could be set as the link between Ethernet ring nodes C and D.

Ethernet ring nodes C and D, which are common to both ERP1 and ERP2, are called the interconnection nodes. The ring links between the interconnection nodes are controlled and protected by the Ethernet ring it belongs to. In the example of Figure 9-5, the ring link between Ethernet ring nodes C and D is part of ERP1 and, as such, controlled and protected by ERP1. The ETH_CI traffic corresponding to the traffic channel may be transferred over a common Ethernet connection function (ETH_C function [ITU-T G.8021]) for ERP1 and ERP2 through the interconnection nodes C and D. Interconnection nodes C and D have separate ERP control processes for each Ethernet ring.

**Figure 9-5 – Ethernet ring interconnection architecture –
normal condition (multi-ring/ladder network)**

Figure 9-6 illustrates a situation where protection switching has occurred due to an SF condition on the ring link between interconnection nodes C and D. The failure of this ring link triggers protection only on the Ethernet ring it belongs to, in this case ERP1. The traffic and R-APS channels are blocked bidirectionally on the ports where the failure is detected and bidirectionally unblocked at the RPL connection point on ERP1. The traffic channels remain bidirectionally blocked at the RPL connection point on ERP2. This prevents the formation of a loop.
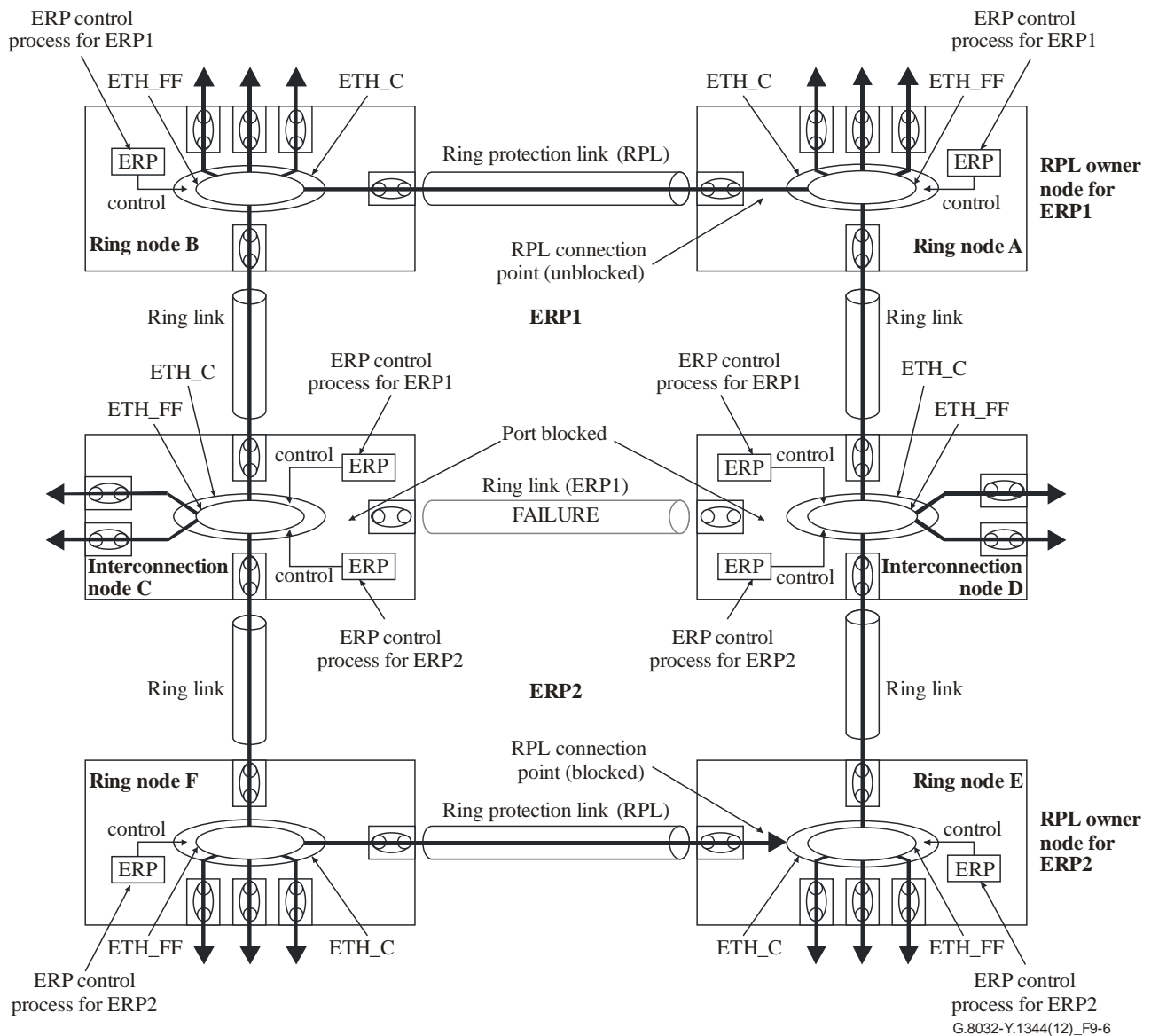
Figure 9-6 – Ethernet ring interconnection architecture – signal fail condition on a link between interconnection nodes (multi-ring/ladder network)

The interconnection nodes include functions to support the two Ethernet rings. Interconnection nodes C and D have a set of functions similar to Figure 9-4 to support Ethernet ring ERP1. Sub-ring ERP2 on these interconnection nodes only controls and protects one ring port; for this reason, the model required to support sub-ring ERP2 on these interconnection nodes is presented as follows – clause 9.7.1 presents the model with an R-APS virtual channel and clause 9.7.2 presents the model without an R-APS virtual channel.

9.7.1 Ring interconnection model with an R-APS virtual channel

For the sub-ring, the connectivity at the interconnection node is provided between a sub-ring link and the domain of another network. In the example of Figure 9-5, this network corresponds to Ethernet ring ERP1. An R-APS virtual channel provides R-APS connectivity between this interconnection node and the other interconnection node of the same sub-ring, over the network.

An example of the functional model of an interconnection node for a sub-ring using the R-APS virtual channel is depicted in Figure 9-7.
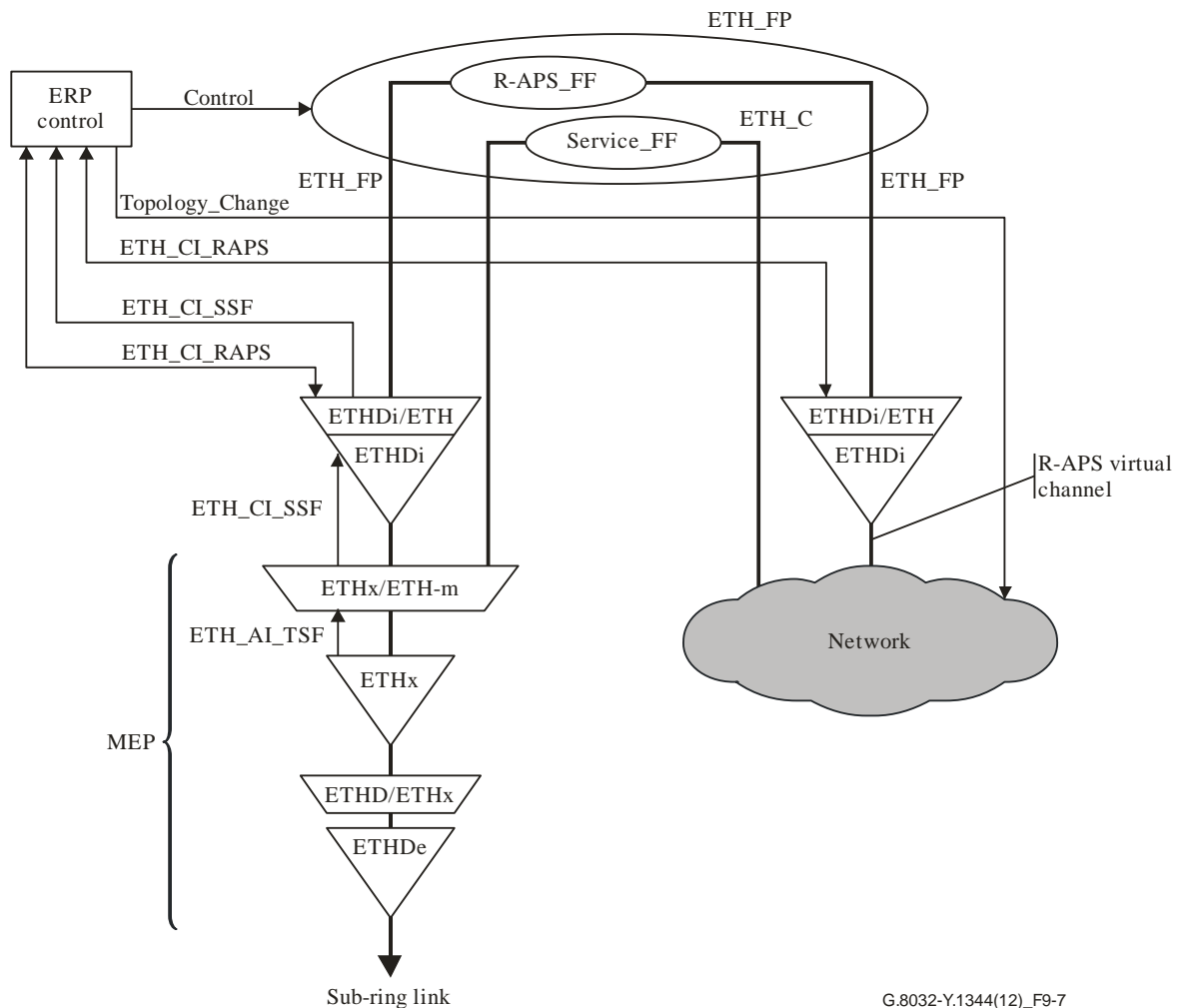
**Figure 9-7 – MEPs and R-APS insertion function in an interconnection node
(for a sub-ring connected to other network)**

The R-APS virtual channel may follow the same path as the traffic channel over the network. The ERP control process of the sub-ring is capable of receiving and inserting R-APS messages over the R-APS virtual channel.

R-APS messages of this sub-ring that are forwarded over its R-APS virtual channel are broadcast or multicast over the interconnected network. For this reason, the broadcast or multicast domain of the R-APS virtual channel could be limited to the necessary links and nodes. For example, the R-APS virtual channel could span only the interconnecting Ethernet rings or sub-rings that are necessary for forwarding R-APS messages of this sub-ring. Care must be taken to ensure that the local R-APS messages of the sub-ring being transported over the R-APS virtual channel into the interconnected network can be uniquely disambiguated from those of other interconnected ring R-APS messages. This can be achieved by, for example, using separate VIDs for the R-APS virtual channels of different sub-rings.

Sub-ring topology changes may impact flow forwarding over the domain of the other (interconnected) network, as such topology change events are signalled to the domain of the other network using the Topology_Change signal. It is outside of the scope of this recommendation to define the use of Topology_Change signal by other technologies, such as the spanning tree protocol (STP) or virtual private local area network service (VPLS).

Figure 9-8 represents the model of an interconnection node combining the functions required to support the two Ethernet rings.

Figure 9-8 – MEPs and R-APS insertion function in an interconnection node with an R-APS virtual channel (different R-APS VIDs)

The MEPs on ring links 0 and 1 are used for monitoring the ring links of ERP1. The MEP on the sub-ring link monitors the ring link of the sub-ring ERP2. In the model of Figure 9-8, R-APS channels are separated in ERP1 using different R-APS VIDs. R-APS messages for ERP1 are received on ring links 0 or 1 and separated based on the VID used for the R-APS_1 flow at the ETH to ETH multiplexing adaptation function (ETHx/ETH-m_A [ITU-T G.8021]) function. The ETHDi/ETH_A functions extract ETH_CI_RAPS information from the received R-APS messages and send the ETH_CI_RAPS information to the ERP control process of ERP1. The R-APS messages of the sub-ring received on ring link 0 and on ring link 1 are separated based on the VID used for the R-APS_2 flow at the ETHx/ETH-m_A function and they are then forwarded by the R-APS_2_FF function to the ETHDi/ETH_A function where it extracts ETH_CI_RAPS information from the received R-APS messages and sends the ETH_CI_RAPS information to the ERP control process of ERP2. If not blocked at the ETH_C function of ERP2, these messages are then further transmitted to the sub-ring port.

The R-APS VID of ERP2 may be considered as protected traffic spanning all ring links of ERP1, being blocked on the ring links of ERP1 by the same function that blocks the traffic channel on the ring links of that Ethernet ring. Figure 9-8 is only one example, other options for the construction of the R-APS virtual channel may be used.

NOTE – Other solutions for the construction of the R-APS virtual channel are for further study.

Service traffic may be forwarded between any of the three ring ports, or even other ports. This forwarding is also subject to the blocking state of the Ethernet ring and sub-ring ports as defined by the respective ERP control processes.

A Topology_Change signal is generated from ERP2 to the ERP1 control process whenever sub-ring ERP2 performs a protection switching event that results in a topology change; this occurs when an FDB flush is generated for the ERP2 interconnection node. Depending on the configuration, this signal may be used by the ERP control process of ERP1 to initiate actions to also trigger a topology update over Ethernet ring nodes on Ethernet ring ERP1.

9.7.2 Ring interconnection model without an R-APS virtual channel

In certain network scenarios, it may be desirable for the R-APS virtual channel of the sub-ring over the other network domain not to be used.

An example of the functional model of an interconnection node for a sub-ring not using the R-APS virtual channel is depicted in Figure 9-9.
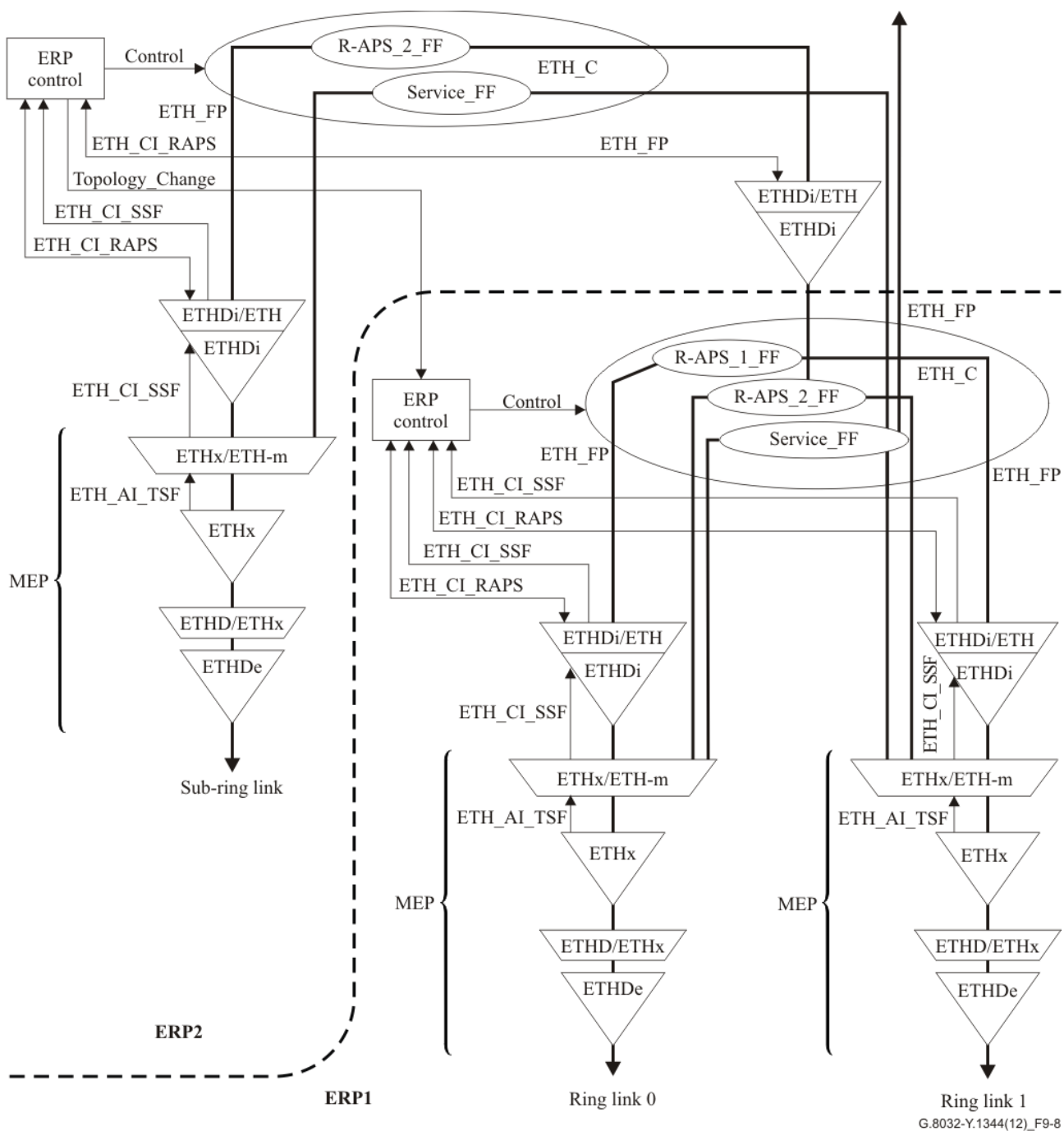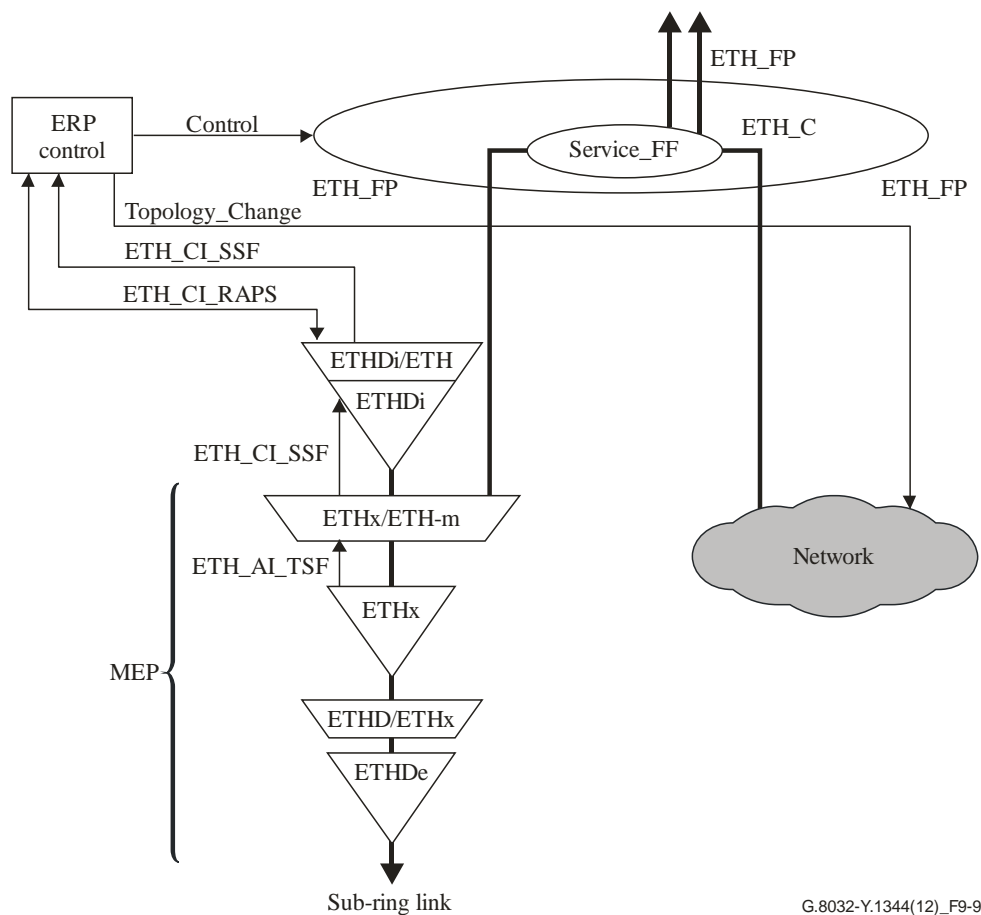
Figure 9-9 – MEPs and R-APS insertion function in a sub-ring interconnection node without an R-APS virtual channel (for a sub-ring connected to another network)

As depicted in Figure 9-9, the R-APS channel of the sub-ring is terminated at the interconnection nodes.

