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Ethernet ring protection switching

ITU-T G-series Recommendations – Supplement 52

ITU-T

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Supplement 52 to ITU-T G-series Recommendations

Ethernet ring protection switching

Summary

Supplement 52 to ITU-T G-series Recommendations provides supplemental information to Recommendation ITU-T G.8032/Y.1344, *Ethernet ring protection switching*. It provides examples of network application scenarios, Ethernet service support, ring interconnection examples, guidelines for configuration and management procedures, protection switching for multiple Ethernet ring protection (ERP) instances and end-to-end network/service resiliency involving ITU-T G.8032.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G Suppl. 52	2012-09-21	15

FOREWORD

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

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1 Scope

This supplement describes how [ITU-T G.8032] can support the various Ethernet services and how it can be used in various network applications. Additionally, examples of Ethernet ring interconnection, guidelines for configuration and management procedures, protection switching for multiple Ethernet ring protection (ERP) instances and end-to-end network/service resiliency involving [ITU-T G.8032], are described.

This supplement is intended to consolidate and expand upon related material that is current in [ITU-T G.8032].

2 References

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

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

[ITU-T G.808.1] Recommendation ITU-T G.808.1 (2010), *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 (2010), *Terms and definitions for optical transport networks.*.

[ITU-T G.8001] Recommendation ITU-T G.8001/Y.1354 (2010), *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.8011] Recommendation ITU-T G.8011/Y.1306 (2004), *Ethernet service characteristics*.

[ITU-T G.8011.1] Recommendation ITU-T G.8011.1/Y.1307.1 (2009), *Ethernet private line service*.

[ITU-T G.8011.2] Recommendation ITU-T G.8011.2/Y.1307.2 (2009), *Ethernet virtual private line service*.

[ITU-T G.8013] Recommendation ITU-T G.8013/Y.1731 (2008), *OAM functions and mechanisms for Ethernet based networks: Amendment 1 (2010)*.

[ITU-T G.8021] Recommendation ITU-T G.8021/Y.1341 (2011), *Characteristics of Ethernet transport network equipment functional blocks*.

[ITU-T G.8031] Recommendation ITU-T G.8031/Y.1342 (2011), *Ethernet linear protection switching*.

[ITU-T G.8032] Recommendation ITU-T G.8032/Y.1344 (2012), *Ethernet ring protection switching*.

[IEEE 802.1ag] IEEE Std 802.1ag-2007, *IEEE Standard for Local and Metropolitan Area Networks – Virtual Bridged Local Area Networks – Amendment 5: Connectivity Fault Management*.

[IEEE 802.1D] IEEE Std 802.1D-2004, *IEEE Standard for Local and Metropolitan Area Networks: Media Access Control (MAC) Bridges*.

[IEEE 802.1Q] IEEE Std 802.1Q-2005, *IEEE Standard for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks*.

[IEEE 802.3] IEEE Std 802.3-2008, *Information Technology – Local and Metropolitan Area Networks – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*.

[MEF 6.1] The Metro Ethernet Forum, MEF Technical Specification (2008), *Ethernet Services Definitions Phase 2, April, 2008*.

3 Terms and definitions

3.1 Terms defined elsewhere

This supplement uses the following terms defined elsewhere:

3.1.1 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)

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

a) adaptation

b) flow

c) layer network

d) network

e) port

f) transport

g) transport entity

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

a) APS protocol

b) hold-off time

c) non-revertive operation

d) protection

e) protected domain

f) revertive operation

g) signal

h) switch

i) switching time

j) transport entity:

   a. protection transport entity

   b. working transport entity

k) wait-to-restore time

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

a) maintenance entity (ME)

b) maintenance entity group (MEG)

c) Ethernet ring

d) Ethernet ring node

e) ERP instance

f) interconnection node

g) major ring

h) R-APS virtual channel

i) ring MEL

j) ring protection link (RPL)

k) RPL neighbour node

l) RPL owner node

m) sub-ring

n) sub-ring link

o) wait to block timer

3.1.5 Terms defined and described in [ITU-T G.8010] and [ITU-T G.8013]:

a) maintenance entity group end point (MEP)

b) maintenance entity group level (MEL)

3.1.6 Terms defined and described in [ITU-T G.8011]:

a) Ethernet virtual connection (EVC)

4 Abbreviations and acronyms

This supplement uses the following abbreviations and acronyms:

APS Automatic Protection Switching

CCM Continuity Check Message

CE Customer Equipment

CPE Customer Premises Equipment

E-LAN Ethernet LAN Service

E-Line Ethernet Line Service

EPL Ethernet Private Line

ERP Ethernet Ring Protection

E-services Ethernet services

E-Tree Ethernet Tree Service

EVC Ethernet Virtual Connection

FDB	Filtering Database
FS	Forced Switch
ID	Identification
IP	Internet Protocol
IPTV	Internet Protocol Television
LAN	Local Area Network
MAC	Media Access Control
MEF	Metro Ethernet Forum
MEG	Maintenance Entity Group
MEL	Maintenance Entity Group Level
MEP	Maintenance Entity Group End Point
MI	Management Information
MIP	Maintenance Entity Group Intermediate Point
MPLS	Multiprotocol Label Switching
MPLS-TP	MPLS Transport Profile
MS	Manual Switch
NR	No Request
OAM	Operations, Administration and Maintenance
OTN	Optical Transport Network
PBB-TE	Provider Backbone Bridge Traffic Engineering
PDU	Protocol Data Unit
RAN	Radio Access Network
R-APS	Ring APS
RB	RPL Blocked
RPL	Ring Protection Link
RSTP	Rapid Spanning Tree Protocol
SDH	Synchronous Digital Hierarchy
SF	Signal Fail
SONET	Synchronous Optical Network
STP	Spanning Tree Protocol
TDM	Time Division Multiplexing
UNI	User Network Interface
VID	VLAN Identifier
VLAN	Virtual LAN
VPLS	Virtual Private LAN Service
VR	Virtual Ring

5 Introduction

This supplement provides supplemental information to [ITU-T G.8032], *Ethernet ring protection switching*. It describes ITU-T G.8032 suitability to many network applications (e.g., mobile backhaul, business services, etc.), and how [ITU-T G.8032] can be used to support the various Ethernet services (e.g., E-Line, E-LAN and E-Tree services), as defined by MEF [MEF 6.1], using a common ERP protection switching mechanism. Ring interconnections examples involving ITU-T G.8032 major-rings and sub-rings, and configuration and management procedures in support of service provider network requirements and network applications, are also described.

6 ITU-T G.8032 network applications

The fundamental network requirement to operate an ITU-T G.8032 ring is the existence of a sub-network of network elements interconnected in a closed loop[1], such that there are diversely routed forwarding paths between any two network elements.

Networks are often composed of both diversely routed paths and spurs. A network spur exists when there is only a single network path providing connectivity between network elements. Consequently, spurs by their very nature do not provide diversely routed paths and thus could not leverage ITU-T G.8032. However, spurs typically connect network elements to redundant access or aggregation sub-networks. When these redundant sub-networks use diverse routing for redundancy, ITU-T G.8032 can be deployed to provide all the value propositions of this technology.

The existence of diversely routed sub-networks can be found in network architectures for various applications, such as business services, mobile/wireless backhaul and residential services. These applications can make use of ITU-T G.8032 as an access sub-network or as an aggregation transport infrastructure sub-network.

For example, ITU-T G.8032 is suitable for mobile backhaul network applications. As illustrated in Figure 1, ITU-T G.8032 can be used in the backhaul access, as well as the aggregation network, to provide service connectivity with (sub-50 ms) resiliency.

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1 A "closed loop" is a data path through the network that would result in data traffic looping, without a loop prevention mechanism. A closed loop requires diversely routed paths between two nodes within the network. It should be noted that both a major ring and a sub-ring, from a data path perspective, form a closed loop. However, the R-APS channel of a major ring forms a closed loop while the R-APS channel of a sub-ring does not.

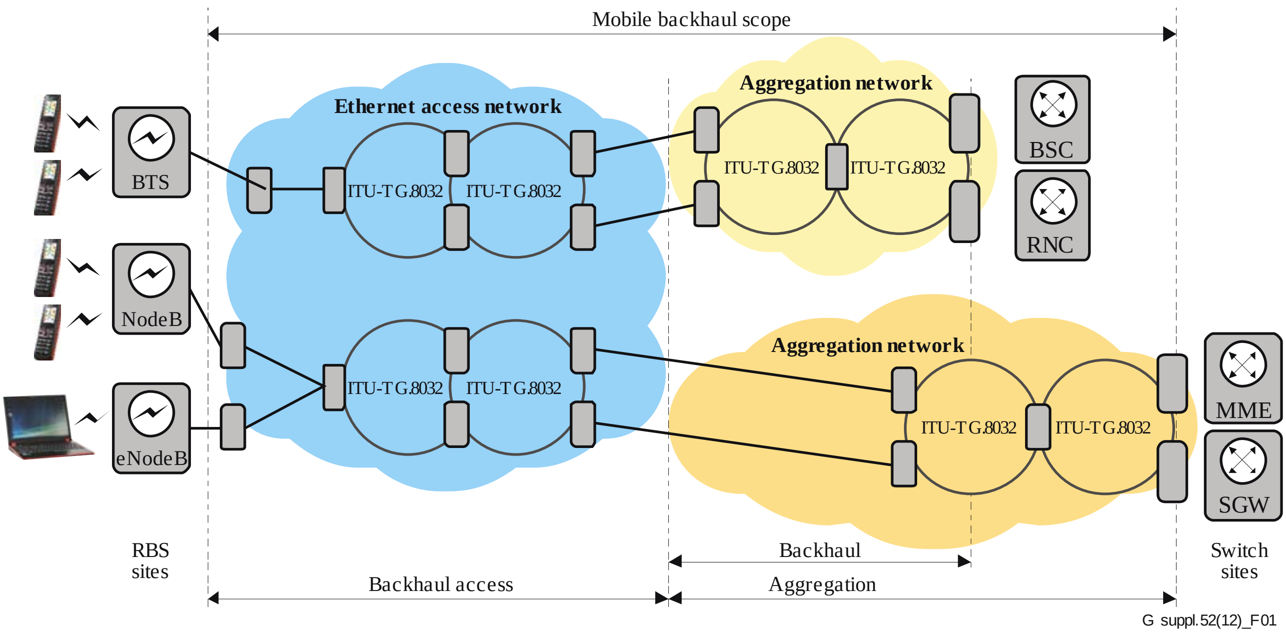

Figure 1 – ITU-T G.8032 mobile RAN and backhaul network application

As illustrated in Figure 2, ITU-T G.8032 can also be applied to business (and residential) services, by providing resilient interconnections within the aggregation network.

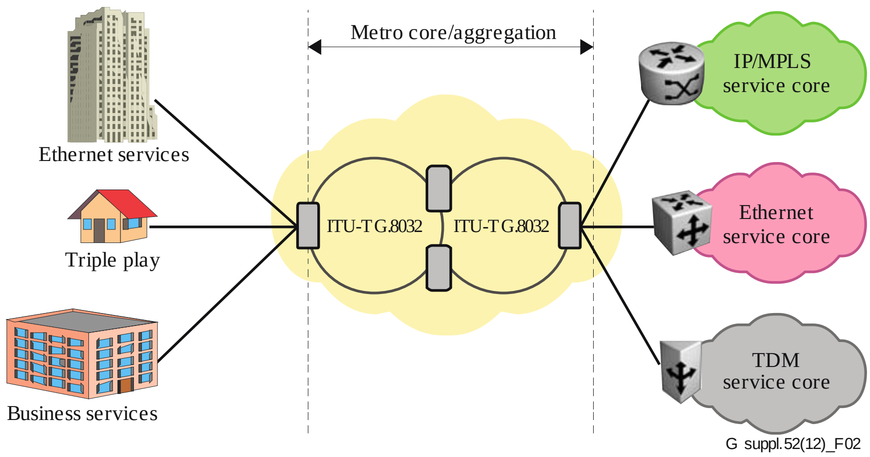

Figure 2 – ITU-T G.8032 business/residential application

7 ITU-T G.8032 support of Ethernet services

7.1 Introduction

[ITU-T G.8032] can be used to support MEF [MEF 6.1] defined E-Line, E-Tree and E-LAN services, along with [ITU-T G.8011] service definitions.

An E-Line service utilizes a point-to-point EVC (between customer UNI points) to provide service connectivity. E-Line services can be used to create Ethernet private lines, virtual private lines and Ethernet Internet access applications. An E-Line service is illustrated in Figure 3.

Figure 3 – E-Line service

An E-Tree service enables point-to-multipoint applications with less provisioning than a typical hub and spoke configuration using E-Lines. An E-Tree service provides traffic separation between users with traffic from one "Leaf" being allowed to arrive at one of more "Roots" but never being transmitted to other "Leaf" nodes. E-Tree services are targeted at multi-host and franchised applications where user traffic must be kept invisible to other users. An E-Tree service is illustrated in Figure 4.

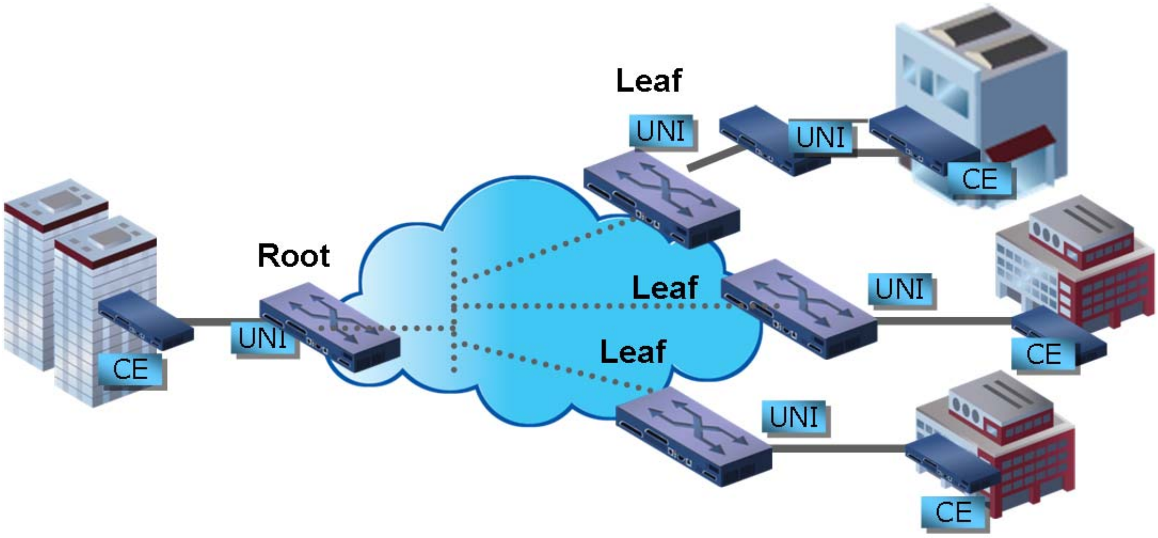

Figure 4 – E-Tree service

An E-LAN service can be used to create multipoint L2 VPNs, transparent LAN services, IPTV and multicast networks, etc. E-LAN services utilize a multipoint EVC, as illustrated in Figure 5.

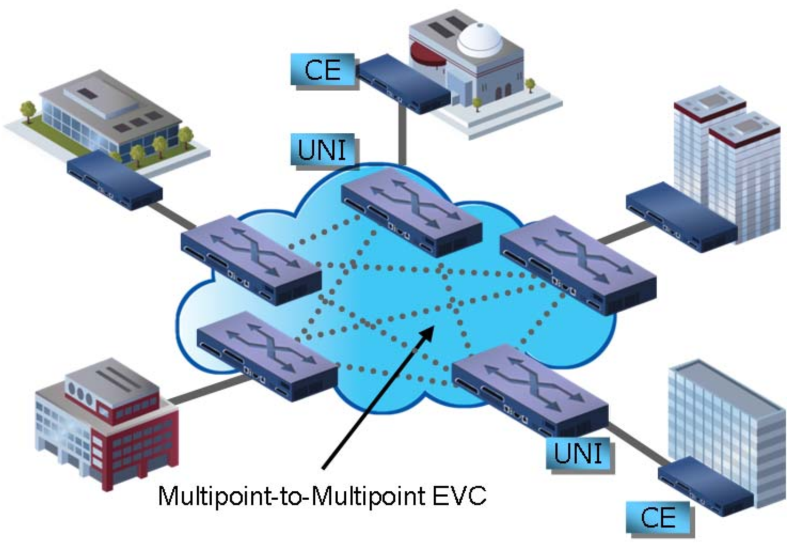

Figure 5 – E-LAN service

7.2 ITU-T G.8032 ring concepts in support of E-services

An ITU-T G.8032 ring is really a logical construct that forms a closed loop over the physical network infrastructure. It can provide (deterministic) rapid protection switching (i.e., sub 50ms). It is client- and server-layer agnostic. The connections between adjacent ring nodes (i.e., the ring spans) are assumed to be bi-directional, and can be a link, a link aggregation group, or a subnet (e.g., MPLS, PBB-TE, OTN, SONET/SDH, etc.)[2].

An illustration of ITU-T G.8032 [logical] rings, within an example network is illustrated in Figure 6. As illustrated, multiple [logical] rings can be supported over the same physical network infrastructure.

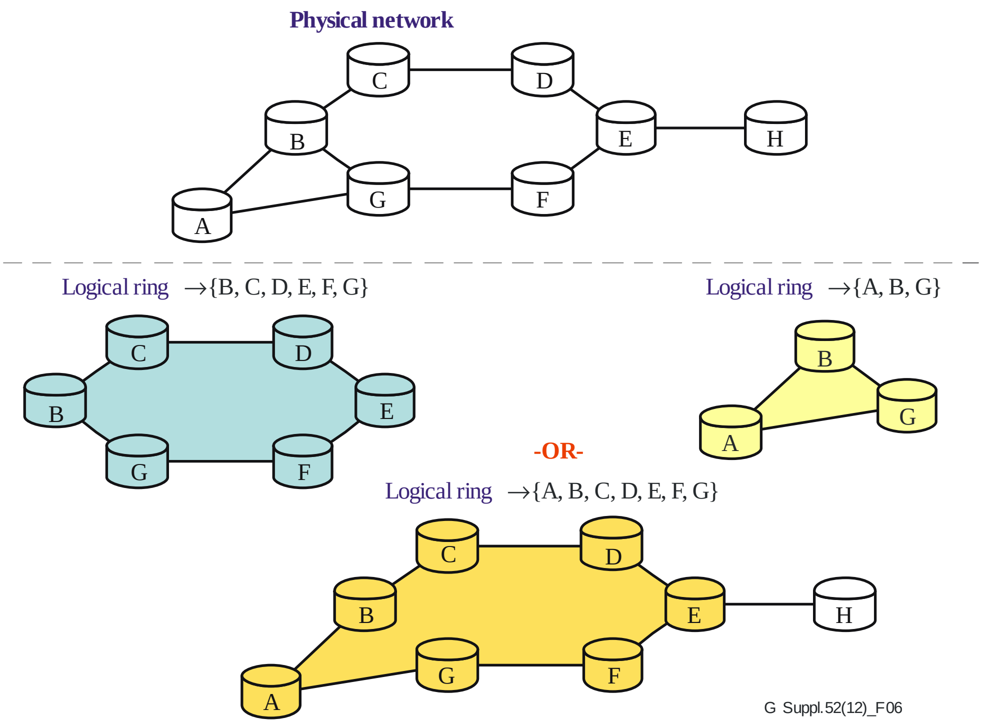

Figure 6 – ITU-T G.8032 [logical] ring

2 Ring spans associated with a ring need not be the same bandwidth or server-layer technology.

Multiple ERP instances (i.e., virtual rings[3]) can be provided over a single ITU-T G.8032 [logical] ring. Each virtual ring is composed of an R-APS channel and a service data channel. The R-APS channel is used to transport the ring control PDUs, while the service data channel is used to transport a defined set of [client] data traffic.

Figure 7 illustrates the R-APS and data channels of a given virtual ring.

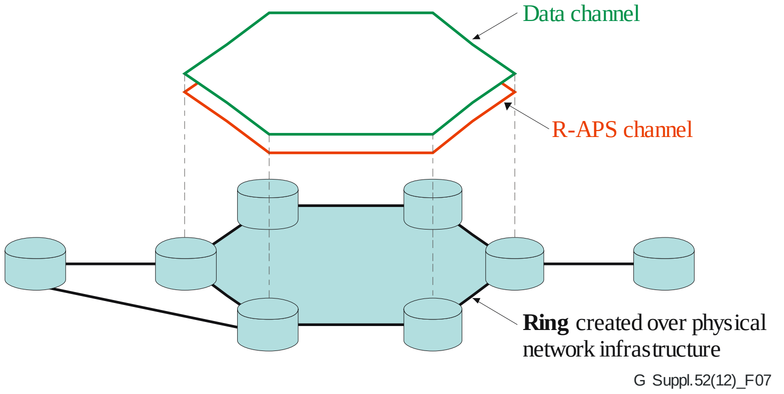

Figure 7 – Virtual ring (ERP instance) composition

Figure 8 illustrates how multiple virtual rings can be created over a single ITU-T G.8032 [logical] ring.

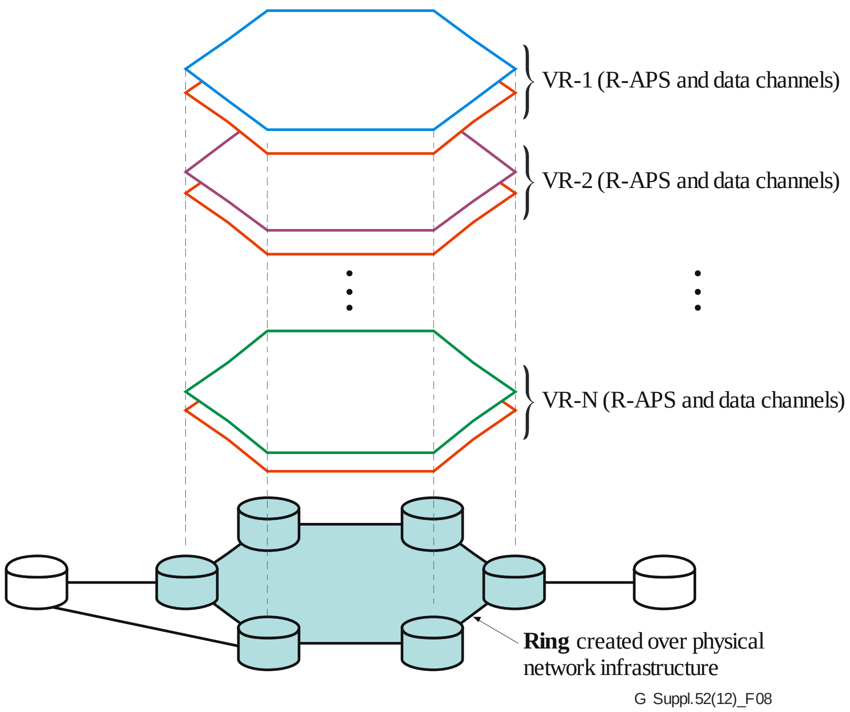

Figure 8 – Multiple virtual rings (ERP instances) → logical ring

As a result of the aforementioned properties of ITU-T G.8032, multiple and diverse E-Services can be supported over the same physical network infrastructure and the same ITU-T G.8032 [logical] ring.

3 A virtual ring (i.e., ERP instance) may be a major ring or a sub-ring.

7.3 ITU-T G.8032 support of E-Line services

E-Line services have a point-to-point topology. They can be supported via a 1-for-1 (1:1) or 1-plus-1 (1+1) protection switching scheme.

In general, ITU-T G.8032 can support an E-Line service. This can be supported by simply creating a logical ring composed of two nodes. As illustrated in Figure 9, an E-Line service can be provided between customer devices CPE1 and CPE2 via ring nodes A and B.

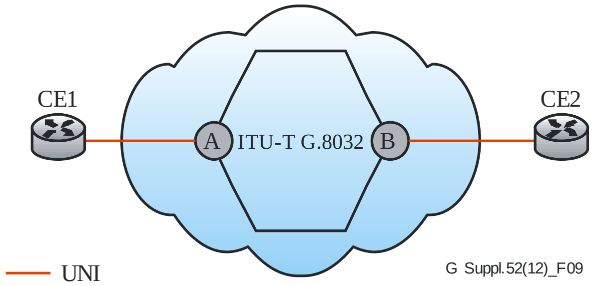

Figure 9 – E-Line service via ITU-T G.8032

[ITU-T G.8032] supports a channel block at one end of the ring protection link (RPL), or on both ends. Blocking the RPL at both ports provides greater network resource utilization. See illustration in Figure 10.

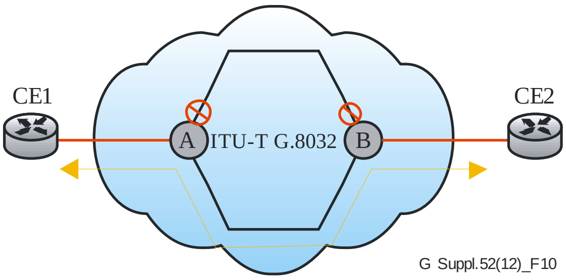

Figure 10 – E-Line service via ITU-T G.8032 – dual RPL block

It should be noted that a logical ring of two nodes can be created over a [physical] network containing multiple (>2) nodes. As illustrated in Figure 11, a network may contain six nodes {A, B, C, D, E, F}; however, only nodes {A, B} can be configured to be an ITU-T G.8032 logical ring. The intermediate nodes {C, D, F, E} are configured at a lower layer (e.g., server layer) and are not participating in ERP. These lower layer nodes could be bridges/switches with point-to-point VLAN cross connects, or even a separate layer (e.g., OTN).

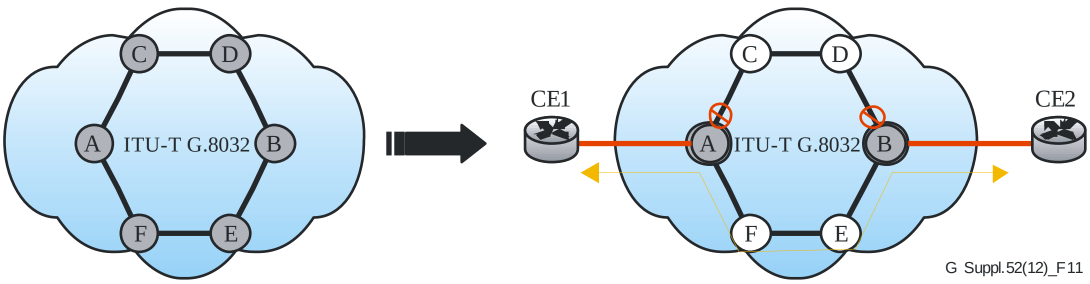

Figure 11 – E-Line service via ITU-T G.8032 logical ring

NOTE – It is recommended to use ITU-T 802.1ag/ITU-T G.8013/Y.1731 CCMs as the mechanism to detect ring span faults (that will trigger ITU-T G.8032 protection switching). For the example shown in Figure 11, the ring spans of this two-node ITU-T G.8032 logical ring are A→ {C, D} →B and A→ {F, E} →B.

For some E-Line service deployments, there may be a desire to not support MAC learning on the ITU-T G.8032 ring nodes. Typical vendor implementations of ITU-T G.8032 can support this capability. If MAC learning is disabled on the ring nodes, then Figure 12-A illustrates a representative 1+1 linear protection scheme, while Figure 12-B illustrates a representative 1:1 linear protection scheme.

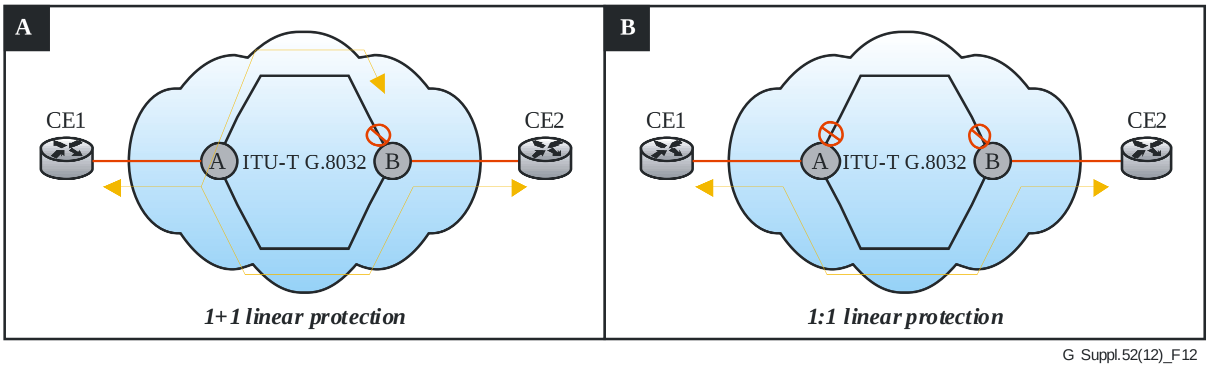

Figure 12 – E-Line service via ITU-T G.8032 – 1+1 and 1:1 schemes

7.4 ITU-T G.8032 support of E-Tree services

For an E-Tree service, a (designated) root node can communicate with other leaf nodes, while leaf nodes can only communicate with the (designated) root node. This is illustrated in Figure 13.