In order to prevent R-APS channel segmentation in the normal Ethernet ring condition, since there is neither an R-APS channel nor an R-APS virtual channel between the interconnection nodes of the sub-ring, the R-APS channel blocking (defined in clause 9.5) is not employed in these sub-ring configurations. If ring link failure of any ring link of the sub-ring occurs, the R-APS channel of the sub-ring may be segmented, preventing R-APS message exchange between some of the sub-ring's Ethernet ring nodes.

Apart from R-APS channel specifics, the operation of the sub-ring without an R-APS virtual channel is identical to that of a sub-ring with an R-APS virtual channel. Interconnection nodes also perform the same functions to inform other networks of topology change and flush propagation.

In addition, in order to ensure correct operation of the FDB flush operation, there are changes to the operation of the flush logic (see clause 10.1.10).

Figure 9-10 represents the model of an interconnection node combining the functions required to support the two Ethernet rings.

G.8032-Y.1344(12)_F9-10
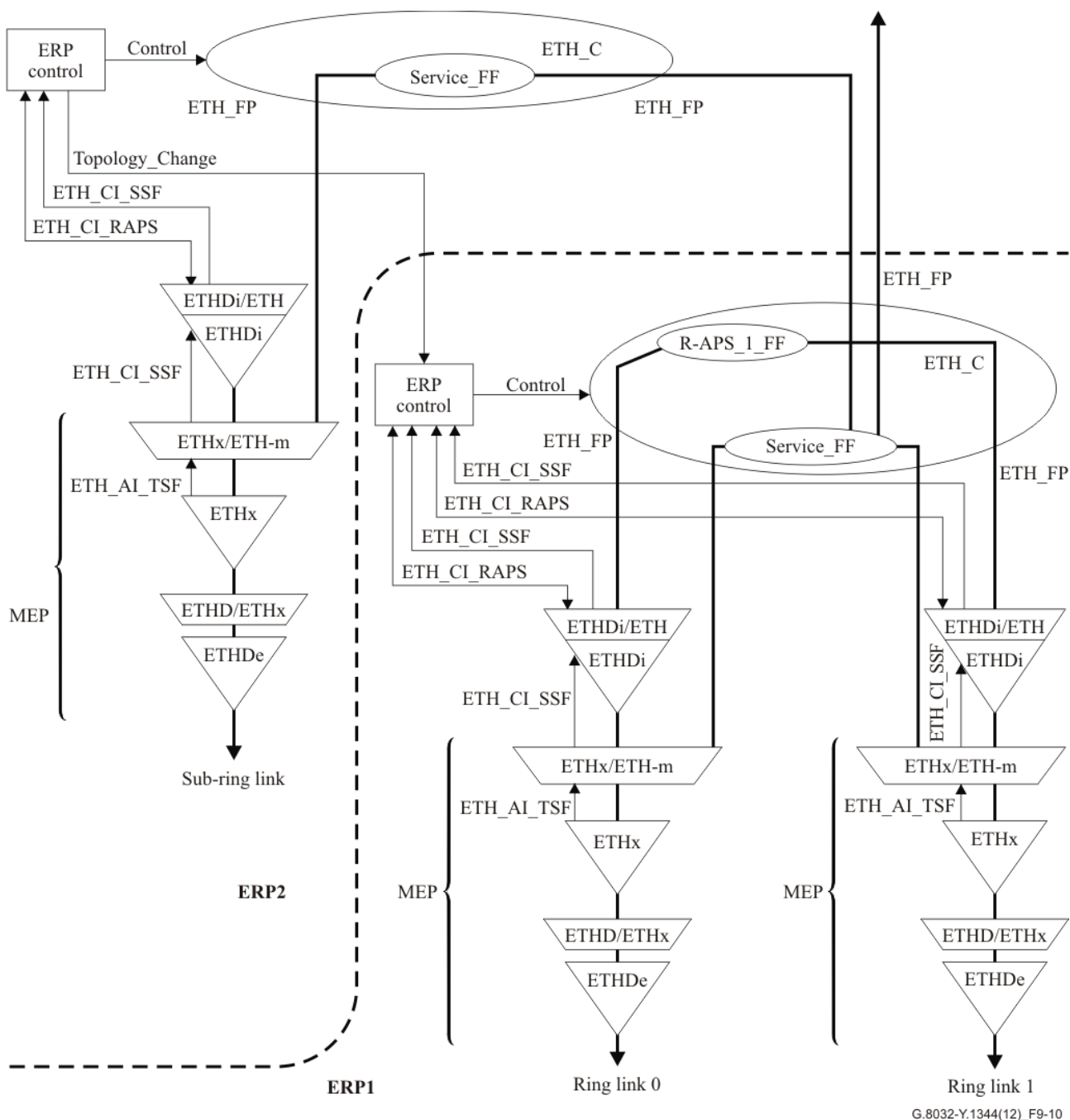
Figure 9-10 – MEPs and R-APS insertion function in a sub-ring interconnection node without an R-APS virtual channel (for a sub-ring connected to a major ring)

9.7.3   Guidelines for using the ring interconnection model with or without an R-APS virtual channel

This Recommendation defines two Ethernet ring interconnection options, as shown in Figure 9-11.

1)   Sub-ring with an R-APS virtual channel: In this option, a virtual channel to tunnel R-APS messages from one interconnection node to the other interconnection node is established.

2)   Sub-ring without an R-APS virtual channel: In this option, the R-APS channel is terminated at the interconnection nodes and its R-APS messages are not tunnelled between the interconnection nodes.
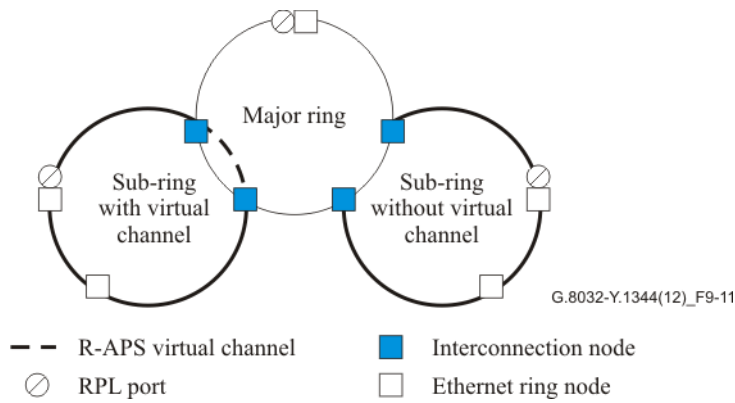
Figure 9-11 – Ring interconnection options

In option 1, the R-APS channel blocking mechanism as defined in clause 9.5 is the same for both single and multi-ring application. In addition, this option allows operators to interconnect multiple Ethernet rings (or non ITU-T G.8032 networks) without the need to reconfigure the major ring as a sub-ring (i.e., regarding the ERP control process and R-APS channel blocking mechanism). In the example of Figure 9-12, both major rings 1 and 2 can be interconnected via a newly configured sub-ring 3 with two R-APS virtual channels. However, it should be noted that the R-APS virtual channel requires a certain bandwidth to forward R-APS messages on the interconnected Ethernet ring(s) (or network) where a sub-ring is attached and it is necessary to allocate different VIDs to differentiate between each R-APS channel within a whole interconnected network. It should also be noted that the protection switching time of the sub-ring might be affected if R-APS messages traverse a long distance over an R-APS virtual channel. Major ring 1 might not be flushed due to protection switching in major ring 2 (and vice versa) and major rings 1 and 2 might be flushed due to protection switching in sub-ring 3.
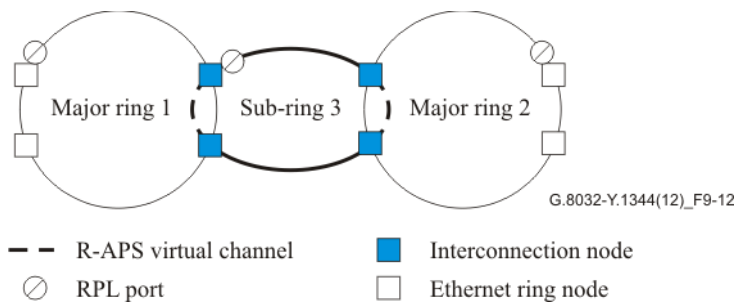
Figure 9-12 – Interconnection of two Ethernet rings with option 1

In option 2, no R-APS messages are inserted or extracted by another Ethernet ring(s) [or sub-ring(s)] at interconnection nodes where a sub-ring is attached. Hence there is no need for either additional bandwidth or different VIDs for the Ethernet ring interconnection. Furthermore, the protection switching time for a sub-ring is independent from the configuration of the interconnected Ethernet ring(s). In addition, this option always ensures that an interconnected network forms a tree topology regardless of its interconnection configuration. This means that it is not necessary to take precautions not to form a loop that is potentially composed of a whole interconnected network. However, the R-APS channel blocking mechanism is different from that of a single Ethernet ring as described in clause 10.1.14. In addition, if two Ethernet rings are interconnected using a sub-ring, the attributes of one of the Ethernet rings may need to be reconfigured to define it as a sub-ring. For example, major ring 2 of Figure 9-12 is reconfigured as a sub-ring (i.e., sub-ring 2 in Figure 9-13) for the interconnection. As a result, service interruption may occur during this reconfiguration and major ring 1 might perform FDB flushing due to protection switching in sub-rings 2 or 3.
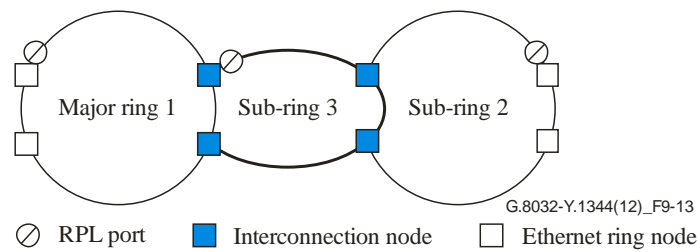
Figure 9-13 – Interconnection of two Ethernet rings with option 2

10 Protection control protocol

Ring protection is based on loop avoidance. This is achieved by guaranteeing that at any time traffic may flow on all but one of the ring links. From this principle the following rule is derived for the protocol:

> *Once a ring port has been blocked, it may be unblocked only if it is known that there remains at least one other blocked ring port in the Ethernet ring.*

This rule is used as the basis to control all actions of traffic channel unblocking in the Ethernet ring, as well as to define the information that is necessary to distribute between all Ethernet ring nodes.

10.1 Principles of operations

Figure 10-1 shows a breakdown of the ERP control process. This process is performed at all Ethernet ring nodes.

The protection algorithm is based on the transmission of local switch requests and local status to all Ethernet ring nodes via the R-APS specific information. Format and content of an R-APS message are described in clause 10.3.
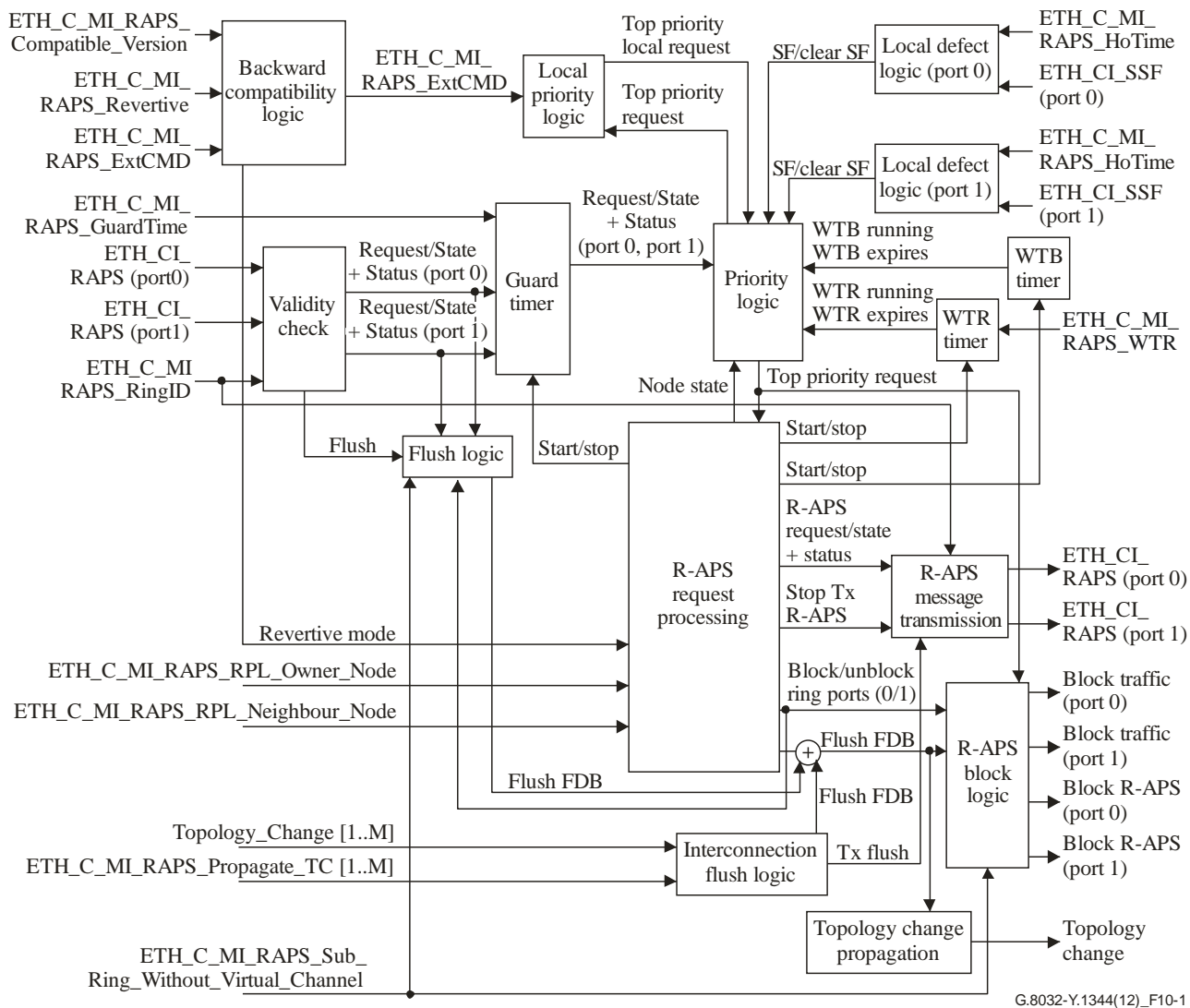
Figure 10-1 – Breakdown of the ERP control process

The following is an overview of the ERP control process. The behaviour of each sub-process is described in detail in clauses 10.1.1 to 10.1.14.

At an Ethernet ring node, one or more local protection switching requests may be active. The local priority logic determines which of these requests is of top priority, using the priority order given in Table 10-1. This top priority local request information is passed to the priority logic.

The status of the local Ethernet ring node's ring ports is evaluated according to the methods defined in clause 9.2.1. This information is passed on to the local defect logic for each of the Ethernet ring node's ports. The local defect logic evaluates these signals, processes the hold-off timer and passes them to the priority logic. On the ERP control process for a sub-ring at an interconnection node, only one local defect logic process exists, assigned to the sub-ring link of that Ethernet ring node. The local Ethernet ring node receives information from the other Ethernet ring nodes via R-APS messages. The validity check, as described in clause 10.1.6, verifies that the R-APS message is correctly constructed. The received request/state and status information, which indicates the top priority request and status of other Ethernet ring nodes, is then passed to the guard timer. At an interconnection node, the R-APS messages may be received via an R-APS virtual channel.

The guard timer functionality is described in clause 10.1.5. While the guard timer is running, the received R-APS request/state and status information is not forwarded to the priority logic. If the guard

timer is not running, the R-APS request/state and status information is forwarded to the priority logic entity.

The functionality of the WTR timer is described in clause 10.1.4. While the WTR timer is running, the WTR Running signal is input to the priority logic. The expiration of the WTR timer is indicated by the WTR Expires signal and is passed to the priority logic entity.

The functionality of the WTB timer is described in clause 10.1.4. While the WTB timer is running, the WTB Running signal is input to the priority logic. The expiration of the WTB timer is indicated by the WTB Expires signal and is passed to the priority logic entity.

An R-APS message is defined as accepted if the message passes the validity check, is passed by the guard timer to the priority logic and is identified as the current top priority request signalled to the R-APS request processing logic.

The priority logic accepts as inputs: (a) the R-APS request/state and status information (after screening by the validity check and the guard timer), (b) status and events from the WTR timer, (c) status and events from the WTB timer, (d) status of the local Ethernet ring node's ring ports, (e) top priority local request (from the local priority logic) and (f) the current node state from the R-APS request processing. It processes the priority according to Table 10-1 to determine the top priority signal.

ETH_C_MI_RAPS_RPL_Owner_Node represents management information (MI) that indicates whether the local Ethernet ring node is an RPL owner node and, if it is, specifies which ring port is attached to the RPL.

ETH_C_MI_RAPS_RPL_Neighbour_Node provides MI that indicates whether this Ethernet ring node is adjacent to the RPL and, if it is, specifies which ring port is attached to the RPL. By default the ETH_C_MI_RAPS_RPL_Neighbour_Node indicates the Ethernet ring node as not being adjacent to the RPL.

Both ETH_C_MI_RAPS_RPL_Owner_Node and ETH_C_MI_RAPS_RPL_Neighbour_Node cannot be enabled at the same Ethernet ring node for a single ERP instance.

NOTE – If ETH_C_MI_RAPS_RPL_Neighbour_Node is not configured for any Ethernet ring node on a ring, only one end of the RPL (i.e., only at the RPL owner node) is blocked.

The R-APS request processing receives the current top priority request and defines the necessary actions to take based on the local Ethernet ring node state. These actions may include transmission of R-APS messages, blocking or unblocking ring ports, flushing the FDB and starting or stopping the timers. The decision logic of the R-APS request processing is defined in clause 10.1.2 and represents the ERP behaviour described in clause 10.2.

The ERP switching algorithm commences immediately after any input signal (see Figure 10-1) changes, i.e., when the status of any local request changes or when a different R-APS message is received.

The flush logic is described in clause 10.1.10; it receives as inputs R-APS requests from the ring ports. Based on this information, it infers whether the logical topology of the Ethernet ring has been changed and, if so, triggers a flush of the local FDB.

The topology change propagation process is described in clause 10.1.12; it generates a signal to inform the entities of other network domains attached to a sub-ring of topology changes on the sub-ring. This process exists only on the ERP control processes of sub-ring interconnection nodes.

The interconnection flush logic is described in clause 10.1.11. It receives topology change notification information from other connected entities, such as a sub-ring's ERP control process and ETH_C_MI_RAPS_Propagate_TC MI. Based on this information, it may initiate flushing of the FDB for the local ring ports and may trigger transmission of R-APS event requests to both ring ports. This logic is included on the ERP control processes of the interconnection nodes of Ethernet rings that

sub-rings are connected to. This logic is not present on Ethernet ring nodes that are not interconnection nodes.

The backward compatibility logic is described in clause 10.1.13. It filters the configuration and requests of this version of this Recommendation when the Ethernet ring node is part of an Ethernet ring that is also composed of other Ethernet ring nodes which are implementing a previous version of this Recommendation.

The R-APS block logic is described in clause 10.1.14. It receives block/unblock ring ports (0/1) from the R-APS request processing, the top priority request from the priority logic and ETH_C_MI_RAPS_Sub_Ring_Without_Virtual_Channel signal. Based on these inputs, it decides to block or unblock the traffic channel or the R-APS channel on ring ports 0 and 1. This logic is present only in the ERP control process of sub-ring nodes.

10.1.1   Priority logic

This process receives requests from multiple sources. The request with the highest priority in Table 10-1, is declared as the top priority request. If an Ethernet ring node state is in FS state, a local SF request is ignored.

The evaluation of the top priority request is repeated every time a local request changes or an R-APS message is received.

Ring protection requests, commands and R-APS signals have the priorities specified in Table 10-1.