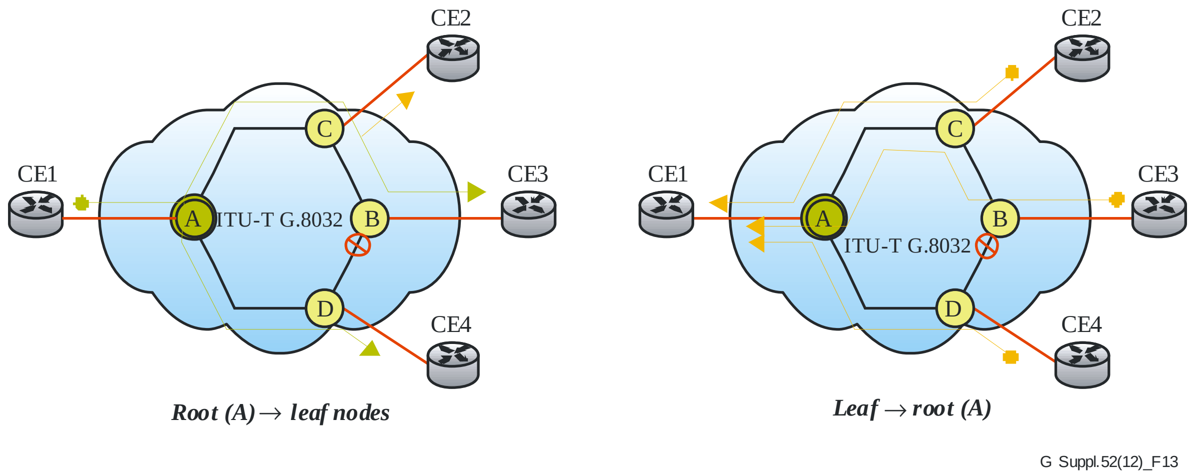

Figure 13 – E-Tree service over ITU-T G.8032

In support of an E-Tree service, the use of asymmetric VLANs [IEEE 802.1Q] can be utilized. Specifically, the root node will transmit client frames (over ITU-T G.8032) using VIDx, while leaf nodes would transmit client frames (over ITU-T G.8032) using VIDy[4]. Root nodes can receive frames from leaf (and other root nodes), via the VLAN identifier being VIDx and/or VIDy. Leaf nodes can only receive frames from a root, via VLAN identifier being VIDx. Basic VID filtering techniques on an IEEE 802.1 bridging device can be applied at the root and leaf nodes in support of the asymmetric communication required by the nodes involved in an E-Tree service.

NOTE – It is possible to assign the root→leaf traffic on a separate virtual ring (i.e., ERP instance) from the leaf→node traffic. This technique could also be used to support the asymmetric communication required by the nodes involved in an E-Tree service.

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4 VIDx ≠ VIDy.

7.5 ITU-T G.8032 support of E-LAN services

ITU-T G.8032 may be traditionally viewed as a technology to support E-LAN services. This is illustrated in Figure 14.

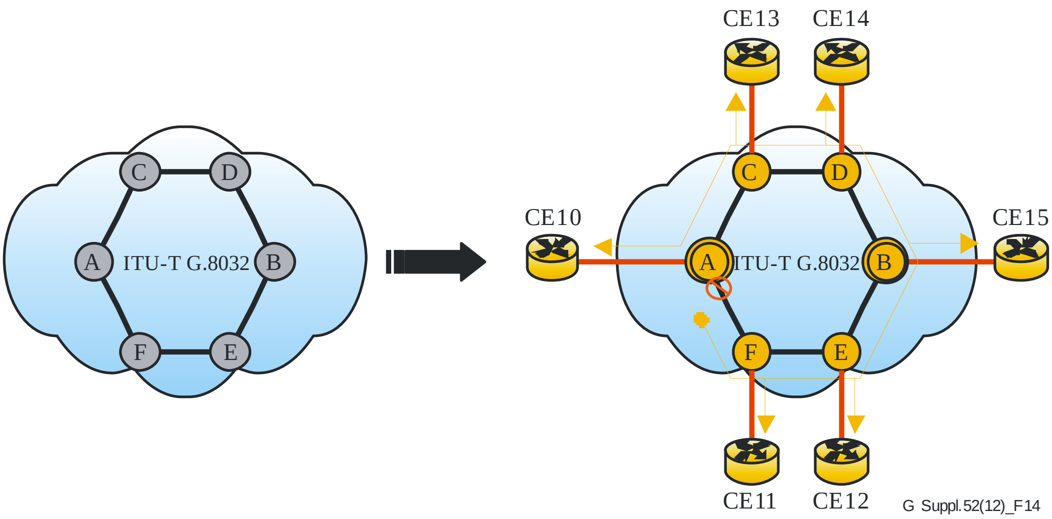
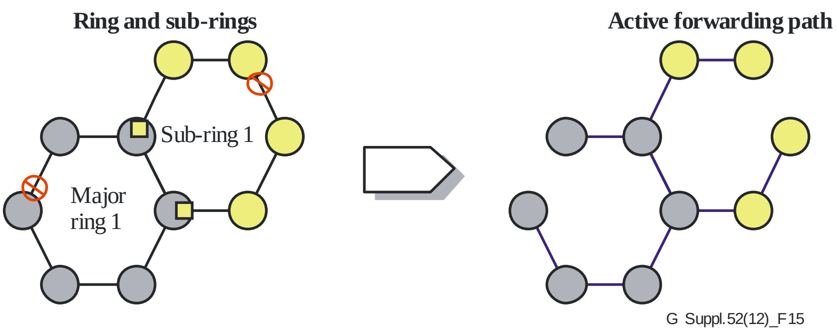


Figure 14 – E-LAN service via ITU-T G.8032

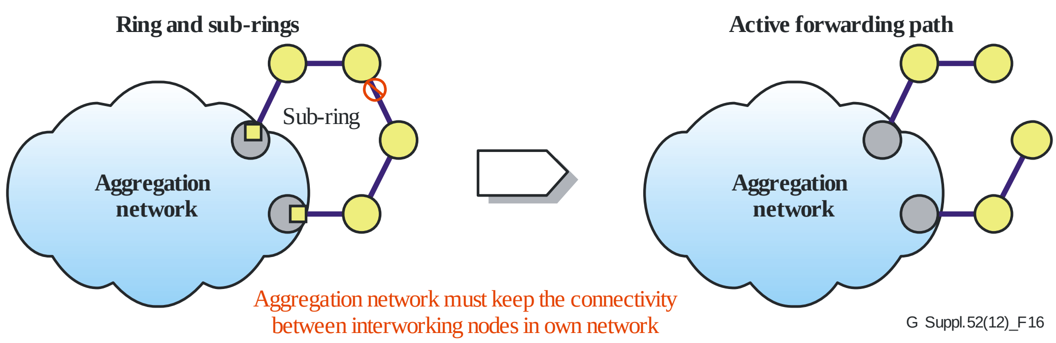
For larger meshed networks, ITU-T G.8032 ring interconnection features (involving rings and sub-rings) can be used to extend E-LAN services across a network.

For example, ITU-T G.8032 rings and sub-rings can be interconnected to support more diverse networks support E-LAN services. This is illustrated in Figure 15 and Figure 16.



NOTE – Loop freeness of active forwarding path is maintained (during all protection events).

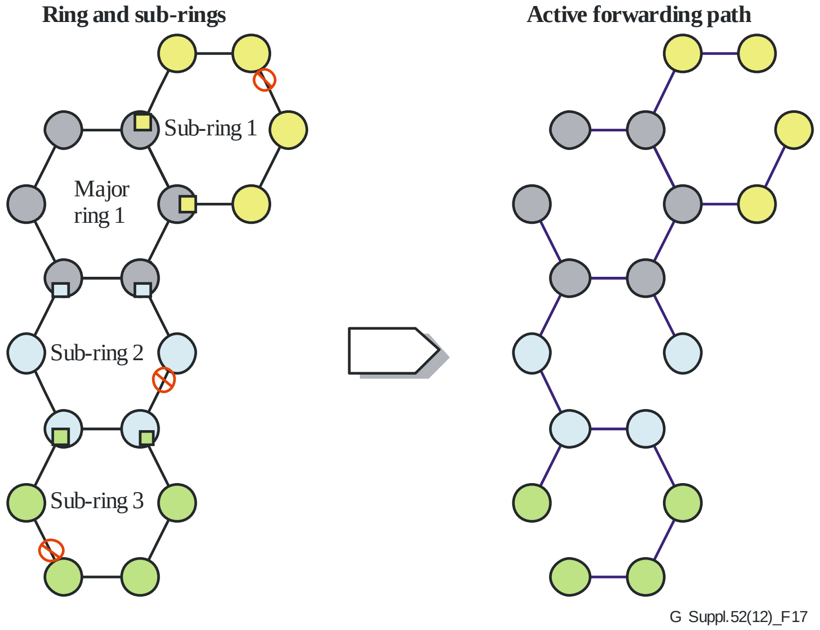
Figure 15 – Basic ITU-T G.8032 application – 1



NOTE – Loop freeness of active forwarding path is maintained (during all protection events).

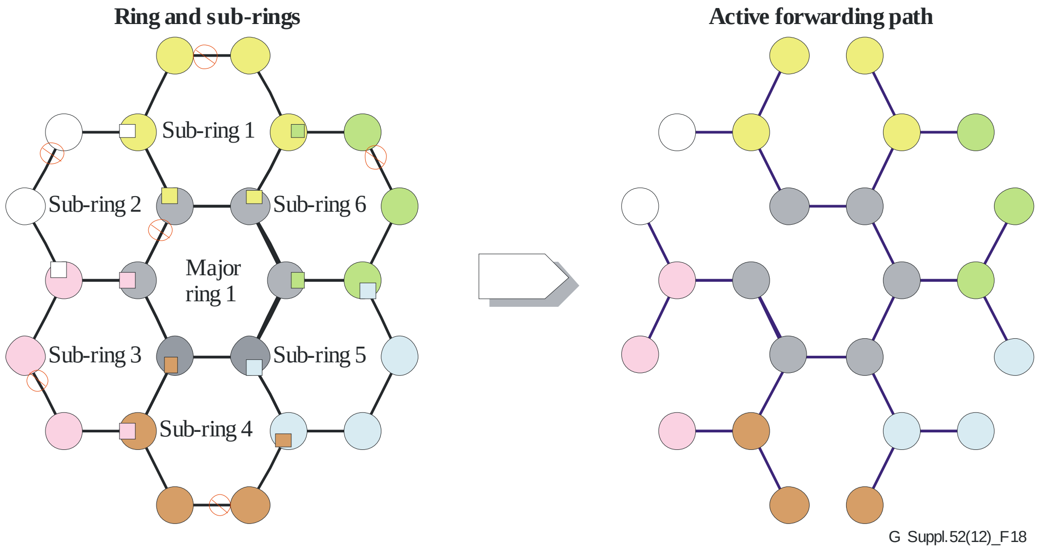
Figure 16 – Basic ITU-T G.8032 application – 2

Even more complex network configurations can be supported, as illustrated in Figure 17 and Figure 18.



NOTE – Loop freeness of active forwarding path is maintained (during all protection events).

Figure 17 – Complex ITU-T G.8032 application – 1



NOTE – Loop freeness of active forwarding path is maintained (during all protection events).

Figure 18 – Complex ITU-T G.8032 application – 2

7.6 ITU-T G.8032 support of mixed E-services

A given network infrastructure using ITU-T G.8032 to provide service resiliency can support multiple, concurrent and diverse E-services.

As described in clause 7.2, the ITU-T G.8032 properties that allow multiple logical rings and support of multiple virtual rings (i.e., ERP instances) to be associated with a given logical ring, allows any combination of E-Line, E-TREE and E-LAN services to be supported over the same ITU-T G.8302 infrastructure.

For example, as illustrated in Figure 19, virtual ring 1 (i.e., ERP instance 1) could be used to support an E-Line service, while virtual ring 2 (i.e., ERP instance 2) could be used to support an E-LAN service.

In general, the application of multiple virtual rings (i.e., ERP instances) per logical ring can be used to facilitate traffic load distribution over the ring, as well as be used as a mechanism to differentiate the processing of different services (having different connectivity properties and/or different quality of service characteristics) being supported by a common infrastructure (i.e., logical ring).

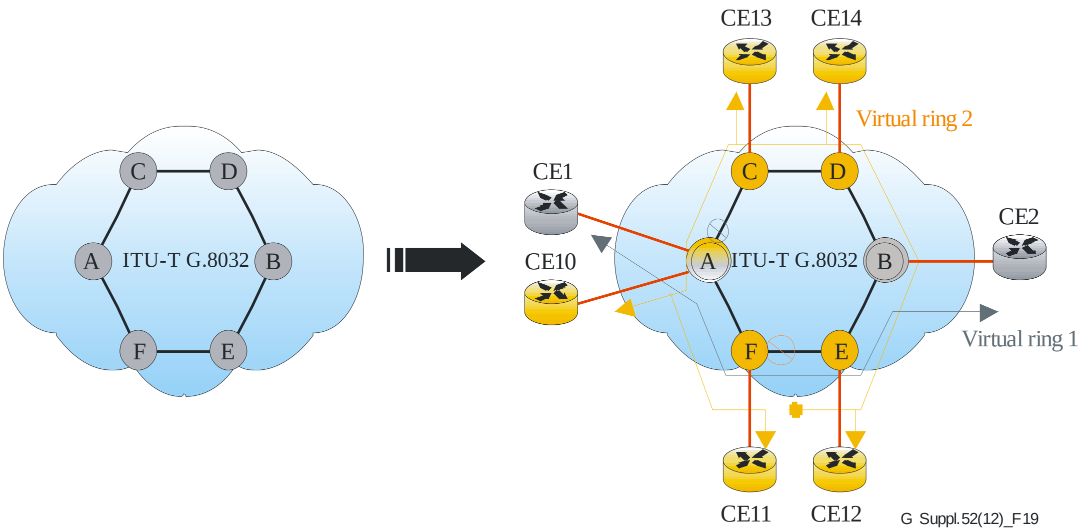


Figure 19 – E-Line and E-LAN services over ITU-T G.8032 example

Here, we can see that the E-Line service can be created over an ITU-T G.8032 logical ring involving nodes {A, B}, while the E-LAN service can be created over said same physical infrastructure but using a separate ITU-T G.8032 logical ring involving nodes {A, C, D, E, F}. Each virtual ring supports a unique E-Service and provides sub-50ms protection switching over the same network infrastructure.

8 Interconnected rings

ITU-T G.8032 sub-50ms protection switching is not confined to a single ring. It can also be applied to inter-ring connections. As illustrated in Figure 20, ITU-T G.8032 can be interconnected via (b) a link (or group of links via link aggregation), (c) via a shared ring node, or even (d) via a dual nodes (which can support site redundancy). All these inter-ring connection configurations are supported by ITU-T G.8032 and provide sub-50ms protection switching.