Table 10-1 – Request/state priority

Request/state and status	Type	Priority
Clear	local	highest
FS	local	|
R-APS (FS)	remote	|
local SF [a)]	local	|
local clear SF	local	|
R-APS (SF)	remote	|
R-APS (MS)	remote	|
MS	local	|
WTR Expires	local	|
WTR Running	local	|
WTB Expires	local	|
WTB Running	local	|
R-APS (NR, RB)	remote	|
R-APS (NR)	remote	lowest
[a)] If an Ethernet ring node is in the FS state, local SF is ignored.		

As a result of this process, once an SF condition or operator command (e.g., FS, MS) is declared at one of the ring ports, the priority logic retains this condition request as the current top priority request, until either a new higher priority request or an appropriate Clear message (i.e., Clear for either FS or MS, local clear SF for SF) is signalled. The local clear SF condition is only signalled as the top priority request if it is the highest priority request present and there is not any higher priority request (such as local SF or local FS) still pending on the other ring port.

Received R-APS request/state and status are not stored in this process. As a result, after the change of a local request, R-APS request/state and status received previously are not taken into consideration for the definition of the new top priority request.

R-APS messages whose node ID field value corresponds to the local node ID are ignored by this process.

A ring ID in the range [1, …, 239] can be configured for each ERP instance. This ring ID is used in the R-APS Message Transmission function to determine the value of the last octet of the MAC destination address field of the R-APS protocol data units (PDUs) generated by this ERP control process. It is also used by the Validity Check function to discard any R-APS PDUs received by this ERP control process with a non-matching ring ID.

With regard to the configuration of the ring ID, the following rules apply.

1.   All ERP control processes instantiated in an ERP protected network composed of interconnected major rings and sub-rings must be identifiable by a unique (ring ID, R-APS VID) pair.

2.   All ERP control processes instantiated on the same underlying physical major ring or sub-ring topologies must be assigned a different value of the R-APS VID. The same ring ID may be used for these ERP control processes.

3.   ERP control processes instantiated on different physical major ring or sub-ring topologies may use different ring IDs and in that case their R-APS VIDs need not be different.

10.1.2   R-APS request processing

The R-APS request processing logic receives the current top priority request and defines the necessary actions to take, based on the local Ethernet ring node state. The R-APS request processing logic is defined in the format of a state machine. Table 10-2 has the following fields.

1)   Node state – The current state of the Ethernet ring node.

2)   Top priority request – The current top priority request as defined in clause 10.1.1. Each possible trigger is represented on a separate row.

3)   Actions – A list of protection switching actions, in order of execution.

4)   Next node state – The state to which the state machine transits.

Table 10-2 – State machine representation of the R-APS request processing logic

Node state	Inputs		Row	Outputs	Next node state
Node state	**Top priority request**		**Row**	**Actions**	**Next node state**

–	State machine initialization		1	Stop guard timer
				Stop WTR timer
				Stop WTB timer
				If RPL owner node:
				    Block RPL port
				    Unblock non-RPL port
				    Tx R-APS (NR)
				    If revertive:
				        Start WTR timer
				Else if RPL neighbour node:
				    Block RPL port
				Unblock non-RPL port
				    Tx R-APS (NR)
				Else:
				    Block one ring port
				    Unblock other ring port
				    Tx R-APS (NR)
					E

A (Idle)	Clear		2	No action	A

	FS		3	If requested ring port is already blocked:
				    Tx R-APS (FS,DNF)
				    Unblock non-requested ring port
				Else:
				    Block requested ring port
				    Tx R-APS (FS)
				    Unblock non-requested ring port
				    Flush FDB
					D

	R-APS (FS)		4	Unblock ring ports Stop Tx R-APS	D

	local SF		5	If failed ring port is already blocked:
				    Tx R-APS (SF,DNF)
				    Unblock non-failed ring port
				Else:
				    Block failed ring port
				    Tx R-APS (SF)
				    Unblock non-failed ring port
				    Flush FDB
					B

	local clear SF		6	No action	A
	R-APS (SF)		7	Unblock non-failed ring port Stop Tx R-APS	B
	R-APS (MS)		8	Unblock non-failed ring port Stop Tx R-APS	C

Table 10-2 – State machine representation of the R-APS request processing logic

Node state	Inputs	Row	Outputs	Next node state
	Top priority request		Actions	

	MS	9	If requested ring port is already blocked:
			    Tx R-APS (MS,DNF)
			    Unblock non-requested ring port
			Else:
			    Block requested ring port
			    Tx R-APS (MS)
			    Unblock non-requested ring port
			    Flush FDB
				C

	WTR Expires	10	No action	A
	WTR Running	11	No action	A
	WTB Expires	12	No action	A
	WTB Running	13	No action	A
	R-APS (NR, RB)	14	Unblock non-RPL port If Not RPL owner node: Stop Tx R-APS	A

	R-APS (NR)	15	If neither RPL owner node nor RPL neighbour node, and remote node ID is higher than own node ID:
			    Unblock non-failed ring port
			    Stop Tx R-APS
				A

B (Protection)	Clear	16	No action	B

	FS	17	If requested ring port is already blocked:
			    Tx R-APS (FS,DNF)
			    Unblock non-requested ring port
			Else:
			    Block requested ring port
			    Tx R-APS (FS)
			    Unblock non-requested ring port
			    Flush FDB
				D

	R-APS (FS)	18	Unblock ring ports Stop Tx R-APS	D

	local SF	19	If failed ring port is already blocked:
			    Tx R-APS (SF,DNF)
			    Unblock non-failed ring port
			Else:
			    Block failed ring port
			    Tx R-APS (SF)
			    Unblock non-failed ring port
			    Flush FDB
				B

	local clear SF	20	Start guard timer Tx R-APS (NR)	E

Table 10-2 – State machine representation of the R-APS request processing logic

| Node state | Inputs | Row | Outputs | Next node state |
	Top priority request		Actions	
			If RPL owner node and revertive mode: Start WTR	
	R-APS (SF)	21	No action	B
	R-APS (MS)	22	No action	B
	MS	23	No action	B
	WTR Expires	24	No action	B
	WTR Running	25	No action	B
	WTB Expires	26	No action	B
	WTB Running	27	No action	B
	R-APS (NR, RB)	28	No action	E
	R-APS (NR)	29	If RPL owner node and revertive mode: Start WTR	E

C
(Manual switch)
	Clear	30	If any ring port blocked:
			    Start guard timer
			    Tx R-APS (NR)
			    If RPL owner node and revertive mode:
			        Start WTB
				E

	FS	31	If requested ring port is already blocked:
			    Tx R-APS (FS,DNF)
			    Unblock non-requested ring port
			Else:
			    Block requested ring port
			    Tx R-APS (FS)
			    Unblock non-requested ring port
			    Flush FDB
				D

	R-APS (FS)	32	Unblock ring ports Stop Tx R-APS	D

	local SF	33	If failed ring port is already blocked:
			    Tx R-APS (SF,DNF)
			    Unblock non-failed ring port
			Else:
			    Block failed ring port
			    Tx R-APS (SF)
			    Unblock non-failed ring port
			    Flush FDB
				B

	local clear SF	34	No action	C
	R-APS (SF)	35	Unblock non-failed ring port Stop Tx R-APS	B
	R-APS (MS)	36	If any ring port blocked:	E[a)]

Table 10-2 – State machine representation of the R-APS request processing logic

Node state	Top priority request	Row	Actions	Next node state
			Start guard timer Tx R-APS (NR) If RPL owner node and revertive mode: Start WTB	
	MS	37	No action	C
	WTR Expires	38	No action	C
	WTR Running	39	No action	C
	WTB Expires	40	No action	C
	WTB Running	41	No action	C
	R-APS (NR, RB)	42	No action	E
	R-APS (NR)	43	If RPL owner node and revertive mode: Start WTB	E

D
(Forced switch)
	Clear	44	If any ring port blocked:
			    Start guard timer
			    Tx R-APS (NR)
			    If RPL owner node and revertive mode:
			        Start WTB
				E

	FS	45	Block requested ring port Tx R-APS (FS) Flush FDB	D
	R-APS (FS)	46	No action	D
	local SF	47	No action	D
	local clear SF	48	No action	D
	R-APS (SF)	49	No action	D
	R-APS (MS)	50	No action	D
	MS	51	No action	D
	WTR Expires	52	No action	D
	WTR Running	53	No action	D
	WTB Expires	54	No action	D
	WTB Running	55	No action	D
	R-APS (NR, RB)	56	No action	E
	R-APS (NR)	57	If RPL owner node and revertive mode: Start WTB	E
E (Pending)	Clear	58	If RPL owner node: Stop WTR Stop WTB If RPL port is blocked: Tx R-APS (NR, RB,DNF)	A

Table 10-2 – State machine representation of the R-APS request processing logic

Node state	Top priority request	Row	Actions	Next node state

			Unblock non-RPL port
			Else:
			    Block RPL port
			    Tx R-APS (NR, RB)
			    Unblock non-RPL port
			      Flush FDB	

	FS	59	If requested ring port is already blocked:
			    Tx R-APS (FS,DNF)
			    Unblock non-requested ring port
			Else:
			    Block requested ring port
			    Tx R-APS (FS)
			    Unblock non-requested ring port
			    Flush FDB
			If RPL owner node:
			    Stop WTR
			    Stop WTB
				D

	R-APS (FS)	60	Unblock ring ports
			Stop Tx R-APS
			If RPL owner node:
			    Stop WTR
			    Stop WTB
				D

	local SF	61	If failed ring port is already blocked:
			    Tx R-APS (SF,DNF)
			    Unblock non-failed ring port
			Else:
			    Block failed ring port
			    Tx R-APS (SF)
			    Unblock non-failed ring port
			    Flush FDB
			If RPL owner node:
			    Stop WTR
			    Stop WTB
				B

	local clear SF	62	No action	E

	R-APS (SF)	63	Unblock non-failed ring port
			Stop Tx R-APS
			If RPL owner node:
			    Stop WTR
			    Stop WTB
				B

	R-APS (MS)	64	Unblock non-failed ring port Stop Tx R-APS If RPL owner node:	C

Table 10-2 – State machine representation of the R-APS request processing logic

Node state	Inputs	Row	Outputs	Next node state
	Top priority request	**Row**	**Actions**	**Next node state**
			Stop WTR Stop WTB	

	MS	65	If RPL owner node:
			    Stop WTR
			    Stop WTB
			If requested ring port is already blocked:
			    Tx R-APS (MS,DNF)
			    Unblock non-requested ring port
			Else:
			    Block requested ring port
			    Tx R-APS (MS)
			    Unblock non-requested ring port
			    Flush FDB
				C

	WTR Expires	66	If RPL owner node:
			    Stop WTB
			     If RPL port is blocked:
			    Tx R-APS (NR, RB,DNF)
			        Unblock non-RPL port
			    Else:
			        Block RPL port
			        Tx R-APS (NR, RB)
			        Unblock non-RPL port
			        Flush FDB
				A

	WTR Running	67	No action	E

	WTB Expires	68	If RPL owner node:
			    Stop WTR
			     If RPL port is blocked:
			    Tx R-APS (NR, RB,DNF)
			    Unblock non-RPL port
			    Else:
			        Block RPL port
			        Tx R-APS (NR, RB)
			    Unblock non-RPL port
			        Flush FDB
				A

	WTB Running	69	No action	E

	R-APS (NR, RB)	70	If RPL owner node:
			    Stop WTR
			    Stop WTB
			If neither RPL owner node nor RPL neighbour node:
			Unblock ring ports
			Stop Tx R-APS
				A

Table 10-2 – State machine representation of the R-APS request processing logic

Node state	Inputs		Row	Outputs		Next node state
	Top priority request			Actions		
				If RPL neighbour node: Block RPL port Unblock non-RPL port Stop Tx R-APS		
	R-APS (NR)		71	If remote node ID is higher than own node ID: Unblock non-failed ring port Stop Tx R-APS		E
^{a)} If both ring ports are unblocked, next node state is C.						

NOTE 1 – Table 10-2 should not be interpreted independently of the other sub-processes of the ERP control process, including the priority logic.

NOTE 2 – In R-APS (msgtype, status_bits), "msgtype" indicates the request/state and "status_bits" indicates that the RB or DNF status bit is 1. If "status_bits" is 0, it is not included in R-APS (msgtype, status_bits). These fields and their possible values are defined in clause 10.3.

Row 1 represents the actions being triggered at the initialization of the state machine. Once those actions are performed, the state machine shall transit to state E and eventually, when the network stabilizes, to state A.

The possible actions triggered by this process and listed in the "Actions" column are as follows.

a)   Block requested ring port − blocks the traffic channel and R-APS channel (in accordance with the process described in clause 10.1.14) on the ring port for which an operator command was issued. If the ring port is already blocked, it remains blocked.

b)   Unblock non-requested ring port − unblocks traffic channel and R-APS channel on the ring port for which no operator command is issued. If the ring port is already unblocked, it remains unblocked.

c)   Block failed ring port − blocks the traffic channel and R-APS channel (in accordance with the process described in clause 10.1.14) on the ring port, which has an SF condition. If the ring port is already blocked, it remains blocked.

d)   Unblock non-failed ring port − unblocks the traffic channel and R-APS channel on either of the ring ports if it does not have an SF condition. If the ring port is already unblocked, it remains unblocked. In the case of an interconnection node of a sub-ring, this action is only applied to the sub-ring port.

e)   Block RPL port − blocks the traffic channel and R-APS channel (in accordance with the process described in clause 10.1.14) on the ring port, which is connected to the RPL. If the ring port connected to the RPL is already blocked, it remains blocked.

f)   Unblock non-RPL port − unblocks the traffic channel and R-APS channel on the ring ports if it is not the RPL port. If the ring port is already unblocked, it remains unblocked. In the case of an interconnection node of a sub-ring, this action is only applied to the sub-ring port.

g)   Block one ring port − blocks the traffic channel and R-APS channel (in accordance with the process described in clause 10.1.14) on one of the ring ports.

h)   Unblock other ring port – unblocks traffic channel and R-APS channel on the second ring port where the port is not unblocked. In the case of an interconnection node of a sub-ring, this action is not applied.

i)   Unblock ring ports – unblocks the traffic channel and R-APS channel on both ring ports. If a ring port is already unblocked, it remains unblocked. In the case of an interconnection node of a sub-ring, this action is only applied to the sub-ring port.

j)   Start WTR – starts the WTR timer, if it is stopped. If the WTR timer is already running, no action is taken.

k)   Stop WTR – stops the WTR timer, if it is running.

l)   Start WTB – starts the WTB timer, if it is stopped. If the WTB timer is already running, no action is taken.

m)   Stop WTB – stops the WTB timer, if it is running.

n)   Start guard timer – starts the guard timer.

o)   Stop guard timer – stops the guard timer, if it is running.

p)   Stop Tx R-APS – stops the transmission of any R-APS messages.

q)   Tx R-APS (msgtype, status_bits) – starts the continuous transmission of R-APS messages on both ring ports as described in clause 10.1.3.

r)   Flush FDB – Triggers an FDB flush as described in clause 9.6.

In the multi-ring/ladder network, a failure on the ring link connecting the interconnection nodes triggers the above actions only on the Ethernet ring that it is configured to be part of. In case of a link failure on one of the sub-ring links, this triggers the above actions only on that sub-ring.

10.1.3   R-APS message transmission

R-APS messages are transmitted with the request/state and status information defined by the R-APS request process and with the ring ID (configured via ETH_C_MI_RAPS_RingID) encoded in the MAC destination address.

The action Tx R-APS (msgtype, status_bits) starts the transmission of an R-APS message with the request/state field set to the value defined by msgtype and with the status bits enumerated in status_bits with value 1 and the remaining status bits with value 0. R-APS messages are transmitted over both ring ports. This also stops the continuous transmission of any other messages, with the exception of "event" messages described below.

The action Stop Tx R-APS, results in stopping transmission of any R-APS messages.

The R-APS messages are transported via an R-APS specific VLAN.

A new R-APS message should be transmitted immediately when required as an output action of Table 10-2.

If the R-APS information to be transmitted has been changed, a burst of three R-APS messages is transmitted as quickly as possible. This ensures that fast protection switching is possible even if one or two R-APS messages are lost or corrupted. For protection switching within 50 ms, the interval between the first three R-APS messages should be not more than 3.33 ms, which is the same interval as CCM messages for fast defect detection. For messages other than the "event" message, the R-APS message continues to be transmitted, after the first three messages are transmitted, with a frequency of one message every 5 s.

Unless otherwise stated, all R-APS messages are transmitted on both ring ports. If interconnection nodes of a sub-ring have an R-APS virtual channel, the R-APS messages are always transmitted over the sub-ring link and the R-APS virtual channel. On interconnection nodes of a sub-ring without an R-APS virtual channel, the sub-ring R-APS messages are transmitted only to the sub-ring port. This

is, in general, also applied in cases where transmission of messages is described to be performed on "both ring ports".

The transmission of R-APS "event" messages is performed only as a single burst of three R-APS messages, i.e., it is not continuously repeated beyond this burst. Contrary to other messages, the transmission of this R-APS message is done in parallel to other existing transmission. It does not stop the transmission of other messages and is not stopped by the transmission of other messages. Flush messages are R-APS "event" messages transmitted using a sub-code field (see clause 10.3) with value "0000" and with a status field (see clause 10.3) with value "00000000".

10.1.4   Delay timers

The RPL owner node uses a delay timer before initiating an RPL block in case of both revertive mode of operation or before reverting to idle state (state A) after clearing operator commands (FS, MS). In the revertive mode of operation, the WTR timer is used to prevent frequent operation of the protection switching due to intermittent SF defects. The WTB timer is used when clearing FS and MS commands. As multiple FS commands are allowed to co-exist in an Ethernet ring, the WTB timer ensures that clearing of a single FS command does not trigger the re-blocking of the RPL. When clearing a MS command, the WTB timer prevents the formation of a closed loop due to a possible timing anomaly where the RPL owner node receives an outdated remote MS request during the recovery process.

a)   When recovering from an SF, the delay timer must be long enough to allow the recovering network to become stable. This delay timer, called the WTR timer, may be configured by the operator (via ETH_C_MI_RAPS_WTR) in 1 min steps between 1 and 12 min; the default value being 5 min.

b)   When recovering from an operator command (i.e., FS or MS) the delay timer must be long enough to receive any latent remote FS, SF or MS. This delay timer called the WTB timer is defined to be 5 s longer than the guard timer (see clause 10.1.5). This is enough time to allow a reporting Ethernet ring node to transmit two R-APS messages and allow the Ethernet ring to identify the latent condition.

This delay timer is activated on the RPL owner node. When the relevant delay timer expires, the RPL owner node initiates the reversion process by transmitting an R-APS (NR, RB) message. The delay timer, (i.e., WTR or WTB) is deactivated when any higher priority request pre-empts this delay timer.

The delay timers (i.e., WTR and WTB) may be started and stopped. A request to start running the delay timer does not restart the delay timer. A request to stop the delay timer stops the delay timer and resets its value. The Clear command can be used to stop the delay timer.

While a delay timer is running, the appropriate WTR or the WTB Running signal is continuously generated. After a delay timer expires, the WTR or WTB Running signal is stopped and the WTR or WTB Expires signal, respectively, is generated. When a delay timer is stopped by the Clear command, neither the WTR nor WTB Expires signal is generated.

10.1.5   Guard timer

R-APS messages are transmitted as defined in clause 10.1.3. This forwarding method, in which R-APS messages are copied and forwarded at every Ethernet ring node, can result in a message corresponding to an old request, that is no longer relevant, being received by Ethernet ring nodes. Reception of an old R-APS message may result in erroneous ring state interpretation by some Ethernet ring nodes. The guard timer is used to prevent Ethernet ring nodes from acting upon outdated R-APS messages and prevents the possibility of forming a closed loop.

The guard timer is activated whenever an Ethernet ring node receives an indication that a local switching request has cleared (i.e., local clear SF, Clear). The period of the guard timer may be configured by the operator (via ETH_C_MI_RAPS_GuardTime) in 10 ms steps between 10 ms and

2 s, with a default value of 500 ms. This timer period should be greater than the maximum expected forwarding delay in which an R-APS message traverses the entire ring. The longer the period of the guard timer, the longer an Ethernet ring node is unaware of new or existing relevant requests transmitted from other Ethernet ring nodes and therefore unable to react to them.

A guard timer is used in every Ethernet ring node. Once a guard timer is started, it expires by itself. While the guard timer is running, any received R-APS request/state and status information, except R-APS messages with request/state field = "1110" described in clause 10.1.6, is blocked and not forwarded to the priority logic. When the guard timer is not running, the R-APS request/state and status information is forwarded unchanged.

10.1.6 Validity check

The validity check verifies that the request/state field of the received R-APS message is one of the request/states defined in Table 10-3. R-APS messages with request/state fields described as reserved for future international standardization are filtered. When an R-APS message is received with request/state field = "1110" and the sub-code field is "0000" and the status field has the value "00000000", the flush indication is signalled to the flush logic. The flush indication signal is disabled after a period of 10 ms. R-APS messages with request/state field = "1110" are not affected by the guard timer.

Additionally, the validity check verifies that the ring ID of the received R-APS message matches the ring ID of the ERP instance. R-APS messages with a non-matching ring ID are filtered.

10.1.7 Local defect logic

Local defect logic asserts the SF condition of one ring link based on the received ETH_CI_SSF information and the hold-off timer process. The reception of ETH_CI_SSF results in continuously signalling SF, after the hold-off timer process, until the ETH_CI_SSF is cleared.

Clearance of the ETH_CI_SSF results in producing the clear SF signal.

10.1.8 Hold-off timer

In order to coordinate the timing of protection switches at multiple layers, a hold-off timer may be required. Its purpose is to allow, for example, a server layer protection switch to have a chance to fix the problem before switching at a client layer.

Each ERP control process should have a configurable hold-off timer (configurable via ETH_C_MI_RAPS_HoTime). The suggested range of the hold-off timer is 0 to 10 s in steps of 100 ms with an accuracy of ±5 ms. The default value for the hold-off timer is 0 s.

When a new defect or more severe defect occurs (new SF), this event is not to be reported immediately to protection switching if the provisioned hold-off timer value is non-zero. Instead, the hold-off timer is started. When the hold-off timer expires, the trail that started the timer is checked as to whether a defect still exists. If so, that defect is reported to protection switching. The reported defect need not be the same one that started the timer.

10.1.9 Local priority logic

Local priority logic evaluates the local operator commands (in ETH_C_MI_RAPS_ExtCMD) according to the current top priority request. The commands Clear, MS and FS from the operator, are forwarded to the priority logic.

The Clear command is only valid if:

a)   a local FS or MS command is in effect [clear operation a) described in clause 8], or

b)   a local Ethernet ring node is an RPL owner node and top priority request is neither R-APS (FS) nor R-APS (MS) [clear operations b) or c] described in clause 8].

If local command is overridden by a new top priority request of a higher priority, i.e., a local condition, local command or an R-APS request, that command is forgotten. For example, if a higher priority request is received as the top priority request, any existing local MS or FS is removed and the previous command is no longer signalled as a top priority local request. In this case, the command is automatically deleted without forwarding the specific Clear command to the priority logic.

10.1.10 Flush logic

The flush logic retains for each ring port the information of node ID and blocked port reference (BPR) of the last R-APS message received over that ring port. As part of the initialization of the ERP control process, this information pair should be reset at both ring ports to the following values:

- Node ID: 00:00:00:00:00:00

- BPR: 0

For each new R-APS message received over one ring port, the flush logic extracts the (node ID, BPR) pair and compares it with the previous (node ID, BPR) pair stored for that ring port. If it is different from the previous pair stored, then the previous pair is deleted and the newly received (node ID, BPR) pair is stored for that ring port. If it is different from the (node ID, BPR) pair already stored at the other ring port, then a flush FDB action is triggered, except when the new R-APS message has DNF or the receiving Ethernet ring node's ID. An R-APS (NR) message received by this process does not cause a flush FDB, however, it causes the deletion of the current (node ID, BPR) pair on the receiving ring port. Nonetheless, the received (node ID, BPR) pair is not stored. When the ring port is changed to be blocked – as indicated by the block/unblock ring ports signal – the flush logic deletes the current (node ID, BPR) pair on both ring ports.

For interconnected rings running the sub-ring without the virtual channel model, the following procedure should be followed. For each new R-APS message received over one ring port, the flush logic extracts the (node ID, BPR) pair and compares it with the previous (node ID, BPR) pair stored for that ring port. If it is different from the previous pair stored, then the previous pair is deleted and the newly received (node ID, BPR) pair is stored for that ring port and a flush FDB action is triggered unless the new R-APS message has its DNF bit set. In addition, the (node ID, BPR) pair stored at the other ring port is deleted. An R-APS (NR) message received by this process does not cause a flush FDB; however, it causes the deletion of the current (node ID, BPR) pair on the receiving ring port, while the received (node ID, BPR) pair is not stored. When a ring port's blocking status is changed to be blocked – as indicated by the block/unblock ring ports signal – the flush logic deletes the current (node ID, BPR) pair on both ring ports.

The flush logic triggers a flush FDB action when it receives a flush indication from the validity check.

10.1.11 Interconnection flush logic

The interconnection flush logic of an ERP control process that controls two ring ports (i.e., the target ERP instance) receives as inputs the topology change signal Topology_Change[1..M] from all ERP control processes for sub-rings, located at the same interconnection node. In addition, for each Topology_Change[1..M] signal, there is a corresponding MI ETH_C_MI_RAPS_Propagate_TC[1..M] signal. When one of these Topology_Change signals toggles from disabled to enabled, a flush FDB action is triggered on the ring port of the target ERP instance. In addition to the Topology_Change signal, if the corresponding ETH_C_MI_RAPS_Propagate_TC MI is enabled, a transmission of a burst of three R-APS "event" messages is triggered over the R-APS channel of the target ERP instance.

ETH_C_MI_RAPS_Propagate_TC accepts the values enabled and disabled. The default value of the ETH_C_MI_RAPS_Propagate_TC shall be disabled.

10.1.12 Topology change propagation

The topology change propagation enables the Topology_Change signal when a flush FDB action is triggered by the ERP control process of a sub-ring's ERP instance. The Topology_Change signal is disabled after a period of 10 ms.

10.1.13 Backward compatibility logic

Backward compatibility logic accepts as inputs ETH_C_MI_RAPS_Compatible_Version, ETH_C_MI_RAPS_Revertive and ETH_C_MI_RAPS_ExtCMD, i.e., commands that are specific to this version of this Recommendation. If the ETH_C_MI_RAPS_Compatible_Version is set to the version number of this Recommendation, the inputs and commands are forwarded transparently. If the ETH_C_MI_RAPS_Compatible_Version is set to a previous version number than the version number of this Recommendation, then some inputs and commands may not be forwarded. The default value of the ETH_C_MI_RAPS_Revertive shall be true. When the ETH_C_MI_RAPS_Revertive is set to false, the Ethernet ring is operated in non-revertive mode.

a)   If the ETH_C_MI_RAPS_Compatible_Version is set to '1' then:

   1) MS and FS operator commands in ETH_C_MI_RAPS_ExtCMD are filtered and are not passed to the local priority logic.

   2) Revertive mode is set to the value true.

b)   If the ETH_C_MI_RAPS_Compatible_Version is set to '2' then:

   1) MS and FS operator commands in ETH_C_MI_RAPS_ExtCMD are forwarded to the local priority logic.

   2) Revertive mode is set to the same value as the input ETH_C_MI_RAPS_Revertive.

c)   ETH_C_MI_RAPS_Compatible_Version accepts the values '1' and '2'. The default value of the ETH_C_MI_RAPS_Compatible_Version shall be '2'. The ETH_C_MI_RAPS_Compatible_Version is set to '1' when an Ethernet ring node, supporting only functionalities of ITU-T G.8032 (2008) and its Amendment 1 (2009), exists on the same Ethernet ring.

10.1.14 R-APS block logic

The R-APS block logic receives the block/unblock ring ports (0/1) signal from the R-APS request processing, the top priority request from the priority logic and the ETH_C_MI_RAPS_Sub_Ring_Without_Virtual_Channel signal.

When the ETH_C_MI_RAPS_Sub_Ring_Without_Virtual_Channel is disabled, i.e., the sub-ring is configured to run with an R-APS virtual channel, both the traffic channel and the R-APS channel are blocked, when the block/unblock indicates the need to block a ring port.

When the ETH_C_MI_RAPS_Sub_Ring_Without_Virtual_Channel is enabled, i.e., the sub-ring is configured to run without an R-APS virtual channel and the top priority request is not a local SF or local FS request, then the traffic channel is blocked on the appropriate ring port (0/1) based on the block/unblock ring port (0/1) signal; however, the R-APS channel is not blocked. If the top priority request is either a local SF or local FS then, depending on the value of the block/unblock ring port (0/1) signal, both the traffic channel and the R-APS channel are blocked for the appropriate ring port.

The default value of the ETH_C_MI_RAPS_Sub_Ring_Without_Virtual_Channel shall be disabled.

10.2   Protection switching behaviour

Protection switching behaviours on failure and recovery conditions are described in this clause.

NOTE – Scenarios illustrating the sequence of events in protection switching are included in Appendix III.

10.2.1 Protection switching – Link signal fail

An Ethernet ring with no SF request has a logical topology with the traffic channel blocked at the RPL and unblocked on all other ring links. In this situation, the detection of an SF condition on a ring link triggers protection switching as follows.

a)   If no other higher priority request exists, an Ethernet ring node detecting an SF condition on one of its ring ports blocks the traffic channel and R-APS channel on the failed ring port.

b)   If no other higher priority request exists, the Ethernet ring node detecting an SF condition transmits an R-APS message indicating SF on both ring ports. The R-APS (SF) message informs other Ethernet ring nodes of the SF condition and the fact that the traffic and R-APS channels are blocked on one ring port. The R-APS (SF) message shall be continuously transmitted by the Ethernet ring node detecting the SF condition while this condition persists. For sub-ring interconnection nodes, the R-APS (SF) message is transmitted on the R-APS channel of the sub-ring port.

c)   If no other higher priority request exists and assuming the Ethernet ring node was in an idle state before the SF condition occurred, upon detection of this SF condition the Ethernet ring node triggers a local FDB flush.

d)   An Ethernet ring node accepting an R-APS (SF) message, without any local higher priority request, unblocks any blocked ring port that does not have an SF condition. This action unblocks the traffic channel on the RPL.

e)   An Ethernet ring node accepting an R-APS (SF) message, without any local higher priority request, stops transmission of other R-APS messages.

f)   An Ethernet ring node accepting an R-APS (SF) message without a DNF indication performs a flush FDB action by following the mechanism described in clause 10.1.10.

Protection switching is completed when the above actions are performed by each Ethernet ring node. At this point, the conditions are created to allow the traffic flows to be steered around the Ethernet ring.

In the multi-ring/ladder network scenario, a failure on a ring link between interconnection nodes of a sub-ring triggers the above actions only on the Ethernet ring that the sub-ring is attached to. On the other hand, other ring link failures trigger the above actions within the Ethernet ring that the failed ring link belongs to.

Bidirectional link failures are detected by the two Ethernet ring nodes adjacent to the failed ring link. These two Ethernet ring nodes trigger protection switching and keep the traffic channel blocked at both ends of the failed ring link. Unidirectional link failures are detected by only one of the Ethernet ring nodes adjacent to the failed ring link. This Ethernet ring node is the only node triggering protection switching and keeps the traffic channel blocked at its end of the failed ring link. These ring port blocking behaviours are essential to prevent the Ethernet ring from forming loops when the link failure is recovered. A node failure situation is handled as the failure of both ring links of the Ethernet ring node. The two Ethernet ring nodes adjacent to the failed Ethernet ring node initiate protection switching by detecting the SF condition on ring links connected to the failed Ethernet ring node.

10.2.2 Protection switching – signal degrade on link

Protection switching behaviour in the case of signal degrade (SD) condition is for further study.

10.2.3 Protection switching – recovery

An Ethernet ring node that has one or more ring ports in an SF condition, upon detection of clearance of the SF condition, keeps at least one of these ring ports blocked for the traffic channel and for the R-APS channel, until the RPL is blocked as a result of ERP reversion, or until there is another higher priority request (e.g., an SF condition) in the Ethernet ring.

An Ethernet ring node that has one ring port in an SF condition and detects clearing of this SF condition continuously transmits the R-APS (NR) message with its own node ID as the priority information over both ring ports, with the information that NR is present at the Ethernet ring node and initiates a guard timer as described in clause 10.1.5. Another recovered Ethernet ring node (or nodes) holding the link block receives the message and compares the node ID information with its own node ID. If the received R-APS (NR) message has the higher priority, the Ethernet ring node unblocks its ring ports. Otherwise, the block remains unchanged. There is only one link with one-end block.

The Ethernet ring nodes stop transmitting R-APS (NR) messages when they accept an R-APS (NR, RB), or when another higher priority request is received.

10.2.3.1 Revertive behaviour

When all ring links and Ethernet ring nodes have recovered and no external requests are active, reversion is the action to be taken. Reversion is handled in the following way.

a)   The reception of an R-APS (NR) message causes the RPL owner node to start the WTR timer.

b)   The WTR timer is cancelled if, during the WTR period, a higher priority request than NR is accepted by the RPL owner node or is declared locally at the RPL owner node.

c)   When the WTR timer expires, without the presence of any other higher priority request, the RPL owner node initiates reversion by blocking its traffic channel over the RPL, transmitting an R-APS (NR, RB) message over both ring ports, informing the Ethernet ring that the RPL is blocked and performing a flush FDB action.

d)   The acceptance of the R-APS (NR, RB) message causes all Ethernet ring nodes to unblock any blocked non-RPL link that does not have an SF condition. If it is an R-APS (NR, RB) message without a DNF indication, all Ethernet ring nodes perform a necessary flush FDB action by following the mechanism described in clause 10.1.10.

10.2.3.2 Non-revertive behaviour

In non-revertive operation, the Ethernet ring does not automatically revert when all ring links and Ethernet ring nodes have recovered and no external requests are active. Non-revertive operation is handled in the following way.

a)   The RPL owner node does not generate a response on reception of an R-APS (NR) messages.

b)   When other healthy Ethernet ring nodes receive the NR (node ID) message, no action is taken in response to the message.

c)   When the operator issues a Clear command for non-revertive mode at the RPL owner node, the non-revertive operation is cleared, the RPL owner node blocks its RPL port and transmits an R-APS (NR, RB) message in both directions, repeatedly.

d)   Upon receiving an R-APS (NR, RB) message, any blocking Ethernet ring node should unblock its non-failed ring port. If it is an R-APS (NR, RB) message without a DNF indication, all Ethernet ring nodes perform a necessary flush FDB action by following the mechanism described in clause 10.1.10.

10.2.4 Protection switching – Manual switch

An Ethernet ring with NR has a logical topology with the traffic channel blocked at the RPL and unblocked on all other ring links. In this situation, the operator-initiated MS command triggers protection switching as follows.

a)   If no other higher priority commands exist, the Ethernet ring node, where an MS command was issued, blocks the traffic channel and R-APS channel (as described in clause 10.1.14) on the ring port to which the MS command was issued. The Ethernet ring node shall unblock the other ring port.

b)   If no other higher priority commands exist, the Ethernet ring node where the MS command was issued transmits R-APS messages indicating MS over both ring ports. The R-APS (MS) message shall be continuously transmitted by this Ethernet ring node while the local MS command is the Ethernet ring node's highest priority command. The R-APS (MS) message informs other Ethernet ring nodes of the MS command and the fact that the traffic channel is blocked on one ring port.

c)   If no other higher priority commands exist and assuming the Ethernet ring node was in an idle state before the MS command was issued, upon the MS operator command, the Ethernet ring node triggers a local FDB flush action.

d)   An Ethernet ring node accepting an R-APS (MS) message, without any local higher priority request, unblocks any blocked ring port that does not have an SF condition. This action unblocks the traffic channel over the RPL.

e)   The Ethernet ring node accepting an R-APS (MS) message, without any local higher priority request, stops transmission of R-APS messages.

f)   The Ethernet ring node receiving an R-APS (MS) message performs a necessary flush FDB action by following the mechanism described in clause 10.1.10.

Protection switching on an MS request is completed when the above actions are performed by each Ethernet ring node. At this point the conditions are created to allow the traffic flows to be steered around the Ethernet ring. From this point on, the following rules apply regarding processing of further MS commands.

1)   While an existing MS request is present in the Ethernet ring, any new MS request is rejected. The request is rejected at the Ethernet ring node where the new request is issued and a notification shall be generated to inform the operator that the new MS request was not accepted.

2)   An Ethernet ring node with a local MS command that receives an R-APS (MS) message with a different node ID shall clear its MS request and start transmitting R-APS (NR) messages. The Ethernet ring node shall keep the ring port blocked due to the previous MS command.

3)   An Ethernet ring node with a local MS command that receives an R-APS message or a local request of higher priority than R-APS (MS) shall clear its MS request. The Ethernet ring node shall then process the new higher priority request.

10.2.4.1   Manual switch – clearing

An MS command is removed by the operator by issuing a Clear command to the same Ethernet ring node where the MS is presented. The Clear command removes existing local operator commands and triggers reversion in case the Ethernet ring is in revertive behaviour mode.

The Ethernet ring node where the MS was cleared shall keep the ring port blocked for traffic channel and for the R-APS channel (as described in clause 10.1.14), due to the previous MS command. This ring port is kept blocked until the RPL is blocked as a result of ERP reversion, or until there is another higher priority request (e.g., an SF condition) in the Ethernet ring.

The Ethernet ring node where the MS was cleared continuously transmits the R-APS (NR) message on both ring ports, with the information that NR is present at the Ethernet ring node. The Ethernet ring nodes stop the transmission of R-APS (NR) messages when they accept an R-APS (NR, RB) message, or when another higher priority request is received.

If the Ethernet ring node where the MS was cleared receives an R-APS (NR) message with a node ID higher than its own, it unblocks any ring port that does not have an SF condition and stops the transmission of the R-APS (NR) message on both ring ports.

Revertive behaviour

Reversion is handled in the following way:

a)   The RPL owner node, upon reception of an R-APS (NR) message and in the absence of any other higher priority request, starts the WTB timer and waits for expiration. While the WTB timer is running, any latent R-APS (MS) message is ignored due to the higher priority of the WTB Running signal.

b)   When the WTB timer expires, it generates the WTB Expires signal. The RPL owner node, upon reception of the WTB Expires signal, initiates reversion by blocking the traffic channel on the RPL, transmitting an R-APS (NR, RB) message over both ring ports, informing the Ethernet ring that the RPL is blocked and performing a flush FDB action.

c)   The acceptance of the R-APS (NR, RB) message causes all Ethernet ring nodes to unblock any blocked non-RPL that does not have an SF condition. If it is an R-APS (NR, RB) message without a DNF indication, all Ethernet ring nodes perform a necessary flush FDB action by following the mechanism described in clause 10.1.10. This action shall unblock the ring port that was blocked as a result of an operator command.

Non-revertive behaviour

Non-reversion is handled in the following way.

a)   The RPL owner node, upon reception of an R-APS (NR) message and in the absence of any other higher priority request, does not perform any action.

b)   Then, after the operator issues a Clear command at the RPL owner node, this Ethernet ring node blocks the ring port attached to the RPL, transmits an R-APS (NR, RB) message over both ring ports, informing the Ethernet ring that the RPL is blocked and performs a flush FDB action.

c)   The acceptance of the R-APS (NR, RB) message triggers all Ethernet ring nodes to unblock any blocked non-RPL that does not have an SF condition. If it is an R-APS (NR, RB) message without a DNF indication, all Ethernet ring nodes perform a necessary flush FDB action by following the mechanism described in clause 10.1.10. This action shall unblock the ring port that was blocked as a result of an operator command.