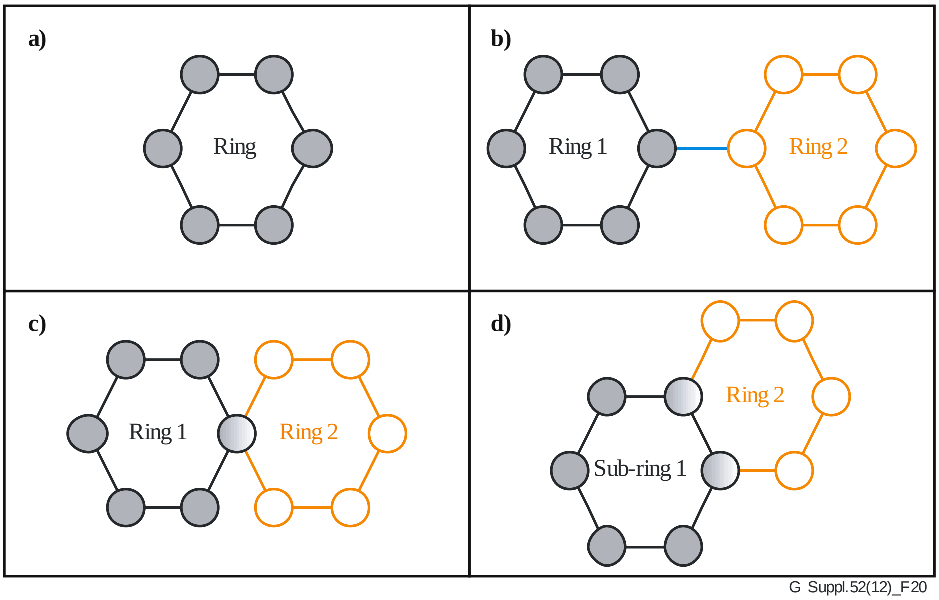


Figure 20 – ITU-T G.8032 interconnections

Caution should be exercised when deploying multiple ITU-T G.8032 ring interconnections involving a shared node, since looping of traffic may occur, as illustrated in the Figure 21 below.

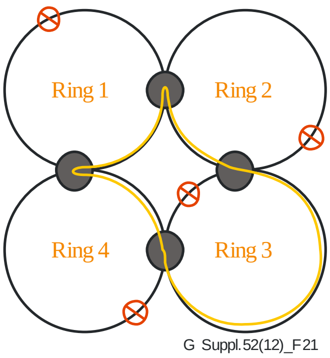


Figure 21 – ITU-T G.8032 ring interconnections with shared node

Additionally, ITU-T G.8032 can provide general network connectivity. ITU-T G.8032 can provide resilient single node (Figure 22-e) and dual-homed (Figure 22-f) connectivity to networks utilizing varying technologies (e.g., MPLS/IP, MPLS-TP, VPLS, PBB-TE, STP, etc.). The network construct illustrated in Figure 22-f is referred to as an ITU-T G.8032 sub-ring, and can be used to provide a generalized dual-homed network access mechanism to an aggregation network. Connectivity between disparate networks (e.g., different administrative network domains) can also be achieved via ITU-T G.8032. As illustrated in Figure 22-g, ITU-T G.8032 can be used to provide resilient inter-network connectivity.

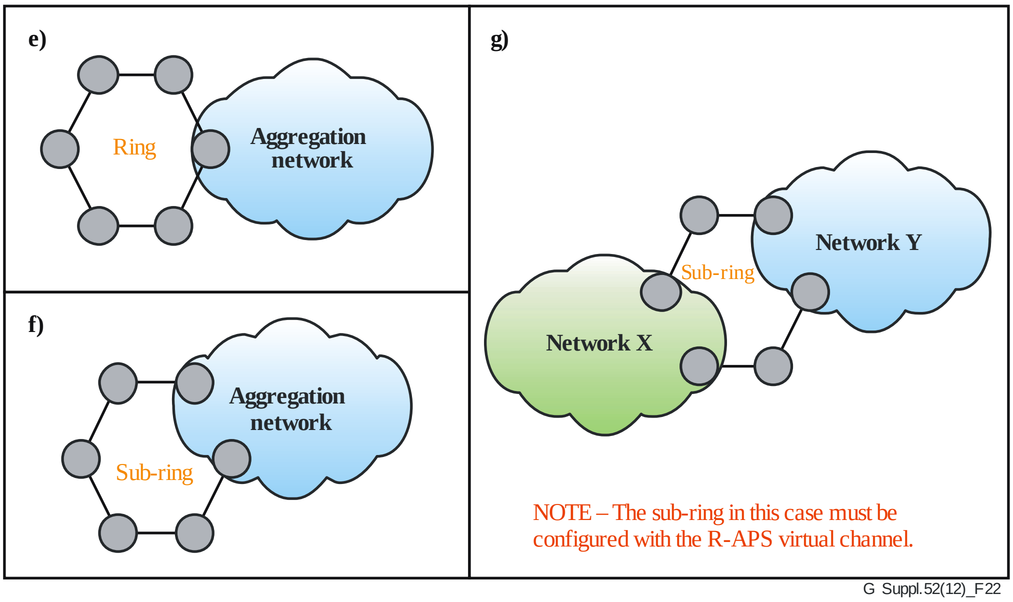


Figure 22 – ITU-T G.8032 network connectivity

8.1 Configuration for interconnected rings

Figure 23 represents an example of a topology composed of two interconnected Ethernet rings. The lower Ethernet ring is a sub-ring. Figure 24 represents an example of a topology composed of three interconnected Ethernet rings and the middle Ethernet ring is a sub-ring.

The R-APS channels of Ethernet rings A and B are consistent with the definition of [ITU-T G.8032].

When the sub-ring is operated with R-APS virtual channel (refer to [ITU-T G.8032] clause 9.7.1), the R-APS channel of the sub-ring is complemented by the use of the R-APS virtual channel to enable R-APS channel connectivity between sub-ring ERP control processes of the two interconnection nodes. When the sub-ring is operated without R-APS virtual channel (refer to [ITU-T G.8032] clause 9.7.2), the R-APS channel of the sub-ring is terminated at the interconnection nodes as illustrated in Figure 23-e).

The ring link between the two interconnection nodes is under the control of the ERP control processes of Ethernet rings A or B that are present at the interconnection nodes. These entities are responsible for triggering protection switching events upon the failure of this ring link, and perform block and unblock operations for traffic on that ring link. The sub-ring is not aware of the existence.

The sub-ring is composed of at least one sub-ring link and one R-APS virtual channel in order to allocate the RPL on a sub-ring.

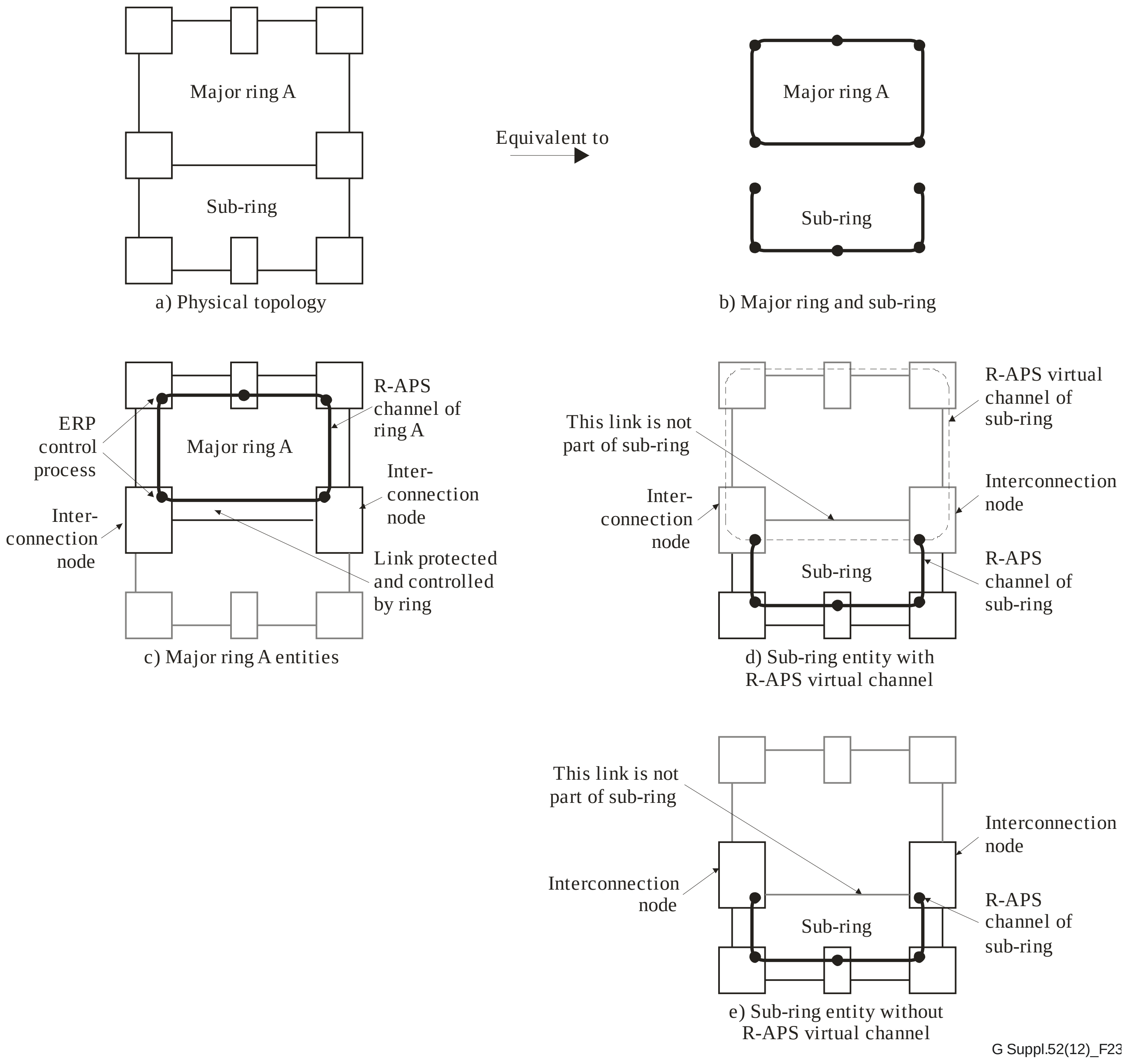


Figure 23 – Configuration for interconnection between a major ring and a sub-ring

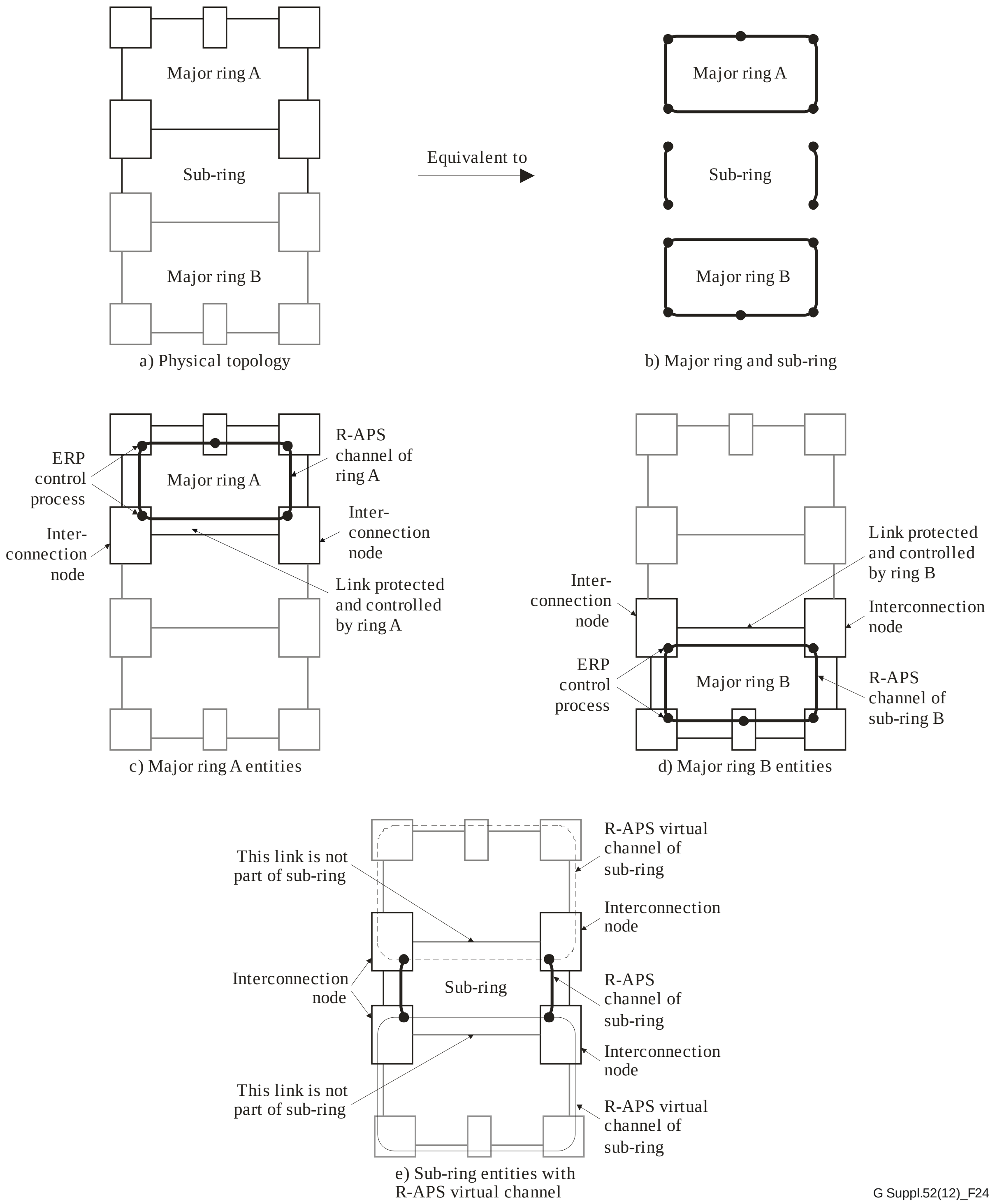


Figure 24 – Configuration for interconnection between multiple major rings and a sub-ring

8.2 Topology examples for interconnected Ethernet rings

Figure 25 represents examples of a topology composed of three or more interconnected Ethernet rings. The R-APS virtual channels are not depicted for simplification. When the sub-ring is operated with an R-APS virtual channel, it is deployed on an Ethernet ring that the sub-ring is connected to, as illustrated in Figure 23 and Figure 24. There is no limit to the number of interconnected Ethernet rings.

a) Location of the RPL for a sub-ring

The RPL can be placed on any ring link of a sub-ring. The RPL for a sub-ring cannot be placed on a major ring link between the interconnection nodes.

b) Intermediate Ethernet ring node(s) between interconnection nodes

Ethernet ring node(s) that are part of a major ring can be placed between the interconnection nodes.

c) Multiple sub-rings connected to a major ring

A major ring can accommodate multiple sub-rings. A pair of two interconnection nodes on a major ring can accommodate multiple sub-rings.

d) Sub-ring(s) interconnection

A sub-ring can accommodate other sub-ring(s) on its ring link(s). The rules of b) and c) can be applied.

e) A sub-ring connected to multiple Ethernet rings

A sub-ring can be accommodated in two or more different major rings or sub-rings. For example, sub-ring 2 is attached to a major ring and sub-ring 1, and sub-ring 5 is attached to both sub-ring 3 and sub-ring 4.

f) A sub-ring attached to multiple major rings

A sub-ring can be attached to multiple major rings that are disjoint relative to each other. Multiple R-APS virtual channels are required (if using the sub-ring with R-APS virtual channel model).

g) A sub-ring connected to a network that supports any technology network

A sub-ring can be attached to a network that supports any other technology (e.g., xSTP, VPLS, etc.).