10.2.5   Protection switching – Forced switch

An Ethernet ring with NR has a logical topology with the traffic channel blocked at the RPL and unblocked on all other ring links. In this situation, the operator-initiated FS command triggers protection switching as follows.

a)   The Ethernet ring node where an FS command was issued blocks the traffic channel and R-APS channel (as described in clause 10.1.14) on the ring port to which the FS command was issued. The Ethernet ring node shall unblock the other ring port.

b)   The Ethernet ring node where the FS command was issued transmits R-APS messages indicating FS over both ring ports. The R-APS (FS) message shall be continuously transmitted by this Ethernet ring node while the local FS command is the Ethernet ring node's highest priority command. The R-APS (FS) message informs other Ethernet ring nodes of the FS command and the fact that the traffic channel is blocked on one ring port.

c)   An Ethernet ring node accepting an R-APS (FS) message, without any local higher priority request, unblocks any blocked ring port. This action unblocks the traffic channel over the RPL.

d)   The Ethernet ring node accepting an R-APS (FS) message, without any local higher priority request, stops transmission of R-APS messages.

e)   The Ethernet ring node receiving an R-APS (FS) message performs a necessary flush FDB action by following the mechanism described in clause 10.1.10.

Protection switching on an FS request is completed when the above actions are performed by each Ethernet ring node. At this point, the conditions are created to allow the traffic flows to be steered around the Ethernet ring. From this point on, the following rules apply regarding processing of further FS commands.

1) While an existing FS request is present in an Ethernet ring, any new FS request is accepted, except for the Ethernet ring node having a prior local FS request. The Ethernet ring nodes where further FS commands are issued shall block the traffic channel and R-APS channel on the ring port to which the FS was issued. The Ethernet ring node where the FS command was issued transmits an R-APS message indicating FS over both ring ports. The R-APS (FS) message shall be continuously transmitted by this Ethernet ring node while the local FS command is the Ethernet ring node's highest priority command. As such, two or more FSs are allowed in the Ethernet ring. This may cause the segmentation of an Ethernet ring. It is the responsibility of the operator to prevent this effect, if it is undesirable.

10.2.5.1 Forced switch – clearing

An FS command is removed by the operator by issuing a Clear command to the same Ethernet ring node where the FS is presented. The Clear command removes existing local operator commands and triggers reversion if the Ethernet ring is in revertive behaviour mode.

The Ethernet ring node where the FS was cleared shall keep the ring port blocked for the traffic channel and the R-APS channel (as described in clause 10.1.14), due to the previous FS command. This ring port is kept blocked until the RPL is blocked as a result of ERP reversion, or until there is another higher priority request (e.g., an SF condition) in the Ethernet ring.

The Ethernet ring node where the FS was cleared continuously transmits the R-APS (NR) message on both ring ports, with the information that NR is present at the Ethernet ring node. The Ethernet ring nodes stop the transmission of R-APS (NR) messages when they accept an R-APS (NR, RB) message, or when another higher priority request is received.

If the Ethernet ring node where the FS was cleared receives an R-APS (NR) message with a node ID higher than its own node ID, it unblocks any ring port that does not have an SF condition and stops the transmission of the R-APS (NR) message over both ring ports.

Revertive behaviour

Reversion is handled in the following way.

a) The reception of an R-APS (NR) message causes the RPL owner node to start the WTB timer.

b) The WTB timer is cancelled if, during the WTB period, a higher priority request than NR is accepted by the RPL owner node or is declared locally at the RPL owner node.

c) When the WTB timer expires, in the absence of any other higher priority request, the RPL owner node initiates reversion by blocking the traffic channel over the RPL, transmitting an R-APS (NR, RB) message over both ring ports, informing the Ethernet ring that the RPL is blocked and performing a flush FDB action.

d) The acceptance of the R-APS (NR, RB) message causes all Ethernet ring nodes to unblock any blocked non-RPL that does not have an SF condition. If it is an R-APS (NR, RB) message without a DNF indication, all Ethernet ring nodes perform a necessary flush FDB action by following the mechanism described in clause 10.1.10. This action shall unblock the ring port that was blocked as a result of an operator command.

Non-revertive behaviour

Non-reversion is handled in the following way.

1) The RPL owner node, upon reception of an R-APS(NR) message and in the absence of any other higher priority request, does not perform any action.
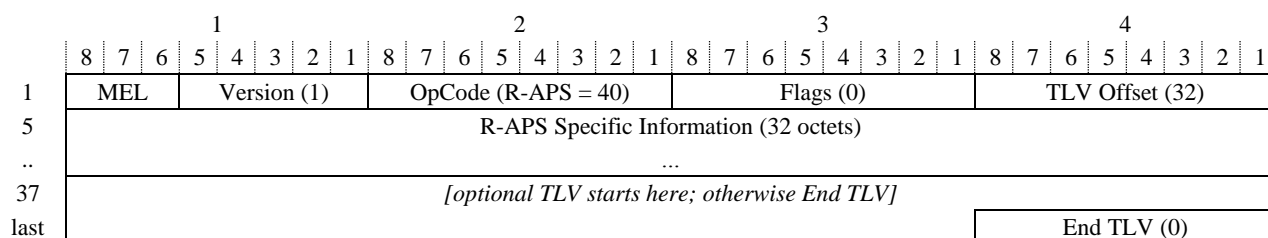
2) Then, after the operator issues a Clear command at the RPL owner node, this Ethernet ring node blocks the ring port attached to the RPL, transmits an R-APS (NR, RB) message on both ring ports, informing the Ethernet ring that the RPL is blocked and performs a flush FDB action.

3) The acceptance of the R-APS (NR, RB) message triggers all Ethernet ring nodes to unblock any blocked non-RPL that does not have an SF condition. If it is an R-APS (NR, RB) message without a DNF indication, all Ethernet ring nodes perform a necessary flush FDB action by following the mechanism described in clause 10.1.10. This action shall unblock the ring port that was blocked as a result of an operator command.

10.3 R-APS format

R-APS information is carried in an R-APS PDU, which is one of a suite of Ethernet OAM messages. The OAM PDU format for each type of Ethernet OAM operation is defined in [ITU-T G.8013]. R-APS specific information is transmitted within specific fields in an R-APS PDU. An R-APS PDU is identified by the Ethernet OAM OpCode 40.

The R-APS messages will use the MAC address range allocated within the ITU organizationally unique identifier (OUI) for [ITU-T G.8032] R-APS communication. The last octet of the MAC address is designated as ring ID (01-19-A7-00-00-[Ring ID]). The default ring ID is 01.

In this Recommendation, 32 octets in an R-APS message are used to carry R-APS specific information. This is illustrated in Figure 10-2. In addition, the TLV Offset field is required to be set to 32.

	1								2								3								4							
	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1
1	MEL			Version (1)					OpCode (R-APS = 40)								Flags (0)								TLV Offset (32)							
5	R-APS Specific Information (32 octets)																															
..	...																															
37	*[optional TLV starts here; otherwise End TLV]*																															
last																									End TLV (0)							

Figure 10-2 – R-APS PDU format

For other fields such as Version, OpCode, Flags and End TLV, the following values shall be used, as defined in [ITU-T G.8013].

a) **Version**: 0x01 shall be transmitted in this edition of this Recommendation.

b) **OpCode**: 40 shall be transmitted as defined in [ITU-T G.8013].

c) **Flags**: 0x00 shall be transmitted in this edition of this Recommendation. This field should be ignored upon reception.

d) **TLV Offset**: 0x20 (=32) shall be transmitted.

e) **End TLV**: 0x00 shall be transmitted.

This Recommendation does not define any R-APS specific TLVs.

In the MEL field, the MEL (described in [ITU-T G.8010]) at which the R-APS PDU is inserted.

The format of the R-APS specific information within each R-APS PDU is defined as per Figure 10-3.

1								2								3								4							
8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1
Request/ State				Sub-code				Status								Node ID (6 octets)															
								RB	DNF	BPR		Status Reserved																			
(Node ID)																															
Reserved 2 (24 octets)																															

Figure 10-3 – R-APS specific information format

The fields of R-APS specific information:

f) Request/state (4 bits) – This field represents a request or state and is encoded as described in Table 10-3.

Table 10-3 – Request/state values

Field	Value	Description
Request/state	1101	Forced switch
	1110	Event
	1011	Signal fail (SF)
	0111	Manual switch (MS)
	0000	No request (NR)
	Other	Reserved for future international standardization

g) Sub-code – encoding for sub-code for some of the request/states defined in the request/state field.

   1) If Request/State field = "1110" Event

      I. Sub-code = "0000" – Flush Request.

      II. Other values are reserved for future use.

   2) For other request/state field values, the sub-code is transmitted as "0000" and ignored upon reception.

h) Status field – This includes the following status information:

   1) RB – RPL Blocked

      I. RB = 1 – indicates that the RPL is blocked.

      II. RB = 0 – indicates that the RPL is unblocked.

    This bit should be 0 when transmitted by non-RPL owner nodes.

   2) DNF – Do Not Flush

      I. DNF = 1 – indicates that an FDB flush should not be triggered by the reception of this message.

      II. DNF = 0 – indicates that an FDB flush may be triggered by the reception of this message.

   3) BPR – Blocked port reference

      I. BPR = 0 corresponds to ring link 0 blocked.

II.   BPR = 1 corresponds to ring link 1 blocked.

This bit shall be set to 0 on messages transmitted from interconnection nodes on the sub-ring's Ethernet ring nodes.

If two ring links are blocked, the encoded value can be either value.

4)   Status reserved (5 bits) – For future specification. This field shall be transmitted encoded all zeroes. This field should be ignored upon reception.

i)   Node ID (6 octets) – A MAC address unique to the Ethernet ring node.

j)   Reserved 2 (24 octets) – This field is reserved for future extensions of the R-APS protocol. In this edition of this Recommendation, this field shall be transmitted encoded all zeroes. This field should be ignored upon reception.

10.4   Failure of protocol defect

Due to errors in provisioning, the ERP control process may detect a combination of conditions which should not occur during "normal" conditions. To warn the operator of such an event, a failure of protocol − provisioning mismatch (FOP-PM) is defined. The FOP-PM defect, detected if the RPL owner node receives one or more NR R-APS message(s) with the RB status flag set (NR, RB) and a node ID that differs from its own. The ERP control process must notify the equipment fault management process when it detects such a defect condition and continues its operation as well as possible. This is only an overview of the defect condition. The associated defect and its details are defined in [ITU-T G.8021].

The ERP control process must notify the equipment fault management process using the failure of protocol – time out (dFOP-TO) defect signal (as defined in [ITU-T G.8021]) if it fails to receive any R-APS messages on a ring port for a period exceeding K message cycles, as described in [ITU-T G.8021]. This defect signal should not be reported if the ring port is reporting a link level failure (operationally disabled), or is either administratively locked or blocked from R-APS message reception. Some examples of these exceptions would be:

•   SF reported on this ring port

•   sub-ring ports when running sub-ring without virtual channel model

•   when both ends are RB.

The ERP control process should continue its operation as well as possible.

This is only an overview of the defect condition. The mechanism for detection and clearance of dFOP-TO is defined in [ITU-T G.8021]. Such notification should allow the operator to take any proper corrective action. Such corrective action might, for example, include performing an MS to allow resetting the Ethernet ring node to re-activate the ERP control process.

Appendix I

Ring protection network objectives

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

The following are the network objectives of the ERP.

I.1   The ERP mechanism shall prevent the creation of loops in an Ethernet ring topology under any circumstances (starting up the network, failure condition and switchover).

I.2   The ETH layer connectivity of ring links should be periodically monitored.

I.3   The ring link ETH layer monitoring should inform the ERP mechanism of SF or SD conditions (e.g., link bandwidth degradation and excessive error).

I.4   Server layer SF and SD conditions should be transmitted to the ERP mechanism.

Service restoration

I.5   ERP shall not contend with the protection mechanisms of the server layer.

General

I.6   The ring shall successfully recover multipoint connectivity in the event of a single ring link failure.

I.7   The ring shall successfully recover multipoint connectivity in the event of a single node failure, except for the traffic at that Ethernet ring node.

I.8   In the event of more than a single failure (e.g., of ring links or Ethernet ring nodes), the result should be ring segmentation with full connectivity within each segment.

I.9   ERP shall operate under all network load conditions.

I.10   ERP shall be independent of the capability of the server layer.

I.11   ERP shall support protection over multi-ring/ladder networks.

    a)   The protection mechanism shall enable the interconnection of rings using a single or dual Ethernet ring node(s). The mechanism shall protect services that are traversing interconnected rings. In the case of interconnected rings using dual Ethernet ring nodes, the mechanism shall ensure that a super loop is not formed in the event that there is ring link failure between interconnection nodes.

I.12   ERP control communication shall be performed using standard Ethernet messages (IEEE 802.3/802.1). The control messages of the ERP mechanism shall use the OAM message format defined in [ITU-T G.8013]. The OAM messages defined in [ITU-T G.8013] may be extended to support the protection control messages.

I.13   The protection process shall be deterministic. All Ethernet ring nodes in the Ethernet ring shall have the same view of the protection state.

I.14   The total communication bandwidth consumed by the protection mechanism shall be a very small fraction of the total available bandwidth and shall be independent of the total traffic supported by the network.

I.15   The protection mechanism shall not impose any limitation or requirements on the Ethernet relay and filtering function.

I.16   The mechanism should not impose any limitation on the number of Ethernet ring nodes that may form the Ethernet ring. From an operational perspective, the maximum number of Ethernet ring nodes supported should be in the range of 16 to 255 Ethernet ring nodes.

I.17   A switchover may be administratively triggered.

I.18   Revertive mode shall be supported.

I.19   Non-revertive mode should be supported.

I.20   In the event of a single Ethernet ring node or link failure, ERP shall support protection switching time (i.e., transfer time, T_t in clause 13 of [ITU-T G.808.1]) of no more than 50 ms.

I.21   ERP may support configurable hold-off times before triggering protection operation.

I.22   ERP may support configurable wait-to-restore times.

I.23   In the event of reversion, ERP shall support a revertive switching time (i.e., transfer time, T_t in clause 13 of [ITU-T G.808.1]) of no more than 50 ms.

I.24   In the event of administratively triggered switchover, ERP shall support a switching time (i.e., transfer time, T_t in clause 13 of [ITU-T G.808.1]) of no more than 50 ms.

I.25   The solution adopted for interconnected Ethernet rings shall allow the transformation of one Ethernet ring into a sub-ring interconnected to another Ethernet ring without decommissioning the services already supported on the first Ethernet ring. It is acceptable that this operation may result in temporary traffic interruption due to protection switching events that result from reconfiguration of the Ethernet rings. It is also acceptable that during the operation, new link failures are not correctly protected.

Appendix II

Ethernet ring network objectives

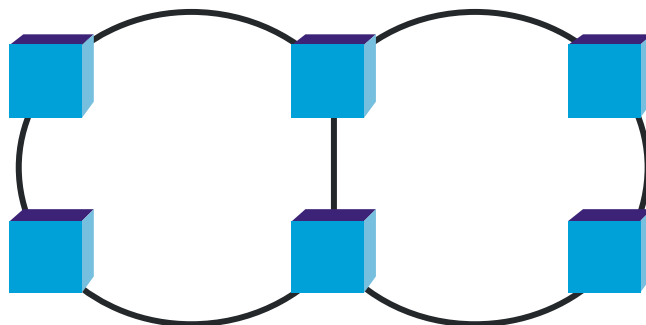(This appendix does not form an integral part of this Recommendation.)

The following are Ethernet ring network objectives.

II.1   An Ethernet ring shall be constructed from a set of Ethernet ring nodes, as defined in clause 3.2.1, which form a ring topology (i.e., a ring).

II.2   Traffic forwarding in an Ethernet ring and between a non-ring port and a ring port shall be based entirely on the forwarding rules defined by the IEEE 802.1 specifications.

II.3   Each Ethernet ring node shall have exactly two ring ports per logical ring.

II.4   The Ethernet ring nodes shall be connected in a closed loop.

II.5   The Ethernet ring shall provide direct or indirect communication between all Ethernet ring nodes in the Ethernet ring.

II.6   In Ethernet ring topology, each Ethernet ring node shall be connected to two other Ethernet ring nodes utilizing ring ports based on [b-IEEE 802.3] MAC.

II.7   The Ethernet MAC may be transported over any server layer.

   a)   The Ethernet ring shall not preclude the use of any transport technology [e.g., synchronous digital hierarchy virtual circuits (SDH VCs)] using generic framing procedure (GFP) mapping, Ethernet physical layer interfaces ETY, multiprotocol label switching (MPLS) ETH pseudo-wires, Ethernet link aggregation [b-IEEE 802.3].

   b)   The capacity of each span in the ring (link) is dependent on the transport technology used. It shall not be a requirement that all ring links need to provide the same capacity.

II.8   The definition of an Ethernet ring shall be applicable to both physical ring topologies and logical ring topologies. Note these are not independent.

II.9   Shall support increased bandwidth utilization via concurrent transmissions, spatial reuse.

II.10   Shall utilize [ITU-T G.8013], [IEEE 802.1Q] and may use other Ethernet OAM specifications.

II.11   Each Ethernet ring node shall support MAC services and QoS according to the [IEEE 802.1Q] specification. The use of Ethernet ring resources at each ring link is controlled by the same rules.

II.12   Ethernet rings shall support E-Line, Ethernet local area network (E-LAN) and E-Tree services including Ethernet private line (EPL) [b-ITU-T G.8011.1] and Ethernet virtual private line (EVPL) [b-ITU-T G.8011.2].

II.13   Ethernet ring topology shall support all types of communication: unicast, multicast and broadcast.

II.14   Normal Ethernet ring behaviour (i.e., without protection) shall prevent mis-ordering or duplication of transported client messages.

II.15   End-to-end services may traverse multiple interconnected rings.

II.16   Ethernet rings may be interconnected through an interconnection point (as depicted in Figure II.1), or through dual interconnection nodes with a ring link (as depicted in Figure II.2) or a multi-ring/ladder network that consists of conjoined Ethernet rings (as depicted in Figure II.3).

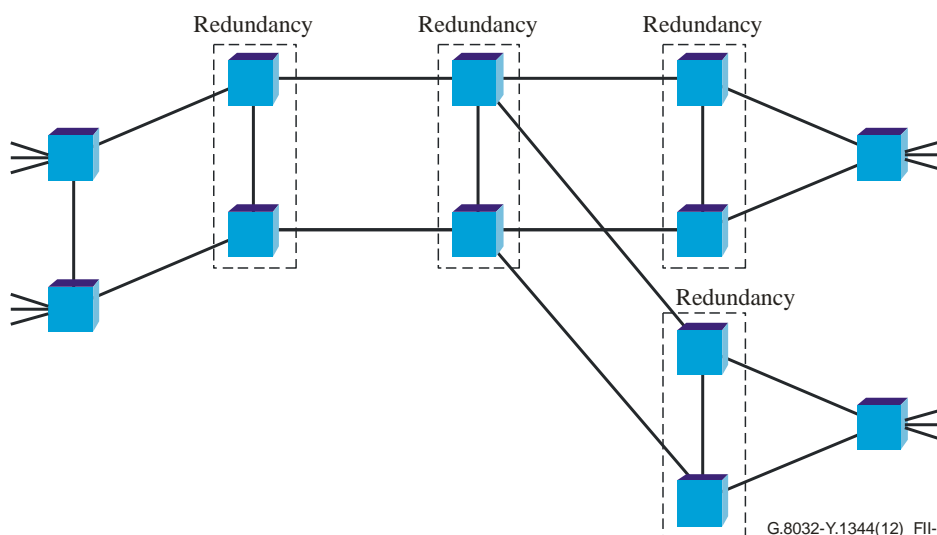II.17   The logical rings shall be identifiable for management purposes.
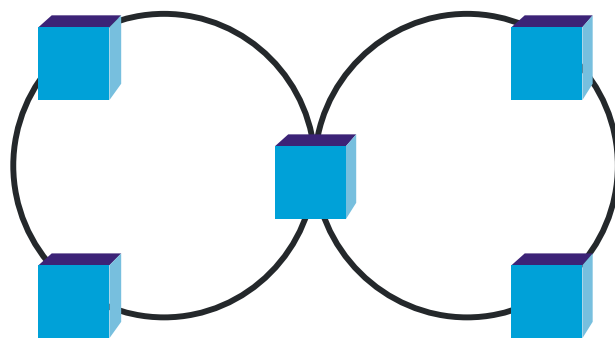
Figure II.1 – Interconnected Ethernet rings via an interconnection node

Figure II.2 – Interconnected Ethernet rings via dual Ethernet ring nodes with a ring link

Figure II.3 – Example of multi-ring/ladder network

Appendix III

Ring protection scenarios

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

The following scenarios represent an Ethernet ring composed of seven Ethernet ring nodes. The RPL is the ring link between Ethernet ring nodes A and G. In these scenarios, both ends of the RPL are blocked. Ethernet ring node G is the RPL owner node and Ethernet ring node A is the RPL neighbour node.

NOTE 1 – The scenarios described in Recommendation ITU-T G.8032 (2008) are fully supported by this edition of this Recommendation. The following scenarios (that may extend the functionality described in previous editions) are also supported by this edition of this Recommendation.

NOTE 2 – In all of the following scenarios that show a (⟨Node ID, BPR⟩ pair, the node ID should be taken as a logical ID that is mapped to an actual node ID.

The following symbols are used:

Scenario A – Single link failure

Figure III.1 represents protection switching in the case of a single link failure.

Figure III.1 – Single link failure
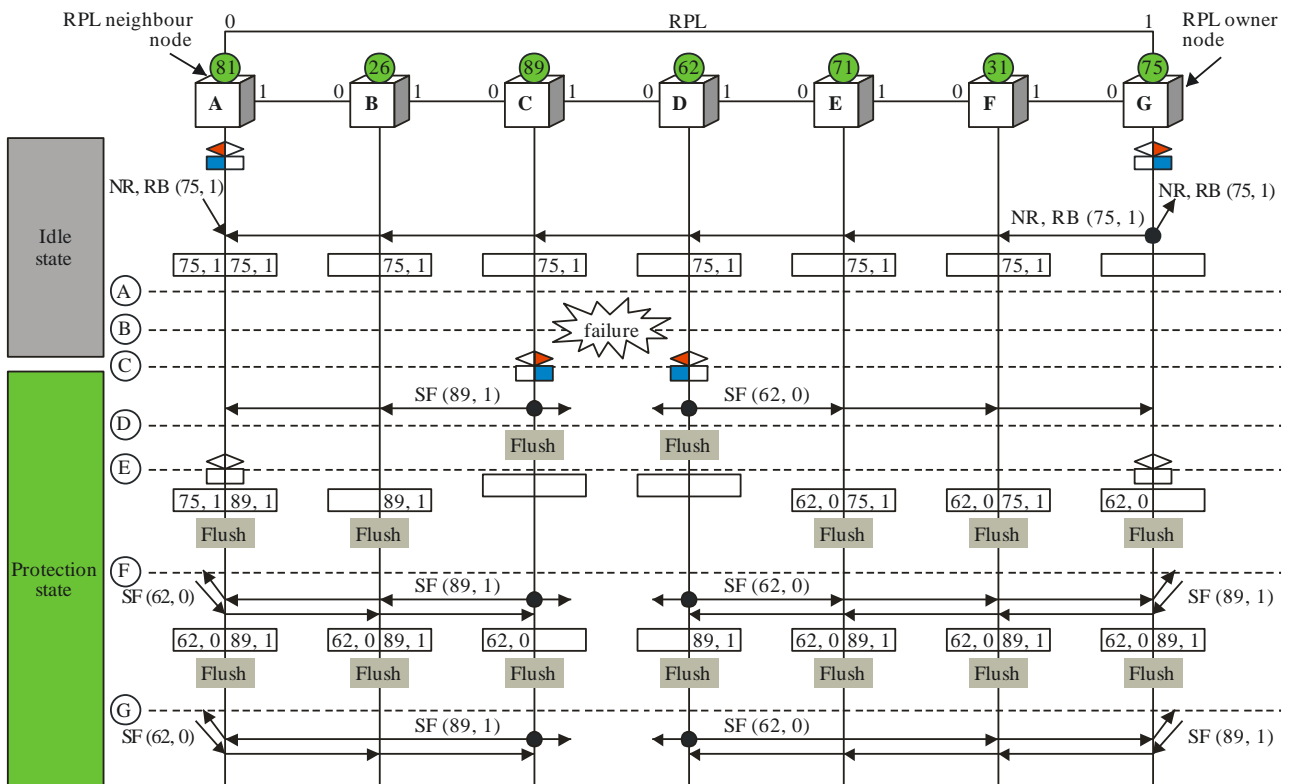
The following sequence describes the steps in Figure III.1.

A. Normal condition.

B. Failure occurs.

C. Ethernet ring nodes C and D detect a local SF condition and after respecting the hold-off time, block the failed ring port and perform the FDB flush.

D. Ethernet ring nodes C and D start sending R-APS (SF) messages periodically with the (node ID, BPR) pair on both ring ports, while the SF condition persists.

E. All Ethernet ring nodes receiving an R-APS (SF) message perform an FDB flush. When the RPL owner node G and RPL neighbour node A receive an R-APS (SF) message, they each unblock their end of the RPL and perform the FDB flush.

F. All Ethernet ring nodes receiving a second R-APS (SF) message perform the FDB flush again due to the node ID and BPR-based mechanism.

G. Stable SF condition – R-APS (SF) messages on the Ethernet ring. Further R-APS (SF) messages trigger no further action.

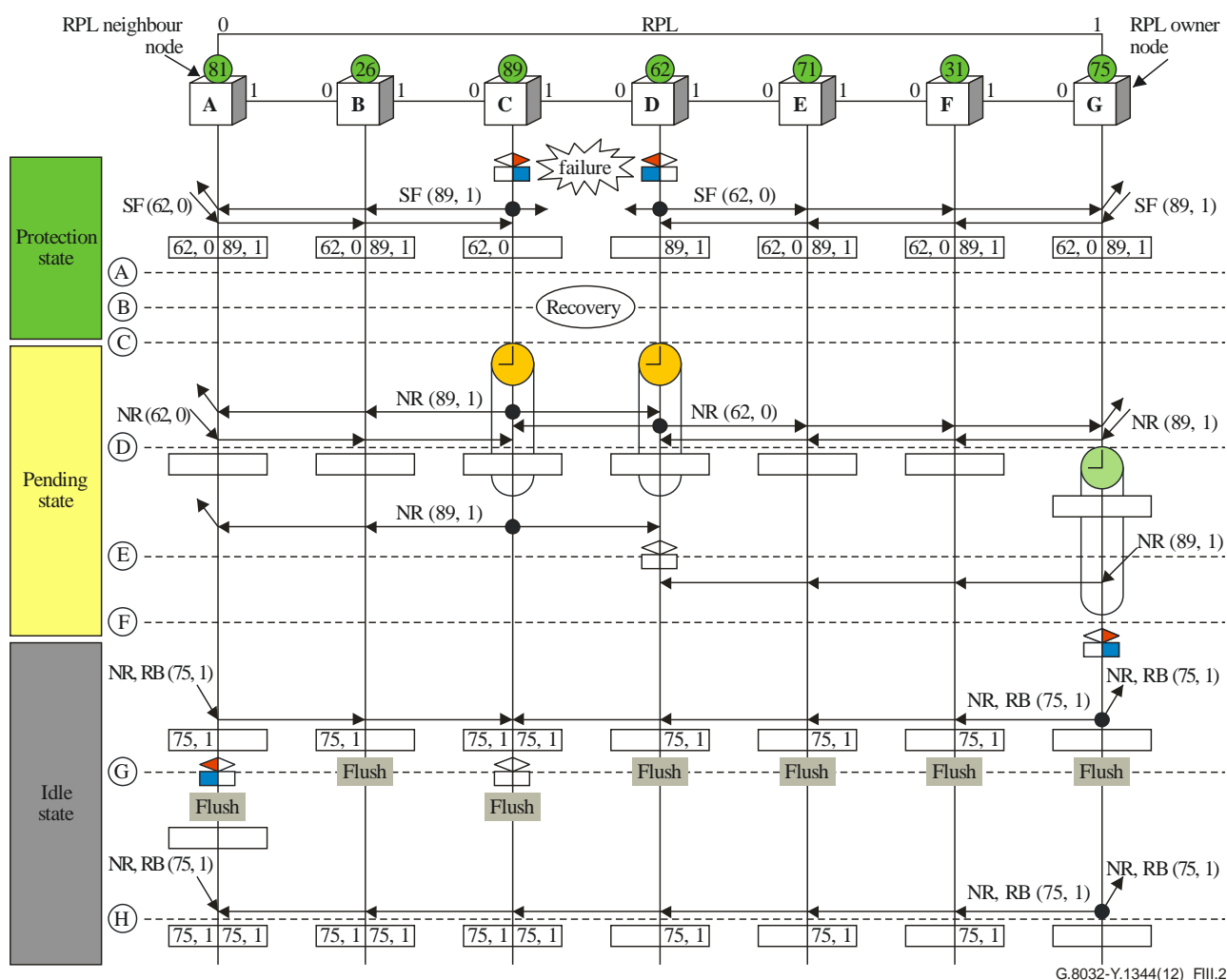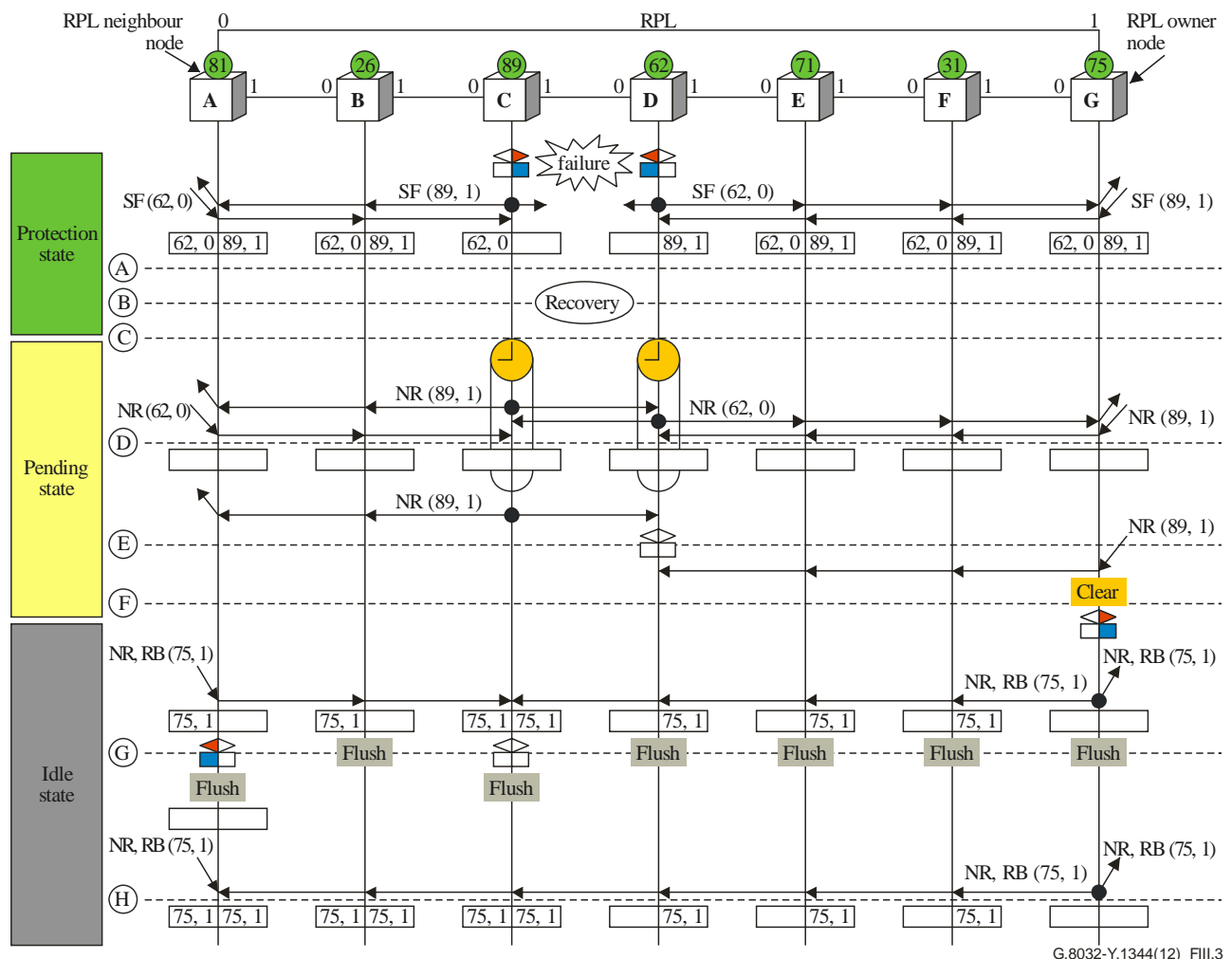Figure III.2 represents reversion in the case of a single link failure.

Figure III.2 – Single link failure recovery (revertive operation)

The following sequence describes the steps in Figure III.2.

A. Stable SF condition.

B. Recovery of link failure.

C. Ethernet ring nodes C and D detect clearing of SF condition, start the guard timer and initiate the periodical transmission of R-APS (NR) messages on both ring ports. (The guard timer prevents the reception of R-APS messages.)

D. When the Ethernet ring nodes receive an R-APS (NR) message, the (node ID, BPR) pair of a receiving ring port is deleted and the RPL owner node starts the WTR timer.

E. When the guard timer expires on Ethernet ring nodes C and D, they may accept the new R-APS messages that they receive. Ethernet ring node D receives an R-APS (NR) message with a higher node ID from Ethernet ring node C and unblocks its non-failed ring port.

F. On expiration of the WTR timer, the RPL owner node blocks its end of the RPL, sends an R-APS (NR, RB) message with the (node ID, BPR) pair and performs the FDB flush.

G. When Ethernet ring node C receives an R-APS (NR, RB) message, it removes the block on its blocked ring ports and stops sending R-APS (NR) messages. On the other hand, when the RPL neighbour node A receives an R-APS (NR, RB) message, it blocks its end of the RPL. In addition to this, Ethernet ring nodes A to F perform the FDB flush when receiving an R-APS (NR, RB) message due to the node ID and BPR-based mechanism.

Figure III.3 represents the non-revertive operation in the case of a single link failure.

Figure III.3 – Single link failure recovery (non-revertive operation)

The following sequence describes the steps in Figure III.3.

A.   Stable SF condition.

B.   Recovery of link failure.

C.   Ethernet ring nodes C and D detect clearing of SF condition, start the guard timer and initiate the periodical transmission of R-APS (NR) messages on both ring ports. (The guard timer prevents the reception of R-APS messages.)

D.   When the Ethernet ring nodes receive an R-APS (NR) message, the (node ID, BPR) pair of received ring port is deleted and the RPL owner node does not start the WTR timer.

E.   When the guard timer expires on Ethernet ring nodes C and D, they may accept the new R-APS messages that they receive. Ethernet ring node D receives an R-APS (NR) message with a higher node ID from Ethernet ring node C and unblocks its non-failed ring port.

F.   When the RPL owner node executes a Clear command, it blocks its end of the RPL, sends an R-APS (NR, RB) message with the (node ID, BPR) pair and performs the FDB flush.

G.   When Ethernet ring node C receives an R-APS (NR, RB) message, it removes the block on its blocked ring ports and stops sending R-APS (NR) messages. On the other hand, when the RPL neighbour node A receives an R-APS (NR, RB) message, it blocks its end of the RPL. In addition to this, Ethernet ring nodes A to F perform the FDB flush when receiving an R-APS (NR, RB) message due to the node ID and BPR-based mechanism.

Scenario B – Single unidirectional link failure

Figure III.4 is similar to Figure III.1 with the difference that the link failure is unidirectional.
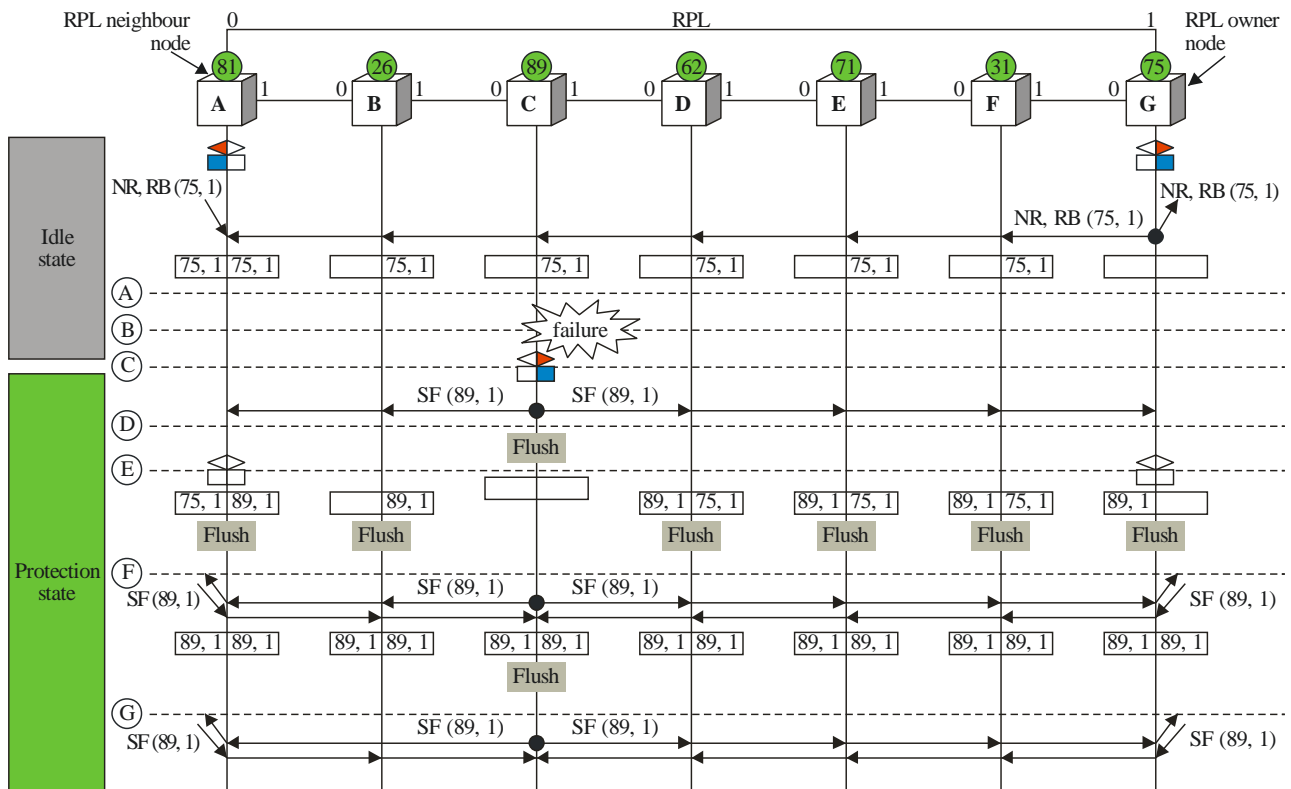
Figure III.4 – Single unidirectional link failure

The following sequence describes the steps in Figure III.4.

A.   Normal condition.

B.   Failure occurs in the direction of D to C, the direction of C to D is unaffected.

C.   Ethernet ring node C detects a local SF condition and after respecting the hold-off period, blocks the failed ring port and performs the FDB flush (Ethernet ring node D performs no action).

D.   Ethernet ring node C starts sending R-APS (SF) messages with the (node ID, BPR) pair on both ring ports, while the SF condition persists.

E.   All Ethernet ring nodes receiving an R-APS (SF) message perform the FDB flush. When the RPL owner node G and RPL neighbour node A receive an R-APS (SF) message, they unblock their end of the RPL and perform the flush FDB.

F.   Ethernet ring node C, on receiving a second R-APS (SF) message, performs the FDB flush again due to the node ID and BPR-based mechanism.

G.   Stable SF condition – R-APS (SF) messages on the Ethernet ring. Further R-APS (SF) messages trigger no further action.