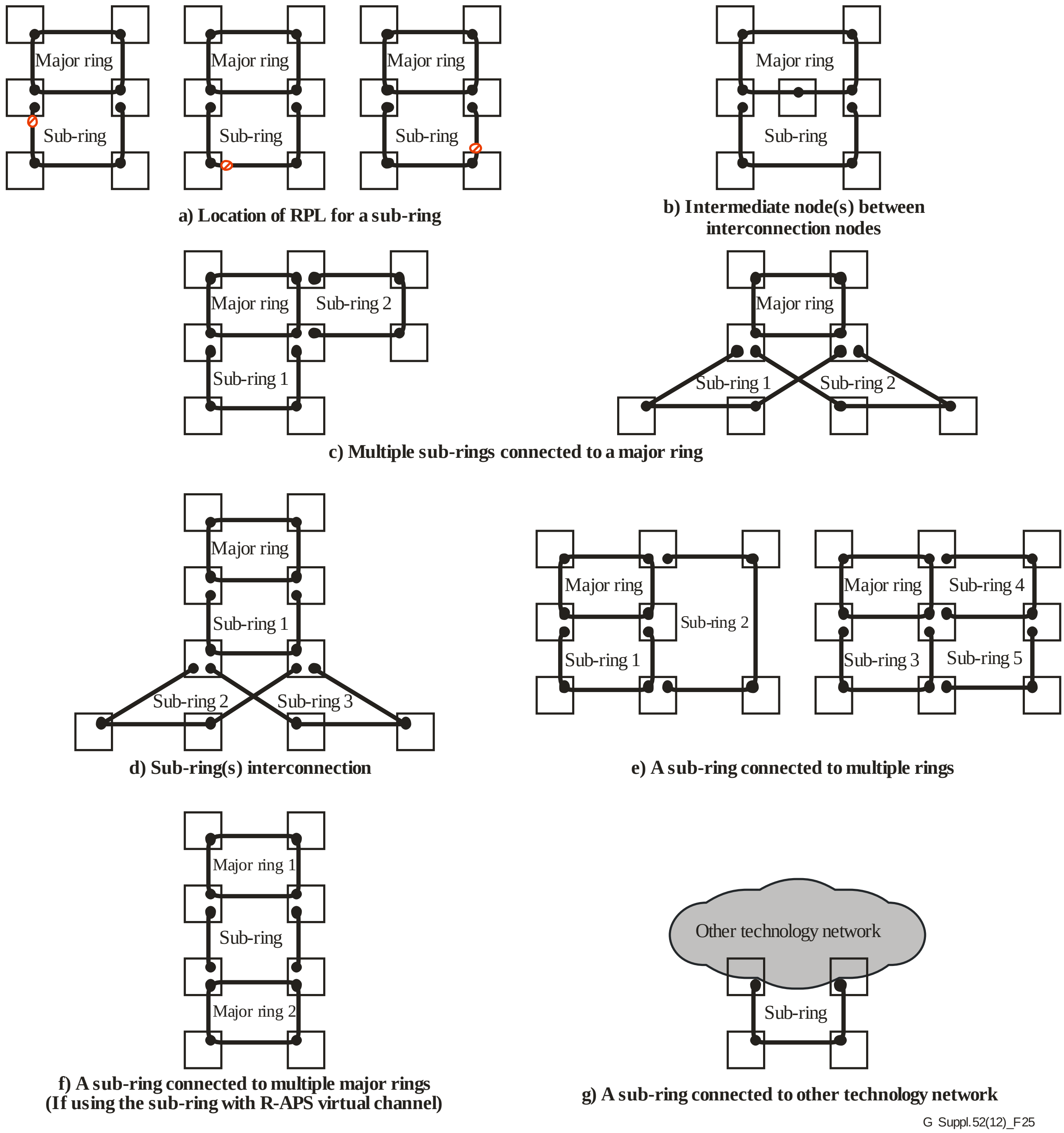


Figure 25 – Topology examples for interconnected rings

9 Guidelines for management procedures

9.1 An example procedure for removing an Ethernet ring node

When an operator wishes to remove an Ethernet ring node, it is recommended to issue FS commands at the Ethernet ring nodes adjacent to the Ethernet ring node that is being removed as illustrated in Figure 26. FS commands are issued at the ring ports of Ethernet ring nodes B and D, adjacent to the target Ethernet ring node, C [(Step b)]. Clear commands are also later issued at Ethernet ring nodes B and D in order to revert from the FS condition to the Idle condition [Step (d)]. If an FS command is issued at the target Ethernet ring node directly, the additional procedure introduced in [ITU-T G.8032] clause 9.2 is required.

NOTE – An MS command may also be used for removing an Ethernet ring node by issuing an MS command at the target Ethernet ring node or at one of the adjacent Ethernet ring nodes.

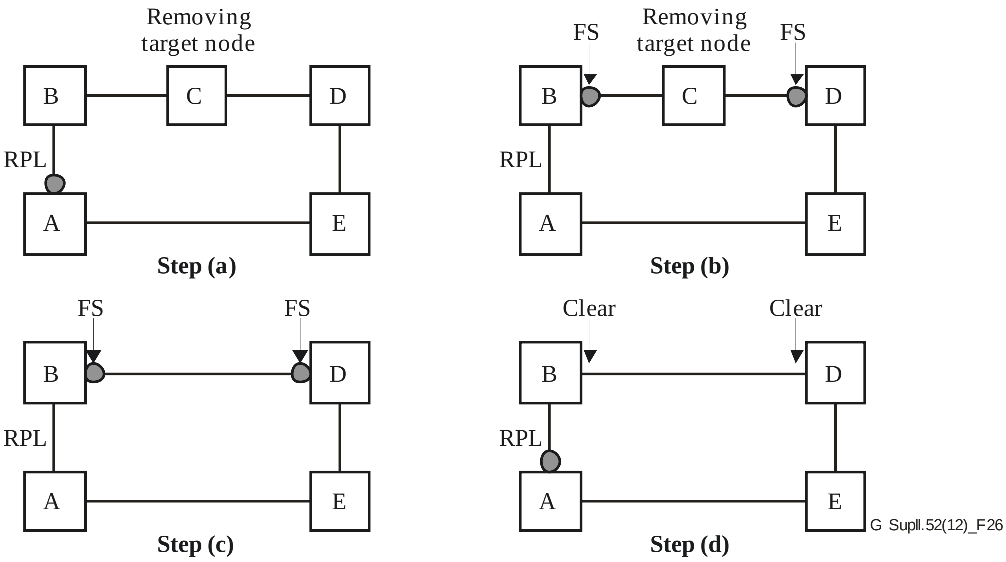


Figure 26 – Example procedure for removing an Ethernet ring node

9.2 Management procedures to exit the FS state in case of failure of an Ethernet ring node under an FS condition

When an Ethernet ring is under an FS condition, and the Ethernet ring node on which an FS command was issued is removed or fails, the Ethernet ring remains in the FS state because the FS command is to be cleared only at the Ethernet ring node where the FS command was issued. In Figure 27, even if Ethernet ring node C where an FS command was issued fails, Ethernet ring nodes B and D, that are adjacent to the failed Ethernet ring node C, do not react to the local SF because a remote FS has higher priority than a local SF. Additionally, there is no Ethernet ring node in the FS state where a Clear command could be issued to revert from the FS condition. This results in an inextricable FS condition.

When an operator has to perform a maintenance procedure (e.g., replacing, upgrading, etc.) on an Ethernet ring node (or a ring link), it is recommended that FS commands be issued at the two adjacent Ethernet ring nodes (e.g., B and D) instead of directly issuing a FS command at the Ethernet ring node (e.g., C) under maintenance in order to avoid falling into the aforementioned problematic situation.

Even if the FS command is issued at the Ethernet ring node under maintenance, it is possible to circumvent the problematic situation by following the procedure starting at step 4 in Figure 27.

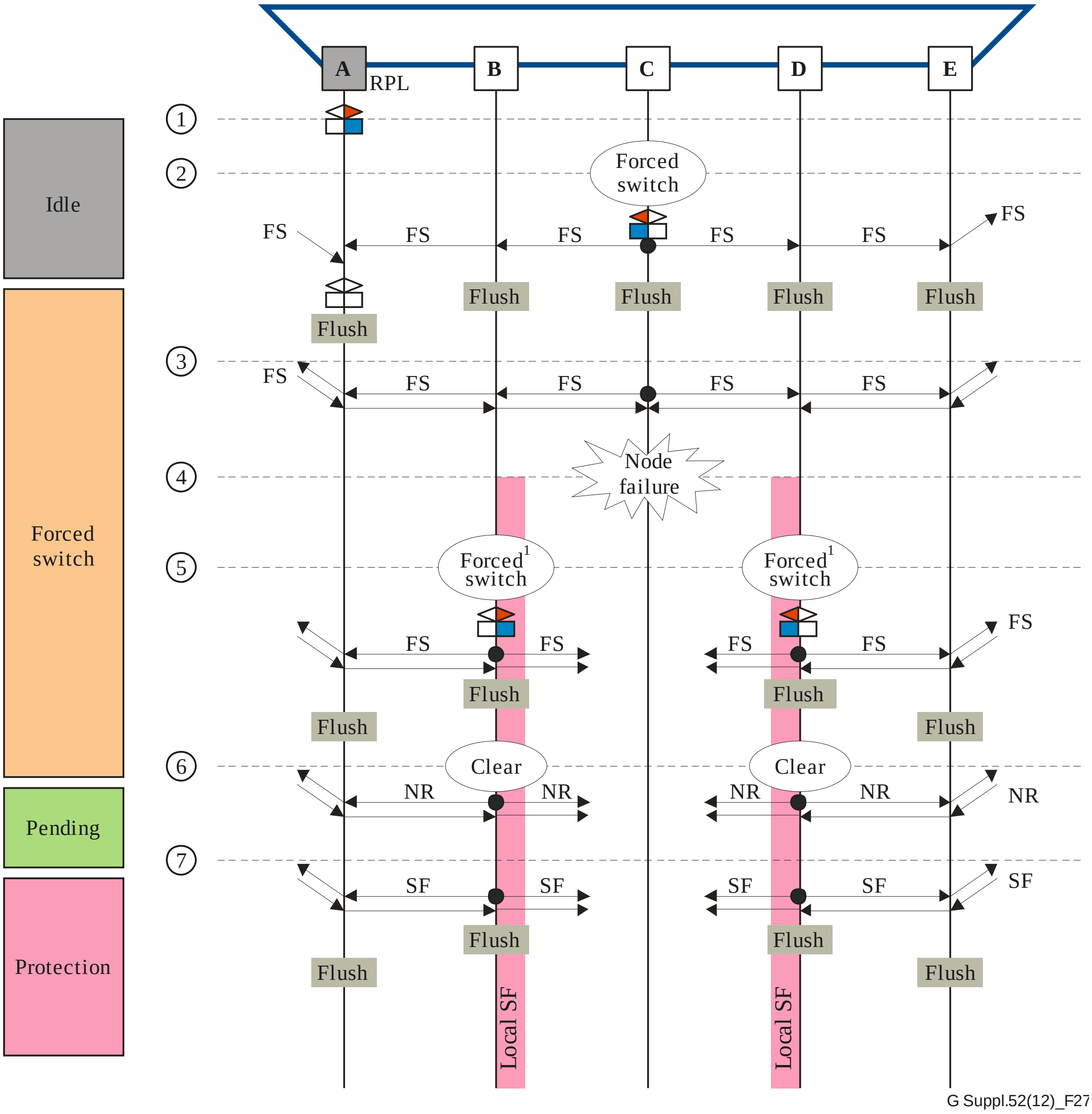


Figure 27 – Ethernet ring node failure scenario with management procedure

When the failure of an Ethernet ring node where a local FS command was issued (e.g., Ethernet ring node C in Figure 27, step 4) is detected, new FS commands are manually issued at Ethernet ring nodes (e.g., B and D in Figure 27, step 5) adjacent to the failed Ethernet ring node. At this point, these adjacent Ethernet ring nodes retain the local FS command. If Clear commands are then issued at these adjacent Ethernet ring nodes (e.g., B and D in Figure 27, step 6), these Ethernet ring nodes transit to the pending state and begin transmitting R-APS (NR) messages. This allows detection of the local SF condition. As a result of these actions, the FS state is successfully cleared within the Ethernet ring.

9.3 Replacing an ITU-T G.8032 (2008) v1 Ethernet ring node with an ITU-T G.8032 (2010) v2 Ethernet ring node

When an Ethernet ring, already deployed using Ethernet ring nodes supporting only the functionalities of ITU-T G.8032-2008 and ITU-T G.8032 Amd.1-2009 (Ethernet ring nodes running G.8032v1), is upgraded with Ethernet ring nodes supporting the functionalities of Recommendation [ITU-T G.8032], an RPL owner node should be upgraded to become an Ethernet ring node running [ITU-T G.8032] ahead of other Ethernet ring nodes deployed on the same Ethernet ring. Otherwise, differences between G.8032v1 and [ITU-T G.8032] flush behaviour might be exposed in the case of unidirectional failure on the non-RPL ring link attached to the RPL owner node.

10 End-to-end service resilience

10.1 Generic end-to-end service resilience

End-to-end service resilience may require protection based on the protection provided as described in [ITU-T G.8032]. However for the access, additional protection may be required. This can be achieved by duplicating the access links as shown in Figure 28.

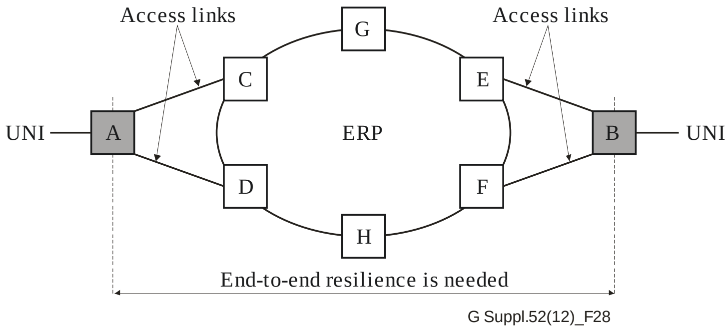


Figure 28 – A network model example for end-to-end service resilience

The protection mechanism used on the access links to provide end-to-end resilience could use the protection mechanisms described in [ITU-T G.8031], [IEEE802.1D] or some other similar protection mechanism.

10.2 Layering ITU-T G.8031 protection over ITU-T G.8032

For the purposes of this clause we pre-suppose that the protection mechanism employed for the end-to-end service is [ITU-T G.8031].