The reversion for the unidirectional case is represented by Figure III.5.
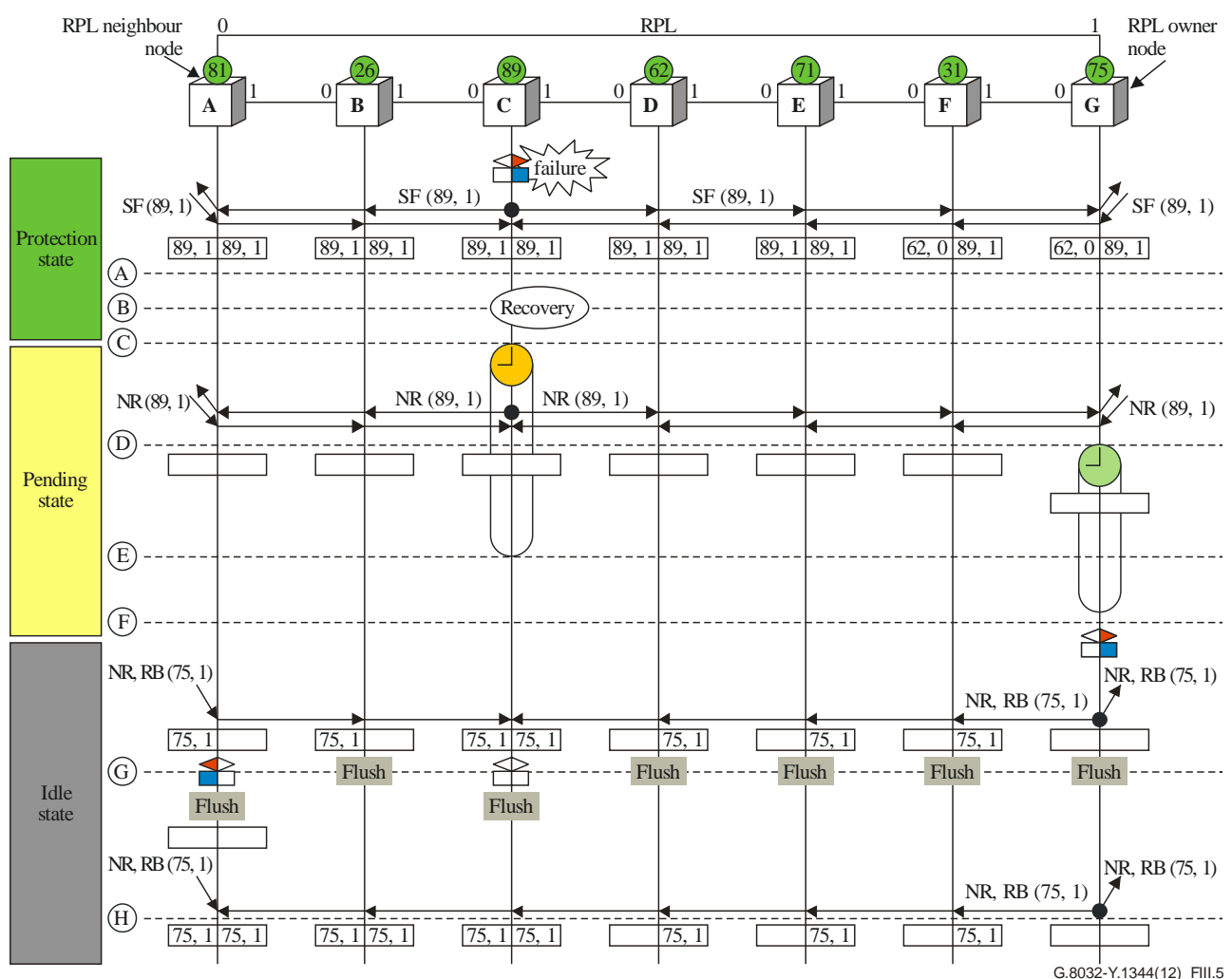
**Figure III.5 – Single link failure unidirectional recovery**

The following sequence describes the steps in Figure III.5.

A.   Stable SF condition.

B.   Recovery of link failure.

C.   Ethernet ring node C detects the clearing of the SF condition, starts the guard timer and initiates the periodical transmission of R-APS (NR) messages on both ring ports. (The guard timer prevents the reception of R-APS messages.)

D.   When the Ethernet ring nodes receive an R-APS (NR) message, the (node ID, BPR) pair of the receiving ring port is deleted and the RPL owner node starts the WTR timer.

E.   When the guard timer expires on Ethernet ring node C, it may accept the new R-APS messages that it receives.

F.   On expiration of the WTR timer, the RPL owner node blocks its end of the RPL, sends R-APS (NR, RB) messages with the (node ID, BPR) pair and performs the FDB flush.

G.   When Ethernet ring node C receives an R-APS (NR, RB) message, it removes the block on its blocked ring port and stops sending R-APS (NR) messages. On the other hand, when the RPL neighbour node A receives an R-APS (NR, RB) message, it blocks its end of the RPL. In addition to this, Ethernet ring nodes A to F perform the FDB flush when receiving an R-APS (NR, RB) message due to the node ID and BPR-based mechanism.

Scenario C – RPL failure

Figure III.6 represents the behaviour in the case of RPL failure and shows an example of the possible use of the DNF status bit.
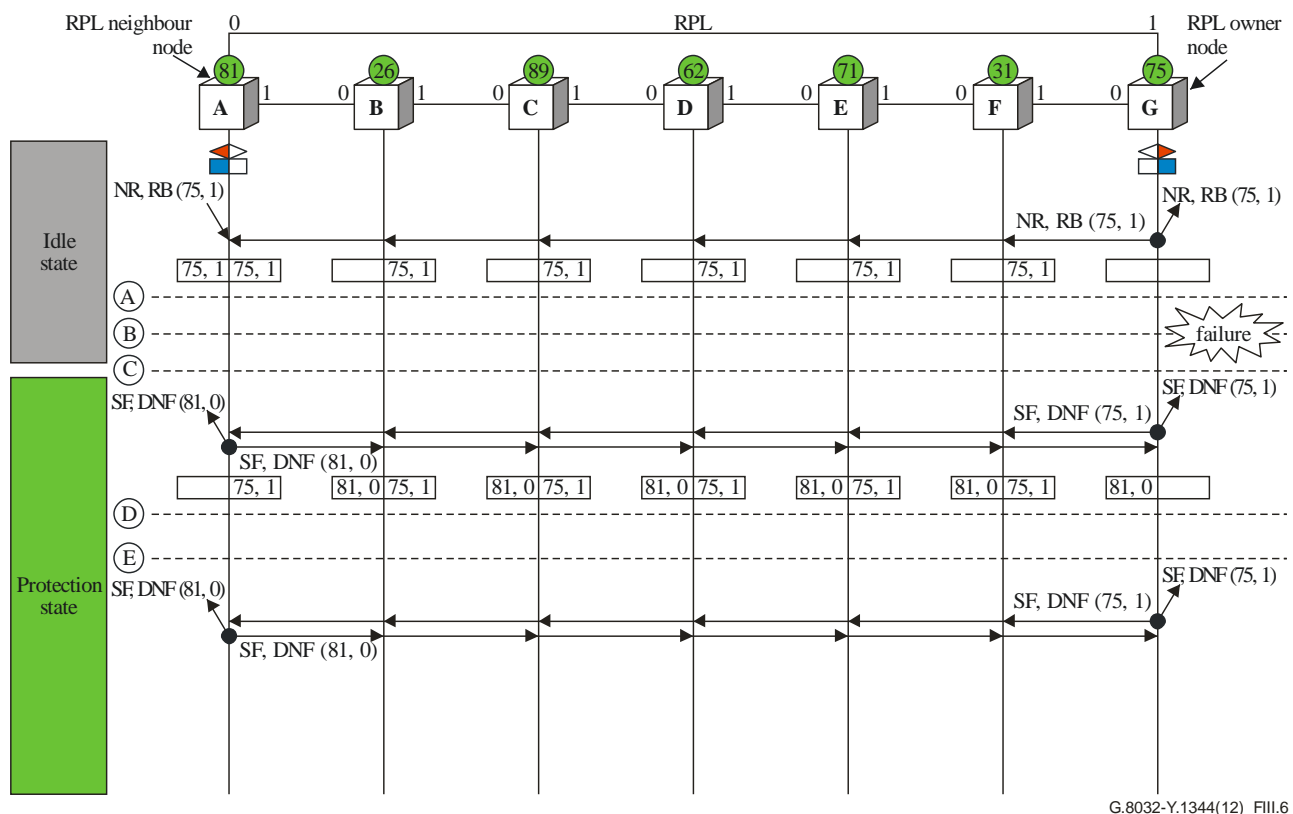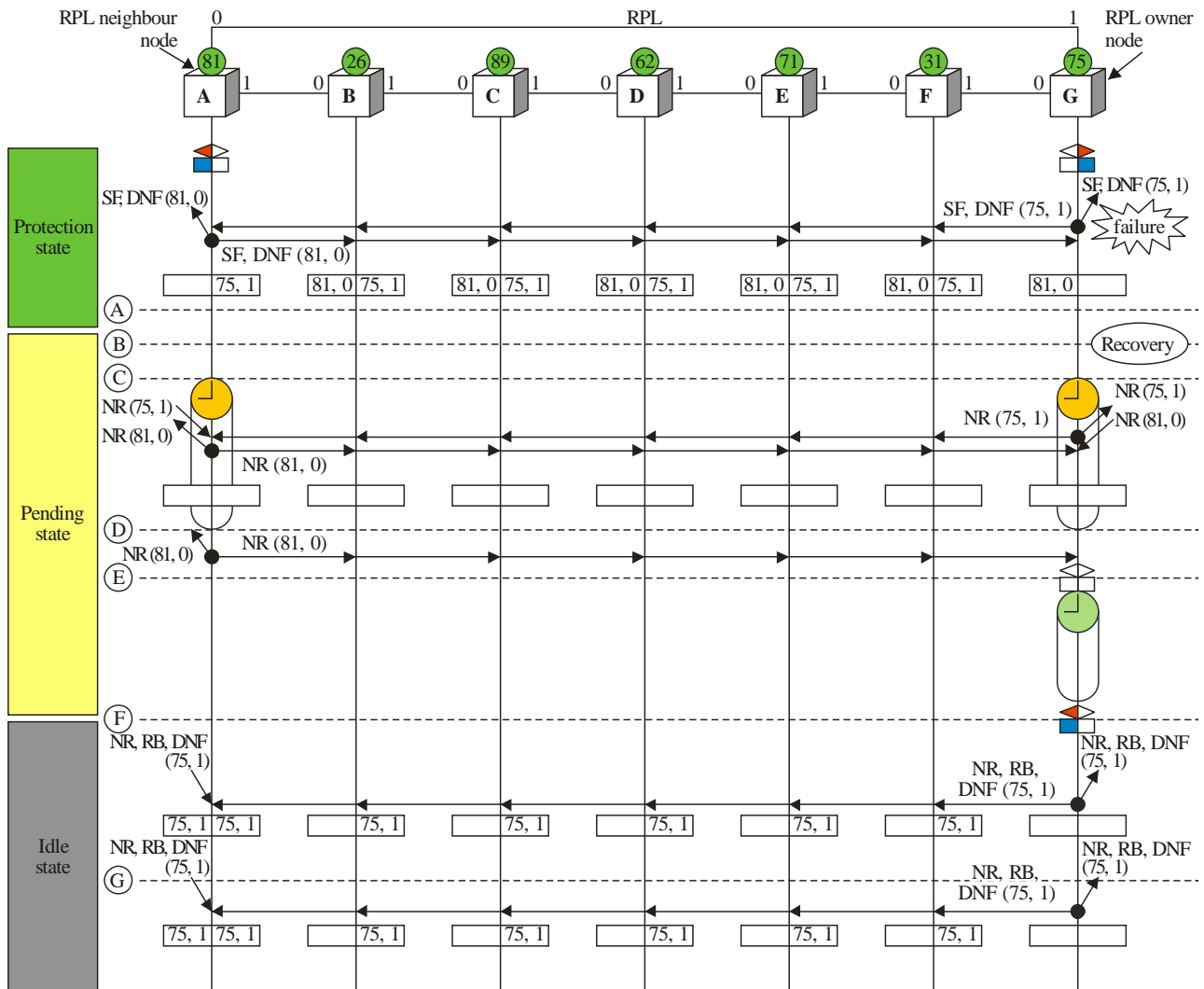

Figure III.6 – RPL failure

The following sequence describes the steps in Figure III.6.

A.   Normal condition.

B.   Failure occurs.

C.   Ethernet ring nodes A and G detect a local SF condition and periodically start sending R-APS (SF) messages with the (node ID, BPR) pair on both ring ports, while the SF condition persists. The R-APS (SF) message includes a DNF indication and this prevents all Ethernet

ring nodes from performing the FDB flush, despite a transition from the idle to the protection state.

D.   The RPL owner node receives an R-APS (SF) message, but it is ignored as there is a local higher priority request (local SF) [no transition]. All other Ethernet ring nodes receive the R-APS (SF) message with a DNF indication (flush is not performed), despite a transition from the idle to the protection state without flushing the FDB.

E.   Stable SF condition – R-APS (SF) messages on the Ethernet ring with DNF indication. Further R-APS (SF) messages trigger no further action.

The actions after the repair of the RPL are represented in Figure III.7.
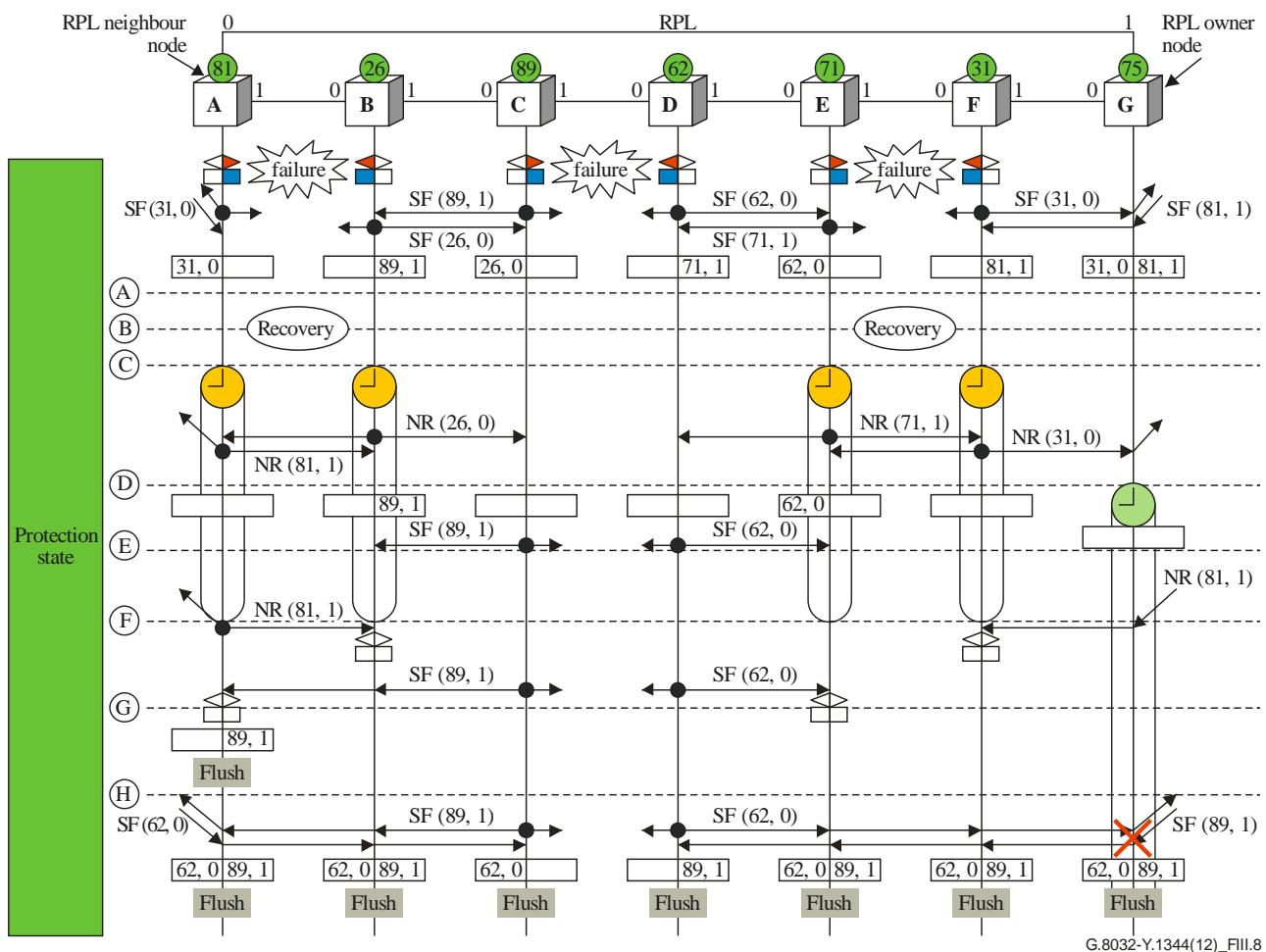

Figure III.7 – RPL failure recovery

The following sequence describes the steps in Figure III.7.

A.   Stable SF condition.

B.   Recovery of link failure.

C.   Ethernet ring nodes A and G detect the clearing of the SF condition, start the guard timer and initiate the periodical transmission of R-APS (NR) messages on both ring ports. (The guard timer prevents the reception of R-APS messages.)

D.   When the guard timer expires on Ethernet ring nodes A and G, they may accept the new R-APS messages that they receive.

E.   When the RPL owner node receives an NR message with a higher node ID, it unblocks the non-failed port and starts the WTR timer.

F.   On expiration of the WTR timer, the RPL owner node blocks its end of the RPL (it was already blocked) and sends R-APS (NR, RB) messages. This message includes a DNF indication and this prevents all Ethernet ring nodes from performing an FDB flush, despite a transition from the pending to the idle state.

G.   When Ethernet ring node A receives an R-APS (NR, RB) message, it keeps blocking its RPL port and stops sending R-APS (NR) messages. All Ethernet ring nodes receiving this message do not perform the FDB flush as the R-APS (NR, RB) messages include the DNF indication, despite a transition from the pending to the idle state without flushing the FDB.

Scenario D – Multiple failure case – recovery

Figure III.8 represents the case of sequential repair of multiple failures. In this case, the failures between Ethernet ring nodes A and B and between Ethernet ring nodes E and F recover almost simultaneously. The SF condition remains on the ring link between Ethernet ring nodes C and D.

Figure III.8 – Multiple link failure

The following sequence describes the steps in Figure III.8.

A.   Stable SF condition.

B.   Recovery of link failures.

C.   Ethernet ring nodes A, B, E and F detect the clearing of the SF condition, start the guard timer and initiate the periodical transmission of R-APS (NR) messages on both ring ports.

The guard timer prevents the reception of R-APS messages, as is the case of an R-APS (SF) message transmitted by Ethernet ring nodes C and D, which are ignored by Ethernet ring nodes B and E.

D. When Ethernet ring nodes receive an R-APS (NR) message, the (node ID, BPR) pair on the receiving ring port is deleted and the RPL owner node starts the WTR timer.

E. Ethernet ring nodes B and E receiving an R-APS (SF) message do not perform the FDB flush due to the node ID and BPR-based mechanism.

F. When the guard timer expires on Ethernet ring nodes A, B, E and F, they may accept the new R-APS messages that they receive. The reception of an R-APS (NR) message with a higher node ID triggers unblocking of the blocked ring port and stops the transmission of R-APS (NR) messages at Ethernet ring nodes B and F.

G. The reception of an R-APS (SF) message triggers unblocking of the blocked ring port and stops the transmission of R-APS (NR) messages at Ethernet ring nodes A and E. Ethernet ring node A receiving an R-APS (SF) message performs FDB flush due to the node ID and BPR-based mechanism.

H. All Ethernet ring nodes receiving an R-APS (SF) message perform the FDB flush due to the node ID and BPR-based mechanism. The reception of an R-APS (SF) message informs the RPL owner node that an error is still present on the Ethernet ring. This results in the WTR timer being stopped.

NOTE – In rare cases where the link adjacent to the RPL owner is involved and recovers, the reversion process of this scenario may cause continued segmentation of the ring for the duration of running of the WTR/WTB timers.