Referring to the service shown in Figure 28 above, we can imagine that the end-to-end protection would configure a working path that traverses the nodes [A-C-E-B] and a protection path that traverses the nodes [A-D-F-B].

10.2.1 Basic guidelines for the layering of ITU-T G.8031 over ITU-T G.8032

When the protection of the end-to-end service, for example when the service runs between nodes A and B in Figure 28, is based on ITU-T G.8031 Ethernet linear protection, where part of the working and/or the protection path crosses a logical ring that is protected by ITU-T G.8032 ERP, then the following guidelines are recommended:

- The working/protection path that crosses the ERP protected ring should only include two Ethernet ring nodes, at the points where the ring is entered and exited.
- The "link" between these two nodes can be considered a logical link; in the sense that the exact path that connects these two nodes is determined by the ERP mechanism (i.e., the ERP protection mechanism may determine that the connection may traverse the ring on either the shorter path or in the opposite direction along the longer path).
- The hold-off timer of the Ethernet linear protection mechanism should be configured with a value large enough to allow the ERP mechanism to complete its procedures prior to triggering linear protection as a result of a failure condition of this logical link.
- The working and protection paths (whichever cross the ring) should use different VIDs that are protected by ERP instances of the ring. Both of these VIDs may be protected by the same ERP instance or by separate ERP instances, at the operator's discretion[5].

---

[5] NOTE – When there are multiple services that are protected by ITU-T G.8031, it may be possible to reuse these same VIDs for the additional services, based on the method of service identification.

This scenario may also be applied to the layering of RSTP [IEEE 802.1D] over ITU-T G.8032 by connecting two Ethernet private line (EPL) services (as defined in [ITU-T G.8011.1], where EPLs are separated by VIDs) between nodes A and B (in Figure 28).

10.2.2 End-to-end service that traverses interconnected rings

If the end-to-end service crosses a network of interconnected rings, as shown in Figure 29 below, then the entire network of interconnected rings may be considered the underlying layer in the sense of the previous clause (10.1). Similar guidelines as stated above would apply, with the following generalization:

- The working/protection path that crosses the network of ERP-protected rings should only include two Ethernet ring nodes, at the points where the chain of Ethernet rings is entered and exited. For example, nodes C and E for the working path and nodes D and F for the protection path in Figure 29 (i.e., nodes {G, H, J, K, L, M} would be transparent to the ITU-T G.8031 protection mechanism).

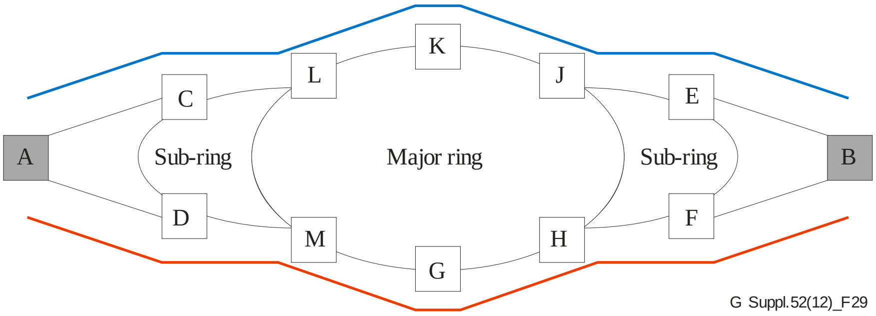


Figure 29 – End-to-end service resilience over interconnected rings

10.3 Access sub-ring connected to major ring

Referring to the service shown in Figure 28 above, we can also imagine that the end-to-end protection is realized by using sub-ring C-A-D connected to major ring C-D-H-F-E-G. However, in this sub-ring, node A does not support ERP functionality and, as a result, is excluded from R-APS communication. Therefore, this sub-ring is a modified version of the sub-ring as presented in the main body of [ITU-T G.8032] and is referred to as an access sub-ring.

10.3.1 Basic configuration

Figure 30 shows the access network with access sub-ring B-A-C connected to major ring B-C-D-E-F-B. Their ERP instances are shown in Figure 31.

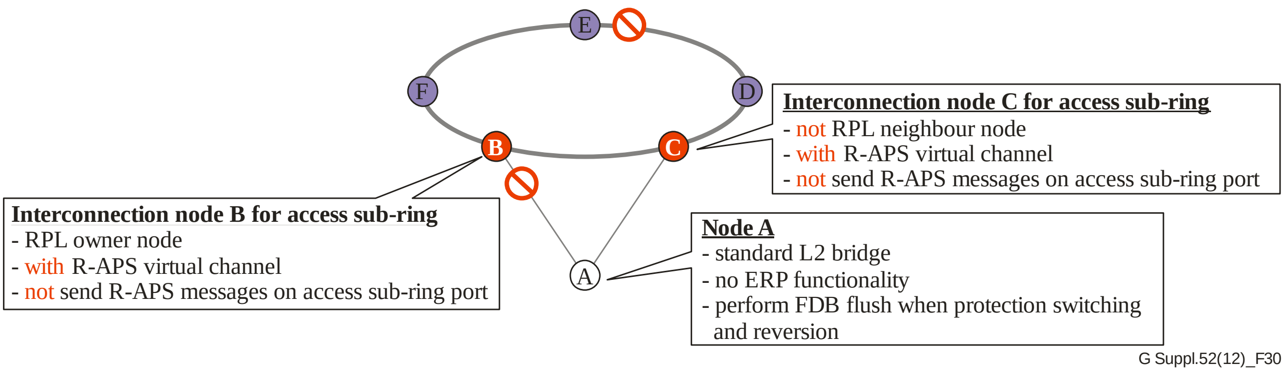


Figure 30 – Access sub-ring connected to major ring

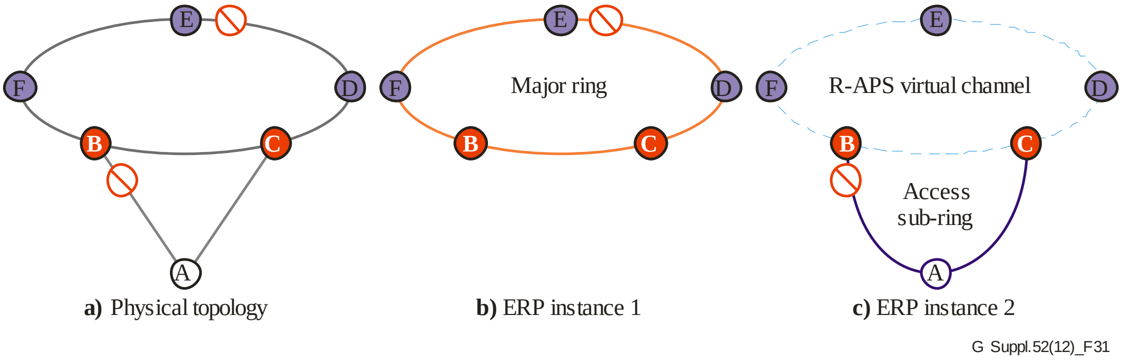


Figure 31 – ERP instances

In this network, Ethernet ring nodes B and C are the interconnection nodes connecting the major ring and access sub-ring. Node A is a user node that does not support an ERP control process. RPLs of major ring and access sub-ring are located on E-D link and B-A link, respectively. The RPL owner node of access sub-ring is node B.

The characteristics of the access sub-ring are as follows:

I. Node A is excluded from R-APS communication (i.e., does not generate nor transfer R-APS messages).

II. Interconnection nodes B and C do not send any R-APS messages on their access sub-ring port.

III. Interconnection nodes B and C must be able to notify node A when protection switching and reversion is invoked on the access sub-ring.

- The notification is needed to trigger the FDB flush when a failure occurs or when it is recovered. This generic flush request should comply with the standard requests that are supported by node A.

IV. Node A should be able to perform an FDB flush when protection switching and reversion are invoked.

V. Access sub-ring must configure an R-APS virtual channel on the major ring.

- This is because node A cannot receive and transfer any R-APS messages, so R-APS message cannot be received from the access sub-ring ports of interconnection nodes B and C.

VI. Access sub-ring should not configure an RPL neighbour node.

- If interconnection node C is configured as RPL neighbour node, both access links are blocked.

10.4 Non-ERP node connected in major ring

Ensuring end to end resilience when connecting into a different technology domain can be made simpler by allowing for a non-ERP node to be located within a major ring. This clause provides guidelines on how to support such a configuration.

10.4.1 Basic configuration

Figure 32 shows a network with Ethernet rings A-B-C-D-E-F-G where node D does not support the ERP functionality, but is a VLAN aware bridge.

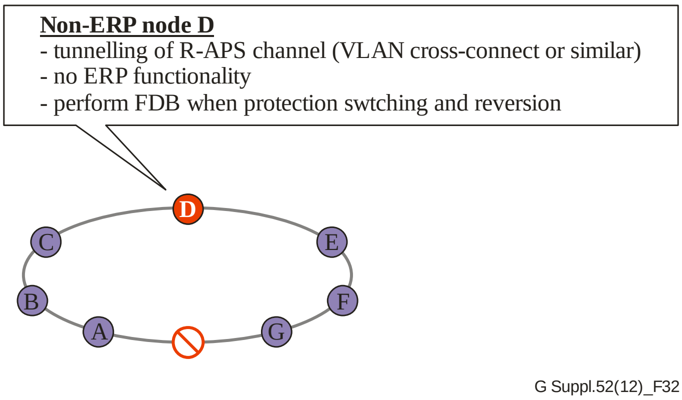


Figure 32 – Non-ERP node as part of major ring

The characteristics of a non-ERP node in an Ethernet ring are as follows:

I. Non-ERP node D tunnels R-APS communication between Ethernet ring nodes C and E.

II. Ethernet ring nodes C and E must be able to notify node D when protection switching and reversion is invoked on the Ethernet ring.

- The notification is needed to trigger the FDB flush when a failure occurs or when it is recovered. This generic flush request should comply with the standard requests that are supported by node D.

III. Non-ERP node D performs FDB flush when protection switching and reversion is invoked.

10.4.2 Principles of operation

The principles of [ITU-T G.8032] clause 10 are used. It should be noted that when a failure occurs on a ring link between an ERP and non-ERP node, all three burst messages triggered by the state machine on a "Tx R-APS()" action are required to ensure successful operation of block/unblock and flush operations. One example of this is the requirement of the RPL owner node to unblock the RPL upon receipt of R-APS(SF). There is no guarantee that the RPL port would be unblocked for R-APS frames fast enough that the second and third R-APS(SF) frames would pass through.

In this case, implementations may optionally include a management configuration option ETH_C_MI_RAPS_Pass_Thru that is applied to the R-APS Block Logic and R-APS Request Processing of [ITU-T G.8032] Figure 10-1. Note that this implies the presence of the R-APS Block Logic in the ERP Control Process of ring nodes on the Ethernet ring. The additions to [ITU-T G.8032] Figure 10-1, to support this functionality are shown in red in Figure 33 below:

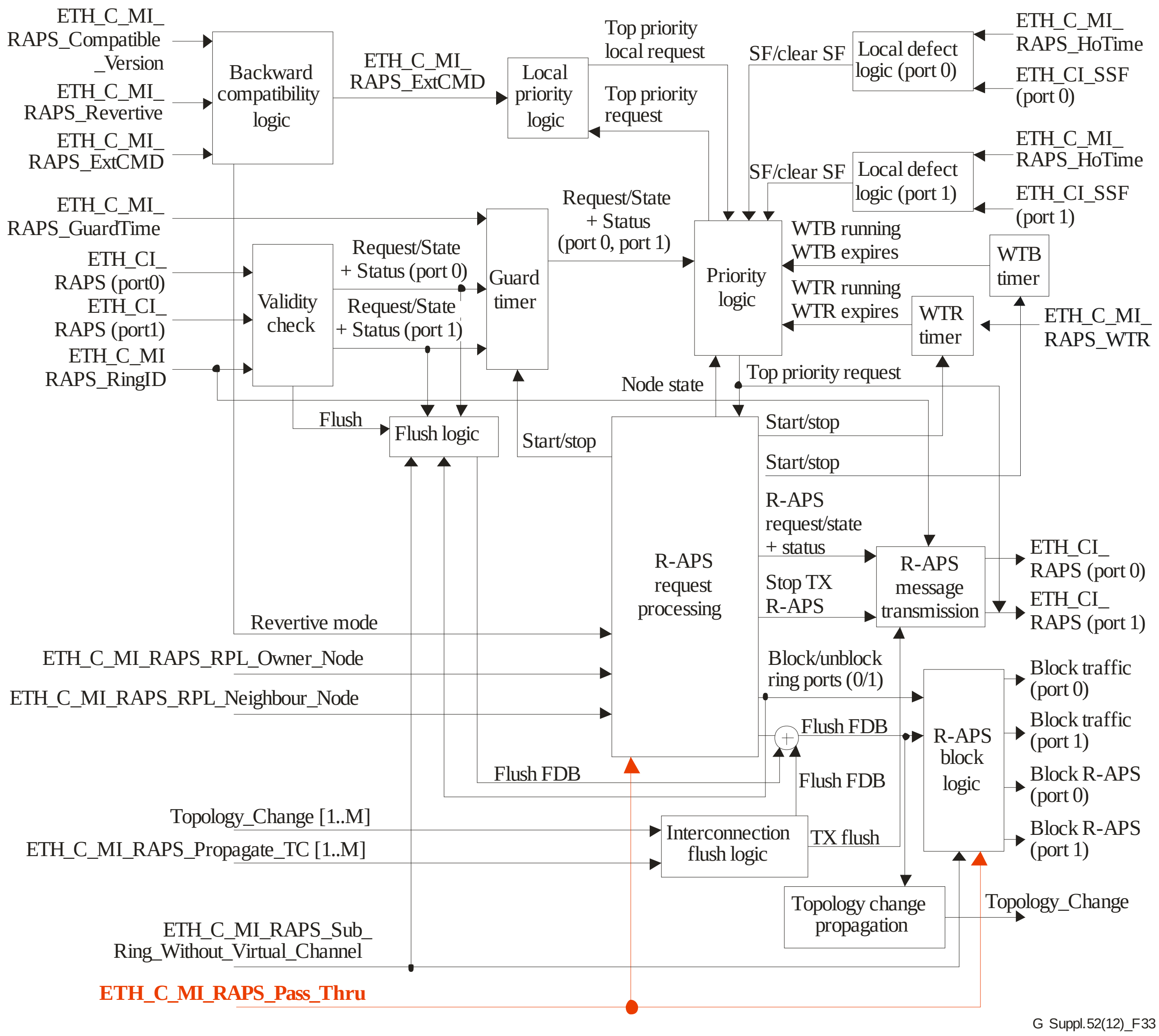


Figure 33 – Decomposition of ERP control process

The management information supplied in ETH_C_MI_RAPS_Pass_Thru may affect the blocking of the R-APS channel at the RPL. This MI may be either Disabled or Enabled. When Disabled, the RPL is blocked and R-APS messages are not transmitted. This is the default value and behaviour. When the MI is Enabled, the RPL owner node and the RPL neighbour node block the RPL traffic channel and will terminate any R-APS messages intended for the RPL, however the R-APS channel will not be blocked. If the action indicated in the state machine, [ITU-T G.8032] Table 10-2, indicates that the RPL owner node or the RPL neighbour node should unblock the RPL Link then, if the MI is Enabled, they will additionally transmit a copy of the last received R-APS message over the RPL immediately.

11 Protection switching for multiple ERP instances

11.1 Multiple ERP instances

An Ethernet ring may support multiple traffic channels that may be grouped into different sets of VLANs. It is possible to define an *ERP instance* as an entity that is responsible for the protection of a subset of the VLANs that transport traffic over the physical Ethernet ring. Each ERP instance is independent of other ERP instances that may be configured on the physical Ethernet ring. Each ERP instance independently applies the protection mechanism described in clause 10 of [ITU-T G.8032] for the subset of the total traffic transmitted over the set of VLANs that the instance is configured for. For each ERP instance, an independent ERP control process exists.

Support of multiple ERP instances is optional for network elements supporting [ITU-T G.8032].

11.2 Applying protection mechanisms to multiple ERP instances

When multiple ERP instances are configured for an Ethernet ring, each ERP instance should configure its own RPL, RPL owner node and RPL neighbour node. The ring link configured as the RPL may be (and generally is) different for each ERP instance supported.

11.2.1 Addressing of multiple ERP instances

The protection mechanism defined in clause 10 of [ITU-T G.8032] is dependent upon the use of the R-APS protocol to notify the Ethernet ring nodes of the current condition of the Ethernet ring and control the protection switching operations. As stated in clause 10.3 of [ITU-T G.8032], the notification and control R-APS messages are transmitted using a MAC destination address 01-19-A7-00-00-01. When multiple ERP instances are activated, each ERP instance activates the protection switching procedures independently of each other. R-APS messages of different ERP instances are differentiated by the use of different R-APS VIDs.

11.2.2 Protection switching – signal failure

If an SF condition is detected on an Ethernet ring supporting multiple ERP instances, then protection switching shall be invoked for each of the ERP instances configured. The R-APS messages should be transmitted on separate VIDs as specified in clause 11.2.1 over the ring links of the ERP instance.

Each ERP instance should perform protection switching under the control of the RPL owner node configured for that particular ERP instance. The functionality and state machine are consistent with those stated in clause 10 of [ITU-T G.8032].

11.2.3 Protection switching – revertive and non-revertive

Support for revertive and non-revertive mode operation of the protection switching may be configured differently for each ERP instance configured in the Ethernet ring.

The recovery mechanism, when the SF condition is detected to be cleared, should be activated separately for each ERP instance in accordance with the revertive or non-revertive mode of the particular ERP instance.

11.2.4 Protection switching – manual switch and forced switch

A manual switch or forced switch command is generated individually for each ERP instance. The ERP instance where the operator command (either FS or MS) is issued should transmit the R-APS message indicating the command over its R-APS channel. The operation of the protection switching and recovery should be compliant with the procedures described in clause 10 of [ITU-T G.8032].

11.3 Protection switching model for multiple ERP instances

The protection mechanism for multiple ERP instances uses the same architecture as used for the single ERP instance case, with the addition that this needs to be cloned for each ERP instance to transmit the R-APS messages for each ERP instance to the proper MAC address.

Figure 34 illustrates the model of an Ethernet ring node supporting two ERP instances. The MEP adaptation function is de-multiplexed, based on the VID to each ERP Instance and informs the ERP control process for each ERP instance, that then asserts the proper condition for the ERP instance.

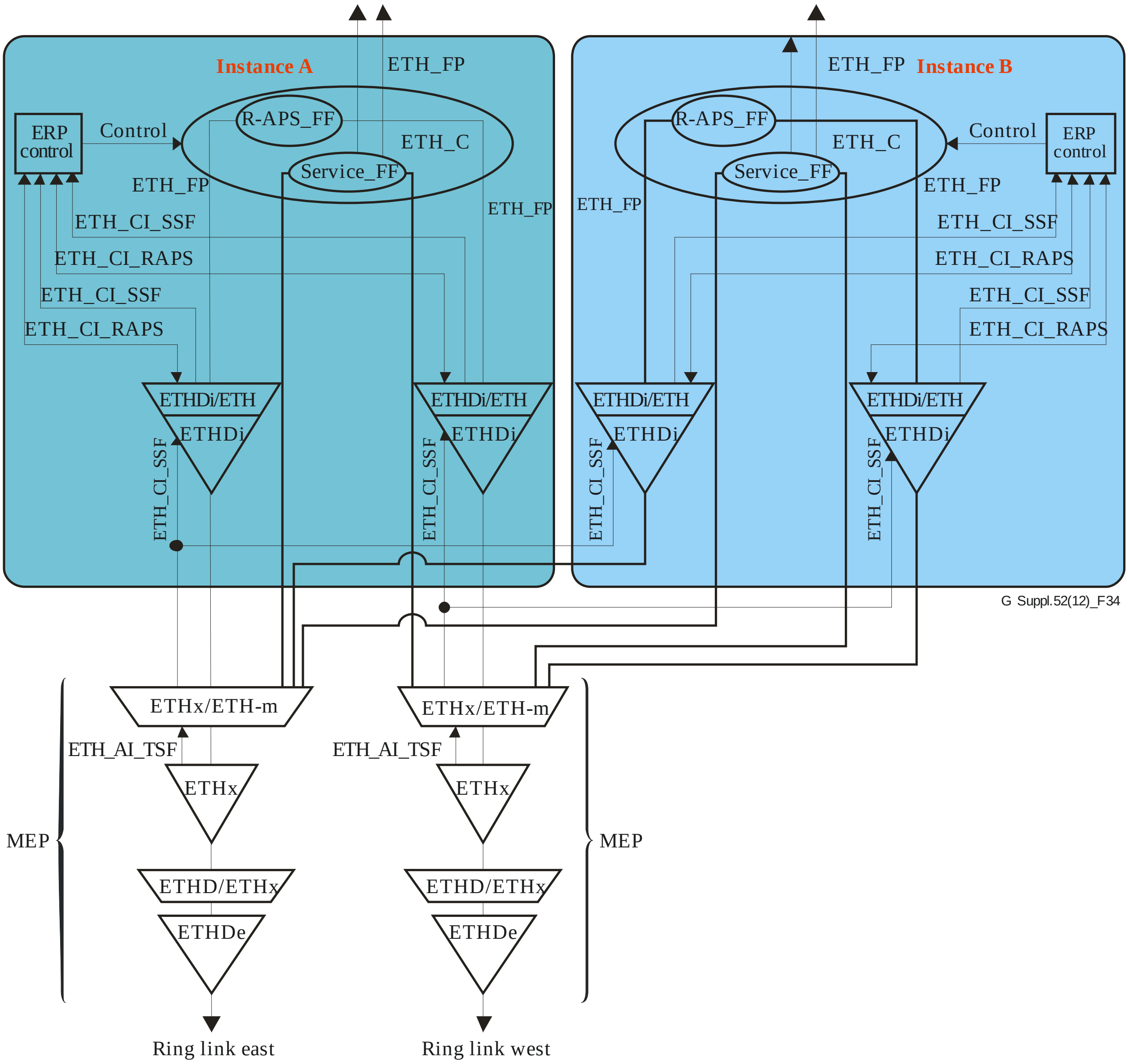


Figure 34 – MEPs and R-APS insertion function for Ethernet ring node supporting two ERP instances

11.4 Multiple instances of interconnected rings

When the network includes interconnected rings, where neighbouring Ethernet rings are connected through a ring link between two interconnection nodes, it should be possible to configure multiple ERP instances in any of the following possible configurations:

a) Sets of VLAN may be limited to only one of the interconnected physical Ethernet rings. In this case, an ERP instance is defined only on that physical Ethernet ring and is responsible for protection of that set of VLANs.

b) A set of VLANS may span multiple interconnected Ethernet rings, in this case an ERP instance is defined on each physical Ethernet ring supporting that set of VLANs.

These possibilities are illustrated in Figure 35. In this figure, the network has two physical Ethernet rings that are connected. On the two Ethernet rings there are three groups of service traffic (red, blue, green) associated with four ERP instances (R1, B1, G1, G2):

a) G2 and B1 are ERP instances on the right-hand physical Ethernet ring

b) G1 and R1 are ERP instances on the left-hand physical Ethernet ring

c) G1 and G2 are ERP instances protecting the green group of service traffic that spans the interconnected Ethernet rings. These interconnected Ethernet rings shall not be two major rings since if the green group of service traffic is associated with both G1 and G2; the ring link between the interconnection nodes could be simultaneously blocked by the ERP control processes of both major rings resulting in a super loop on the group of service traffic.

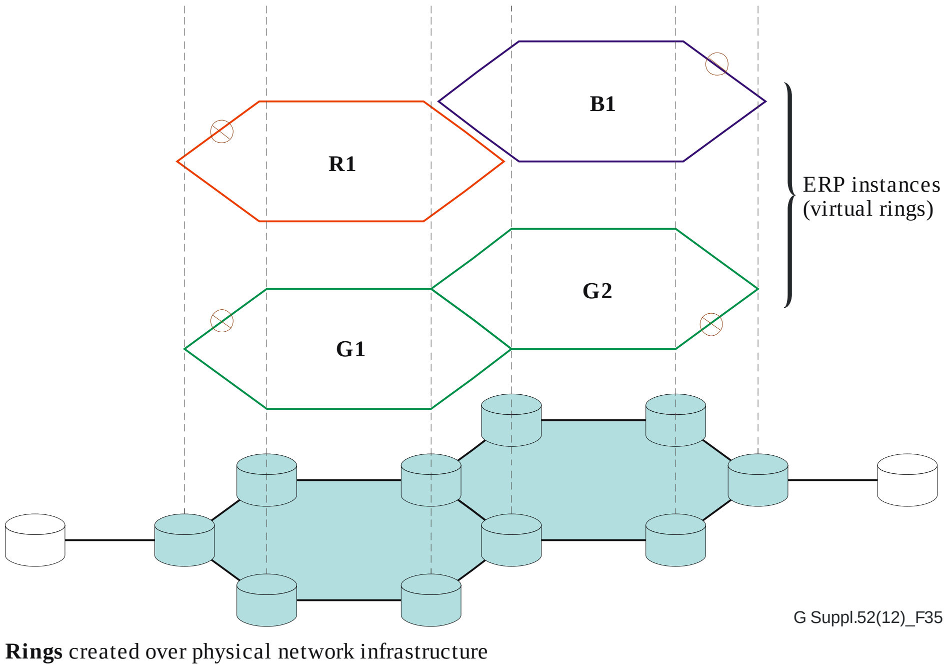


Figure 35 – Multiple ERP instances on interconnected physical Ethernet rings (normal condition)

When an SF condition is detected on the ring link between the interconnection nodes, the protection switching mechanism should be employed separately for each of the three groups of ERP instances:

a) For the G group protection switching is invoked on the Ethernet ring or sub-ring controlled by the R-APS channel of the G group that detected the ring link defect.

b) For the R group protection switching is invoked for R1.

c) For the B group protection switching is invoked for B1.

Figure 36 shows the ERP instances after the protection switching is invoked (on G2 for G group).

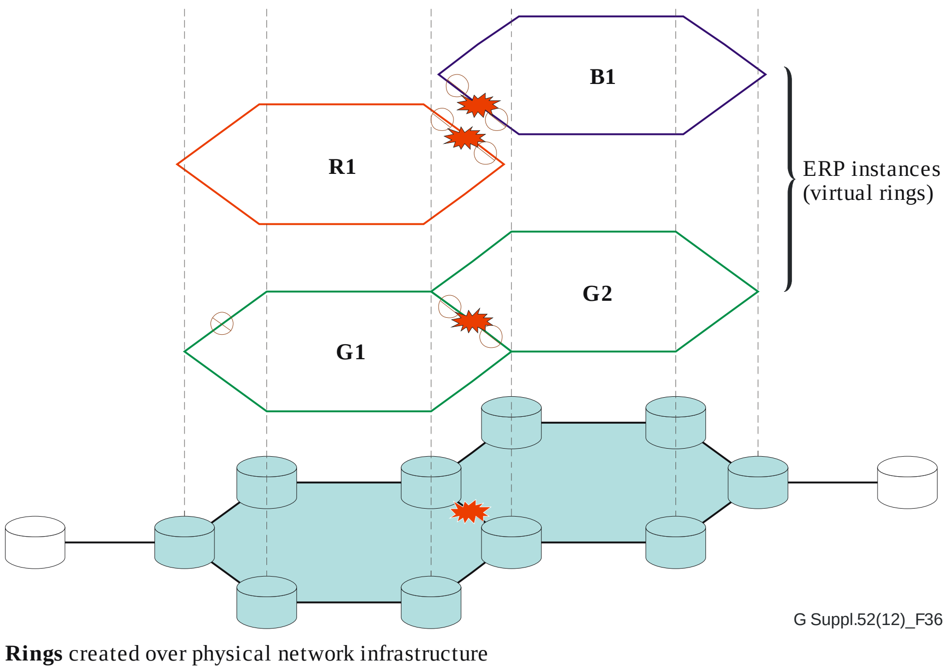


Figure 36 – Multiple ERP instances on interconnected physical Ethernet rings (the ring link between interconnection nodes failure condition)

12 Guidelines for the configuration of VIDs and ring IDs of R-APS channels

The following clauses contain guidelines on assigning VIDs and ring IDs for different sets of ERP Instances configured as per [ITU-T G.8032]. The different guidelines take into consideration the model of interconnected Ethernet ring support that the network operator employs.

12.1 Sub-ring with R-APS virtual channel

12.1.1 Example 1: R-APS channel with different VIDs, and R-APS channel of sub-ring and R-APS virtual channel having different VIDs

Four ERP instances are deployed on interconnected physical Ethernet rings (Rings 1 and 2) in the following figures. Each ERP instance has Ring ID 1. ERP Instance 1 is a major ring deployed on Ring 1 and assigned Ring ID "1". The R-APS channel of ERP Instance 1 is identified by VID "1". ERP Instance 2 is a sub-ring deployed on Ring 2 and connected to ERP Instance 1. The ring ID of ERP Instance 2 is also "1w". The R-APS channel of ERP Instance 2 is identified by VID "2". The R-APS virtual channel is deployed on Ring 1 and identified by VID "21" as data traffic associated with ERP Instance 1. ERP Instances 3 and 4 are similar but with the position of the major ring and sub-ring reversed, relative to ERP Instances 1 and 2. ERP Instances 3 and 4 have ring ID and VID as illustrated in Figure 37. Example 1 uses more VIDs in comparison to the other examples. However, a VID assigned to a sub-ring may be reused on Ethernet rings which are not immediately adjacent without translating VIDs. For example, VID 2 could be reused on an Ethernet ring connected to Ring 1 on the opposite side, i.e., with no common interconnection node.