Appendix IV

Considerations for different timers

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

IV.1   State machine use of timers

There are four timers in this Recommendation – hold-off timer, guard timer, WTR timer and WTB timer. These timers are described in clauses 10.1.8, 10.1.5, 10.1.4 and 10.1.4, respectively. According to Table 10-2, the different timers, except for the hold-off timer, are accessed (start or stop) in the following situations.

a)   During initialization (row 1) – all timers are stopped to verify a clean situation.

b)   During initialization (row 1) – the WTR timer is used by the RPL owner in revertive mode to verify that the node is stabilized before entering the idle state.

c)   An Ethernet ring node that is recovering from an SF condition starts the guard timer (row 20).

d)   An RPL owner node that is recovering from an SF condition starts the WTR timer (rows 20 and 29) – used to verify that the recovered SF is stabilized before reverting to the idle state.

e)   An RPL owner node about to enter the pending state, after receiving an R-APS (NR) message, starts the WTB timer (rows 43 and 57) – used to cause the pending state to time out while the RPL owner node verifies that there are no additional live switching triggers in the Ethernet ring (e.g., two active FS conditions).

f)   An Ethernet ring node that receives a Clear command (following an FS or MS) starts the guard timer (rows 30 and 44) – prior to entering the pending state to protect against stale R-APS messages.

g)   An Ethernet ring node that has an MS command and receives an R-APS (MS) message from another Ethernet ring node in the Ethernet ring (row 36) starts the guard timer prior to entering the pending state.

h)   An RPL owner node that has an MS command and receives either a Clear command or an R-APS (MS) message from another Ethernet ring node in the Ethernet ring (rows 30 and 36) starts the WTB timer prior to entering the pending state.

i)   When the RPL owner node transits out of the pending state, it stops the WTR and WTB timers (rows 58, 59, 60, 61, 63, 64, 65, 66, 68 and 70).

IV.2   Guard timer use to block outdated R-APS messages

Two Ethernet ring nodes could transmit R-APS messages at the same time. In this case, the outdated R-APS message is transmitted by these Ethernet ring nodes until the Ethernet ring node receives the new R-APS message and it overwrites its state. For example, in Figure IV.1, Ethernet ring nodes A and B simultaneously detect local clear SF and start sending R-APS (NR) messages, and they transit to pending state [sequence B]. However, soon after, they may receive an R-APS (SF) message from each other and unblock their recovered ring ports [sequence C]. Unblocking of non-failed ring ports at both Ethernet ring nodes may result in the formation of a loop. To avoid this, Ethernet ring nodes A and B need to discard the received R-APS message for a while. After this period, if they still receive the same R-APS (SF) message, they can properly identify the current SF condition. For this reason, a guard timer is mandatory to avoid forming a loop (rows 20, 30, 36, 44).
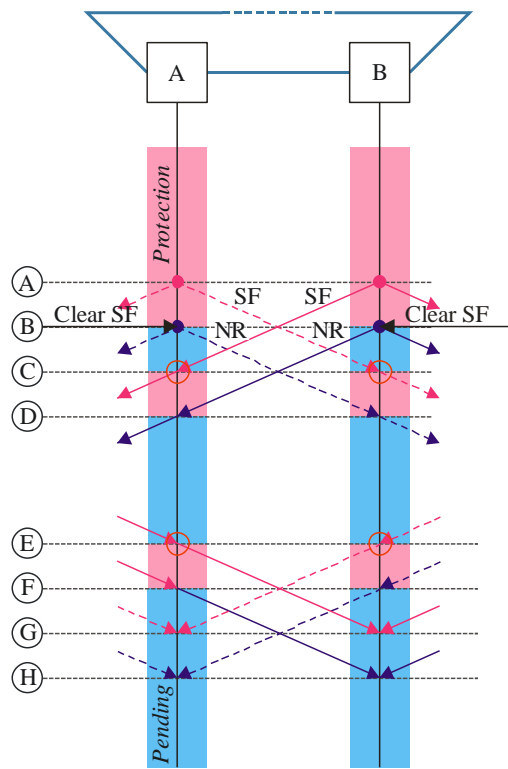
Figure IV.1 – Simultaneous requests from multiple Ethernet ring nodes

Appendix V

This appendix has been moved to [b-ITU-T G.Sup52].

Appendix VI

This appendix has been moved to [b-ITU-T G.Sup52].

Appendix VII

This appendix has been moved to [b-ITU-T G.Sup52].

Appendix VIII

Flush optimization

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

VIII.1 Flushing FDB consideration

The ERP mechanism requires flushing the FDB with the goal of re-learning the correct filtering entries when protection switching has executed. However, in cases where the logical topology of a client channel has not changed as a result of failure, recovery or administrative operation, it is not necessary to flush FDB entries. A flush operation causes traffic flooding on the Ethernet ring and a consequent transient broadcast storm may occur. It is possible to reduce the occurrence of these broadcast storms by avoiding unnecessary FDB flushing.

VIII.2 Scenarios of unnecessary FDB flushing

The following are scenarios of protection switching that do not require FDB flushing. In these scenarios, all blocked ring ports continue to be blocked and the logical topology of a client channel is not changed.

a)   DNF when RPL fails or recovers.

b)   DNF when the RPL owner node or the RPL neighbour node fails or recovers.

c)   DNF when the currently blocked ring port fails or recovers in non-revertive mode.

d)   DNF when a request that results in blocking an already blocked ring link is issued (e.g., MS on RPL owner node).

The latter two scenarios are extensions beyond the scenarios described in the main text. These point to cases where FDB flushing may be omitted.

VIII.3 Example of FDB flush optimization

The following are rules for FDB flush optimization. Ethernet ring nodes connected to the RPL owner node or RPL neighbour node, need to be configured as the RPL next-neighbour node. The ring ports connected to the RPL owner node or the RPL neighbour node are called RPL next-neighbour ports.

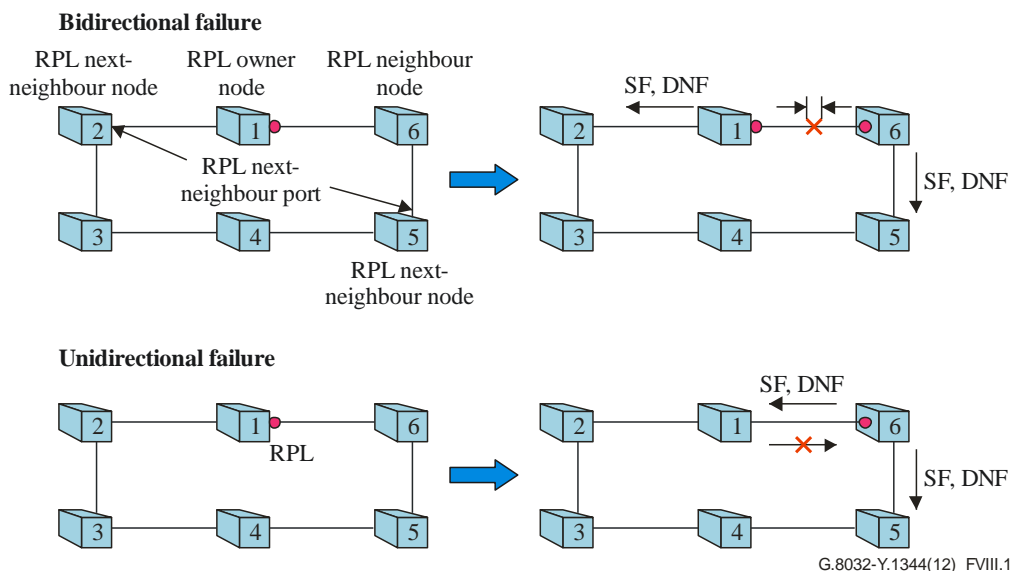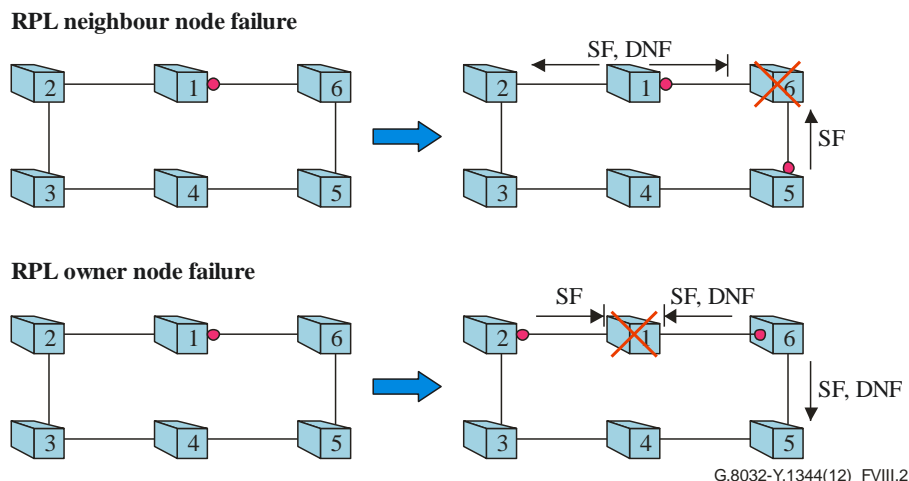Rule 1: If detecting an RPL link failure in [idle state], transmit R-APS (SF, DNF).


Figure VIII.1 – RPL failure case

Rule 2: When detecting a failure from an RPL next-neighbour port, in idle state, transmit an R-APS (SF) message only on the RPL next-neighbour port and do not transmit R-APS messages on the other ring port.

Figure VIII.2 – RPL owner node or RPL neighbour node failure case

Rule 3: If the RPL recovers, transmit the R_APS (NR, RB, DNF) message from the RPL owner node after the WTR timer expires.

Rule 4: If the RPL owner node detects ring recovery in the R-APS (SF, DNF) condition, transmit R_APS (NR, RB, DNF) after the WTR timer expires.
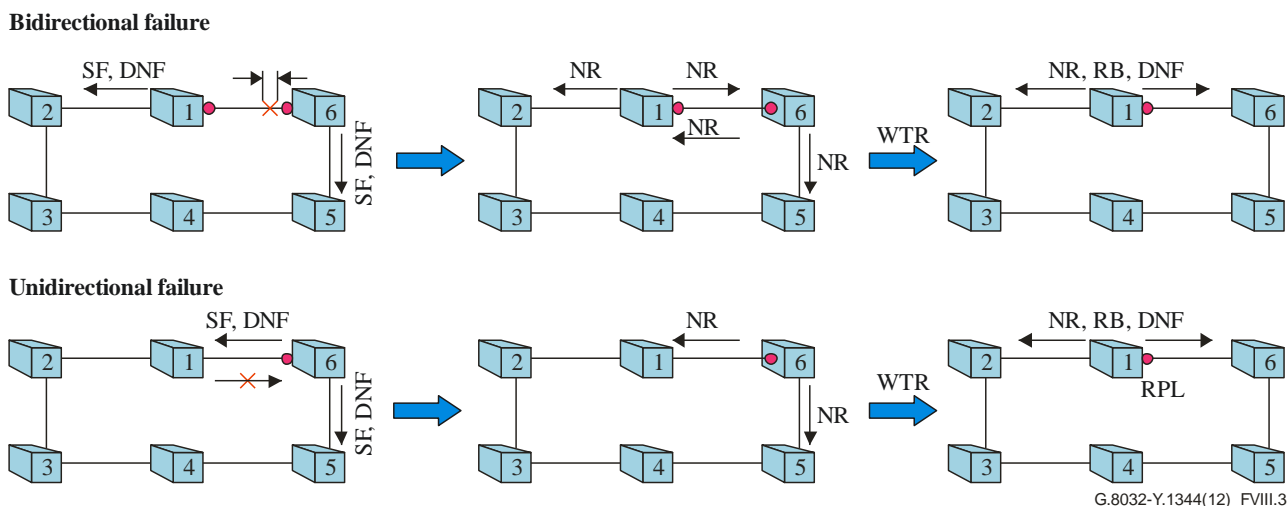
Figure VIII.3 – RPL recovery case

VIII.4   Additional definition of the ERP control process model and state machine

Rules 2 and 4, mentioned in the previous clause, require additional functionality in the ERP control process model and modification to the state machine. It should be noted that rules 1 and 3 are addressed in the basic functionality described in this Recommendation. In particular, rule 4 requires a "history" of DNF to be maintained and a "store/clear DNF status" process to be included in the ERP control process model as illustrated in Figure VIII.4.
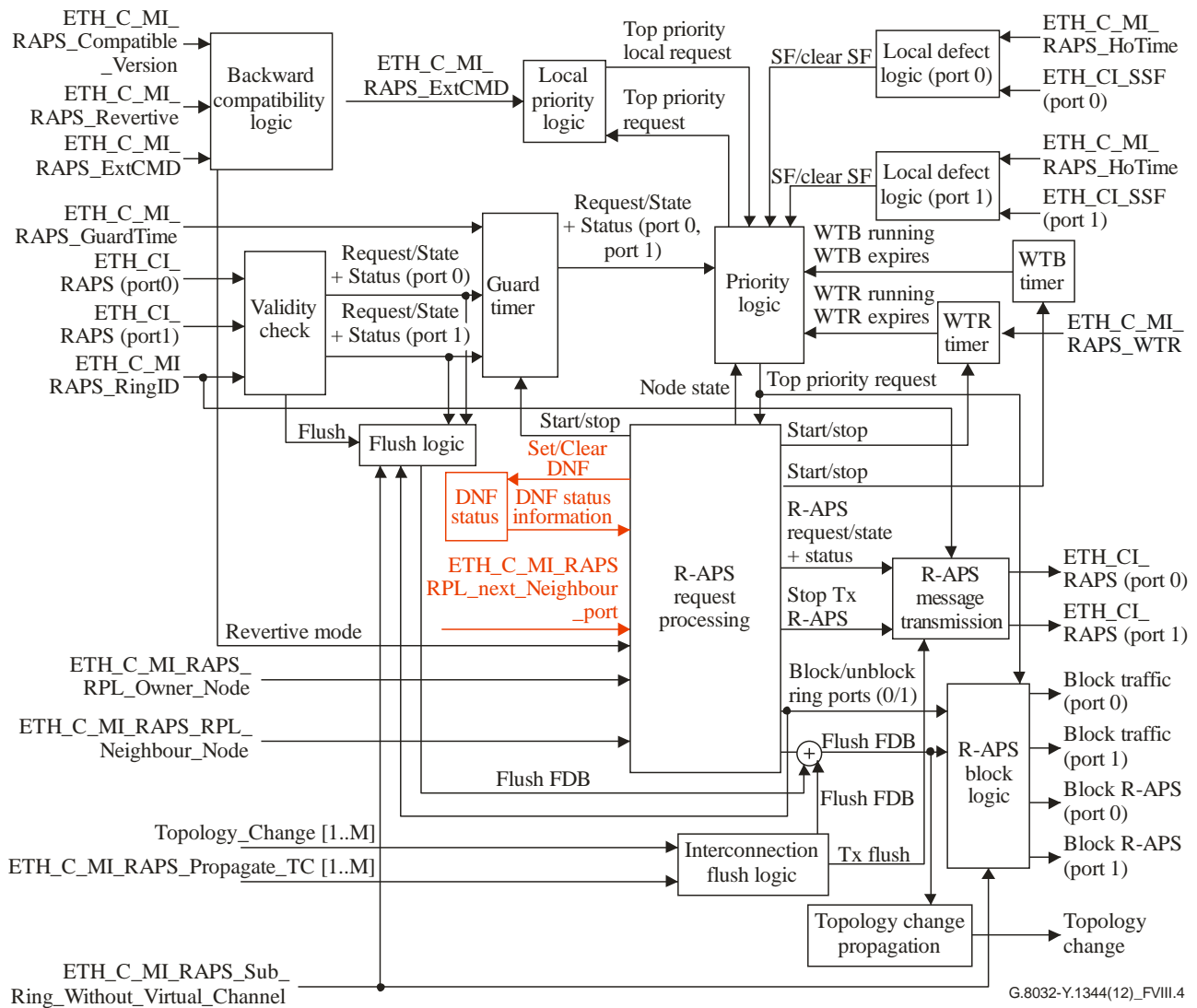
Figure VIII.4 – ERP control process model for flush optimization

In addition to the elements already defined in clause 10, the following are introduced for the specific support of flushing optimization.

The DNF status functionality is described in clause VIII.5 and it represents a memory element which retains the information of whether the protection switching was performed with flush optimization.

ETH_C_MI_RAPS_RPL_next_Neighbour_port represents the MI describing which ring port is connected to an RPL neighbour node or RPL owner node. By omission neither ring ports are considered RPL next-neighbour ports. If one ring port is an RPL next-neighbour port, ETH_C_MI_RAPS_RPL_next_Neighbour_port holds the information of which ring port is the RPL next-neighbour port.

The following Table VIII.1 presents the modification to the state machine (Table 10.2) in compliance with the above rules.

Table VIII.1 – State machine modification

Node state	Top priority request	Actions	Next node state

–	State machine initialization	Stop guard timer
		Stop WTR timer
		Stop WTB timer
		Clear DNF
		If RPL owner node:
		    Block RPL port
		    Unblock non-RPL port
		    Tx R-APS (NR)
		    If revertive:
		        Start WTB timer
		Else if RPL neighbour node:
		    Block RPL Port
		    unblock non-RPL port
		    Tx R-APS (NR)
		Else:
		    Block one ring port
		    unblock other ring port
		    Tx R-APS (NR)
			E (Pending)

A (idle)	local SF	If failed ring port is RPL port:
		    Block failed ring port
		    Tx R-APS (SF, DNF)
		    Unblock non-failed ring port
		    Set DNF status
		Else if failed ring port is RPL next-neighbour port:
		    Block failed ring port
		    Tx R-APS (SF) from failed ring port
		    Unblock non-failed ring port
		Else:
		    Block failed ring port
		    Tx R-APS (SF)
		    Unblock non-failed ring port
		    Flush FDB
			B (Protection)

Table VIII.1 – State machine modification

Node state	Top priority request	Actions	Next node state

A (idle)	R-APS (SF)	Unblock non-failed ring port
		Stop Tx R-APS
		If not DNF
		    flush FDB
		    If RPL next-neighbour node
		        Tx three R-APS (SF) message
		    If RPL owner node
		        Tx three R-APS (SF) message
		        clear DNF status
		Else:
		    If RPL owner node
		        set DNF status
			B (Protection)

E (Pending)	WTR Expires	If RPL owner node:
		    Stop WTB
		    If RPL port is blocked:
		        Tx R-APS (NR, RB,DNF)
		        Unblock non-RPL port
		    Else:
		        Block RPL port
		        If DNF status
		            Tx R-APS (NR, RB, DNF)
		        Else:
		            Tx R-APS (NR, RB)
		            Flush FDB
		        Unblock non-RPL port
		        clear DNF status
			A (idle)

E (Pending)	R-APS (SF)	Unblock non-failed ring port
		Stop Tx R-APS
		If RPL owner node and not DNF
		    clear DNF status
		If RPL owner node:
		    Stop WTR
		    Stop WTB
			B (Protection)

NOTE – The highlighted actions in Table VIII.1 represent the changes relative to Table 10.2.

The following actions triggered by this process are introduced to support flush optimization:

a)   Clear DNF status – triggers the action "clear DNF" of the DNF status.

b)   Set DNF status – triggers the action "set DNF" of the DNF status.

c)   Transmit three R-APS (msgtype, status bits) messages – Triggers the transmission of the initial burst of three R-APS messages over the two ring ports as described in clause 10.1.3.

d)   Transmit R-APS (msgtype, status bits) from failed ring ports – Triggers the continuous transmission of R-APS messages over the failed ring port as described in clause 10.1.3.

VIII.5 DNF status

The DNF status retains the information on the DNF condition so as to support flush optimization, for example, during protection reversion operations. The DNF status information takes the logical values "true" or "false".

The DNF status may be set or cleared. If set, the DNF status information input to the R-APS request processing takes the logical value "true"; if cleared, the DNF status information input to the R-APS request processing takes the logical value "false".

Appendix IX

This appendix has been moved to [b-ITU-T G.Sup52].

Appendix X

This appendix has been moved to [b-ITU-T G.Sup52].

Appendix XI

This appendix has been moved to [b-ITU-T G.Sup52].

Bibliography

[b-ITU-T G.8011.1]   Recommendation ITU-T G.8011.1/Y.1307.1 (2013), *Ethernet private line service*.

[b-ITU-T G.8011.2]   Recommendation ITU-T G.8011.2/Y.1307.2 (2013), *Ethernet virtual private line service*.

[b-ITU-T G.Sup52]   ITU-T G-series Recommendations – Supplement 52 (2012), *Ethernet ring protection switching*.

[b-IEEE 802.3]   IEEE Std 802.3 (2008), *IEEE standard for information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.*

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