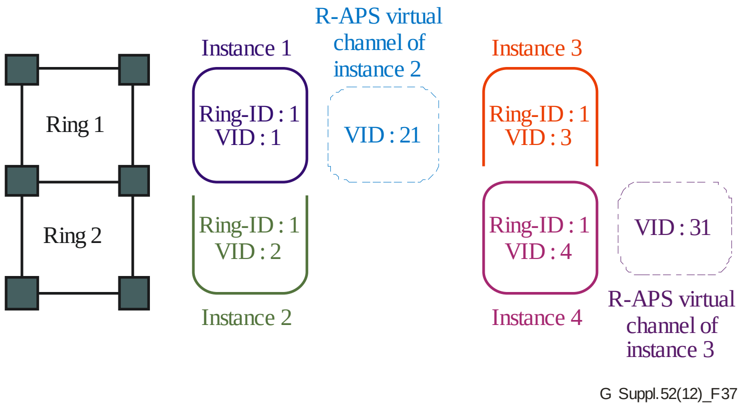


Figure 37 – Example 1: Different VIDs for different ERP instances; different VIDs for the ERP instances of sub-ring and an R-APS virtual channel

The model of an interconnection node, which connects a sub-ring with an R-APS virtual channel and has different VIDs for each ERP instance, is represented in Figure 9-8 of [ITU-T G.8032]. It is assumed that ERP Instances 1 and 2 are depicted as ERP1 and 2 (in Figure 9-8 of [ITU-T G.8032]), respectively. R-APS messages for ERP Instance 1 are received on ring port 0 or ring port 1 and identified by its VID "1" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A function. They are subsequently forwarded to the other ring port through the R-APS_1_FF function which is assigned VID "1". R-APS messages for ERP Instance 2 are received on the Sub-Ring port and identified by its VID "2" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A functions. They are subsequently forwarded through the R-APS_2_FF function which is assigned VID "2" to the ETH_C function of ERP Instance 1. On the ETH_C function, R-APS_2_FF assigned VID "21" is responsible for forwarding the R-APS messages from ERP Instance 2 as service traffic.

12.1.2 Example 2: R-APS channel with different VIDs, and R-APS channel of sub-ring and R-APS virtual channel having the same VID

The ring IDs and VIDs of ERP Instance 1 and ERP Instance 2 depicted in Figure 38 are the same as those in Example 1. The R-APS Virtual Channel of ERP Instance 2 is deployed on Ring 1 as data traffic associated with ERP Instance 1, and identified by VID "2" which is the same as the VID of the R-APS channel of ERP Instance 2 over Ring 2. ERP Instances 3 and 4 are similar but with the position of the Major Ring and Sub-Ring reversed, relative to ERP Instances 1 and 2. ERP Instances 3 and 4 have a Ring ID and VID as illustrated in Figure 38. In Example 2, it seems to be easier to manage the VIDs than for the other Examples. However, the same number of VIDs as in Example 1 may have to be used since a VID assigned to a Sub-Ring may not be reused on Ethernet Rings which are not immediately adjacent without translating VIDs. For example, VID 2 could not be reused on a ring connected to Ring 1 on the opposite side, i.e., with no common Interconnection Node, and a different VID would need to be assigned.

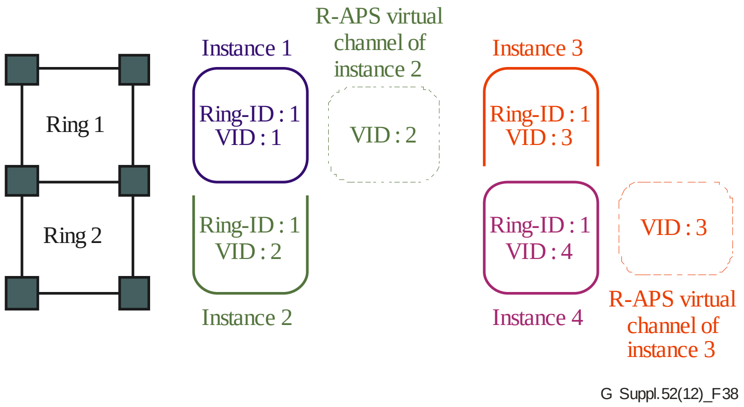


Figure 38 – Example 2: Different VIDs for different ERP instances; same VID for an ERP instance of sub-ring and an R-APS virtual channel

It is assumed that ERP Instances 1 and 2 are depicted as ERP1 and 2 respectively in Figure 9-8 (of [ITU-T G.8032]). R-APS messages for ERP Instance 1 are received on ring port 0 or ring port 1 and identified by its VID "1" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A function. They are subsequently forwarded to the other ring port through the R-APS_1_FF function which is assigned VID "1". R-APS messages for ERP Instance 2 are received on Sub-Ring port and identified by its VID "2" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A functions. They are subsequently forwarded through the R-APS_2_FF function which is assigned VID "2" to the ETH_C function of ERP Instance 1. On the ETH_C function, R-APS_2_FF assigned VID "2" is responsible for forwarding the R-APS messages from ERP Instance 2 as service traffic.

12.1.3 Example 3: R-APS channel with same VIDs and different multicast addresses with ring ID

In Figure 39, ERP Instance 1 is a major ring deployed on the Ring 1 and assigned Ring ID "1". The R-APS channel of ERP Instance 1 is identified by a set of VID "1" and the destination MAC address that includes Ring ID "1". ERP Instance 2 is a sub-ring deployed on Ring 2 and connected to ERP Instance 1. The ring ID assigned to ERP Instance 2 is "2". The R-APS channel of ERP Instance 2 is identified by a set of VID "1" and the destination MAC address that includes Ring ID "2". The R-APS virtual channel is deployed on Ring 1 and identified by a set of VID"1" and the destination MAC address that includes Ring ID "2" for service traffic. ERP Instances 3 and 4 are similar but with the position of the major ring and sub-ring reversed in comparison with ERP Instance 1 and 2. These ERP Instances 3 and 4 have a ring ID and VID as shown in Figure 39.

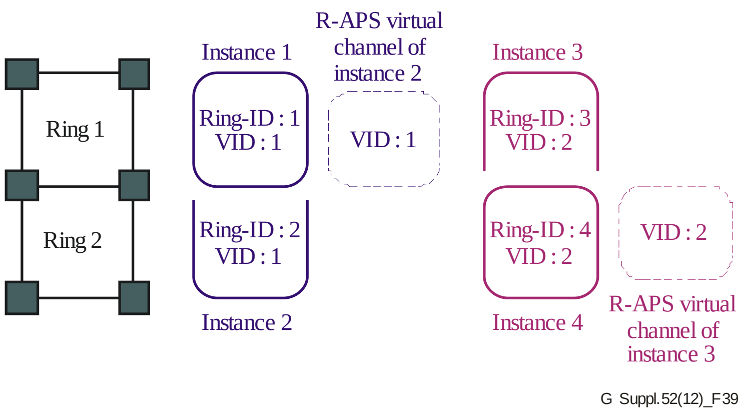


Figure 39 – Example 3: Same VIDs for connected ERP instances and an R-APS virtual channel

The model of an interconnection node, which connects a sub-ring with an R-APS virtual channel and has the same VIDs for each ERP instance, is represented in Figure 9-9 (of [ITU-T G.8032]). It is assumed that ERP Instances 1 and 2 are depicted as Rings 1 and 2 respectively. R-APS messages for ERP Instance 1 are received on ring link 0 or ring link 1 and identified by its VID "1" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A function. When the ETHDi/ETH_A function receives R-APS messagesRing ID, it forwards the R-APS messages to the ERP Control Process and the R-APS_1_FF function. When the ERP Control Process receives R-APS messages which have Ring ID "1" in destination MAC address, it extracts the R-APS messages. When it receives R-APS messages with another Ring ID, it just discards them. Ring IDOn the R-APS_FF function of ERP Instance 1, the R-APS messages with VID "1" and Ring ID "1" are forwarded to ring link 1 and 0, not to the ETHDi/ETH_A of ERP Instance 2. R-APS messages for ERP Instance 2 are received on the sub-ring link and identified by its VID "1" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A functions. When the ETHDi/ETH_A function receives R-APS messagesRing ID, it forwards the R-APS messages to the ERP Control Process and the R-APS_2_FF function. On the R-APS_FF function of ERP Instance 2, the R-APS messages with VID "1" and Ring ID "2" are forwarded to the ETH_C function of ERP Instance 1. They are subsequently forwarded through the R-APS_FF function of ERP Instance 1 based on their VID "1" and Ring ID "2" to ring link 0 or 1.

12.2 Sub-ring without R-APS virtual channel

12.2.1 Example 4: Sub-ring without R-APS virtual channel model, each R-APS channel with different VIDs

In Figure 40, ERP Instance 1 is a major ring deployed on Ring 1 and assigned Ring ID "1". The R-APS channel of ERP Instance 1 is identified by VID "1". ERP Instance 2 is a sub-ring deployed on Ring 2 and interconnected to ERP Instance 1. The ring ID of ERP Instance 2 is "2" and the R-APS channel of ERP Instance 2 is identified by VID "2". ERP Instances 3 and 4 are similar but with the position of the major ring and sub-ring reversed relative to ERP Instances 1 and 2. ERP Instances 3 and 4 have ring ID and VID as illustrated in Figure 40. In Example 3 it seems to be easier to manage the VIDs than in the other examples. However, the same number of VIDs as in Example 2 is used and cannot be reassigned.

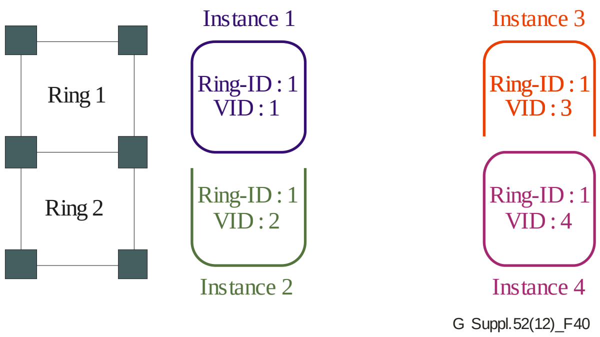


Figure 40 – Example 3: Different VIDs for each ERP instance

The model of an interconnection node, which connects a sub-ring without an R-APS virtual channel and has different VIDs for each ERP instance, is represented in Figure 9-11 (of [ITU-T G.8032]). It is assumed that ERP Instances 1 and 2 are depicted as ERP1 and 2 respectively. R-APS messages for ERP Instance 1 are received on ring port 0 or ring port 1 and identified by its VID "1" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A function. They are subsequently forwarded to the other ring port through the R-APS_1_FF function which is assigned VID "1". R-APS messages for ERP Instance 2 are received on the sub-ring port and identified by its VID "2" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A functions. They are extracted at the ETHDi/ETH_A function and not forwarded to the ETH_C function.

12.2.2 Example 5: R-APS channel with same VIDs and different multicast addresses with ring ID

In Figure 41, ERP Instance 1 is a major ring deployed on Ring 1 and assigned Ring ID "1". The R-APS channel of ERP Instance 1 is identified by a set of VID "1" and the destination MAC address including Ring ID "1". ERP Instance 2 is a sub-ring deployed on Ring 2 and connected to ERP Instance 1. The Ring ID of ERP Instance 2 is "2". The R-APS channel of ERP Instance 2 is identified by a set of VID "1" and the destination MAC address including Ring ID "2". ERP Instance 3 and 4 are similar but with the position of the major ring and sub-ring reversed in comparison with ERP Instances 1 and 2. These ERP Instances 3 and 4 have a Ring ID and VID as shown in Figure 41.

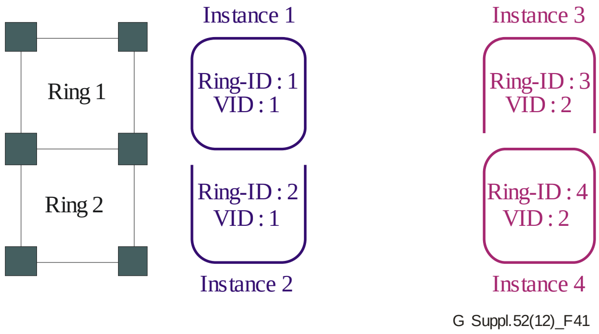


Figure 41 – Example 5: Same VIDs for connected ERP instances

The model of an interconnection node, which connects a sub-ring without an R-APS virtual channel and has the same VIDs for each ERP instance, is represented in Figure 9-10 (of [ITU-T G.8032]). It is assumed that ERP Instances 1 and 2 are depicted as Rings 1 and 2 respectively. R-APS messages for ERP Instance 1 are received on ring link 0 or ring link 1 and identified by its VID "1" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A function. When the ETHDi/ETH_A function receives R-APS messagesRing ID, it forwards the R-APS messages to the ERP Control Process and the R-APS_1_FF function. When the ERP control process receives R-APS messages which have Ring ID "1" in destination MAC address, it extracts the R-APS messages. When it receives R-APS messages with another Ring ID, it just discards them. Ring ID on the R-APS_FF function of ERP Instance 1, the R-APS messages with VID "1" and Ring ID "1" are forwarded to ring links 1 and 0. R-APS messages for ERP Instance 2 are received on the Sub-Ring link and identified by its VID "1" at the ETHx/ETH-m_A function and forwarded to the ETHDi/ETH_A functions. When the ETHDi/ETH_A function receives the R-APS messages ring ID, it forwards the R-APS messages and does not forward them to the ETH_C function of ERP Instance 2.

12.3 Backward compatibility

12.3.1 Example 6: Co-existence on an Ethernet ring of Ethernet ring nodes which support ITU-T G.8032 (2010) v2 and ITU-T G.8032 (2008) v1

When Ethernet ring nodes running ITU-T G.8032v1 and ITU-T G.8032v2 co-exist on an Ethernet ring, note that the ring ID of each Ethernet ring node is configured as "1". Figure 42 is an example of the case of a sub-ring with an R-APS virtual channel. An Ethernet ring node running ITU-T G.8032v1 always transmits R-APS messages with the destination MAC address "01-19-A7-00-00-01". Interconnection nodes running ITU-T G.8032v2 should recognize the interconnected rings as Ring ID "1" in order to extract or transmit R-APS messages from the Ethernet ring nodes running ITU-T G.8032v1. The R-APS channels and the R-APS virtual channels are indicated by a VID. In this figure, a single ERP Instance can be deployed on each Ethernet Ring (Rings 1 and 2) because ITU-T G.8032v1 does not support the multiple ERP instance capability.

When a sub-ring with R-APS virtual channel is used as illustrated in Figure 42, the behaviour of the blocked ring port (e.g., whether it forwards R-APS messages or not), defined in ITU-T G.8032v2, is the same as that specified in ITU-T G.8032v1. On the other hand, when a sub-ring without R-APS virtual channel is used, the behaviour of the blocked ring port is different between ITU-T G.8032v1 and ITU-T G.8032v2 specifications as specified in clause 10.1.14 (of [ITU-T G.8032]). Therefore, when an Ethernet ring node running ITU-T G.8032v1 and ITU-T G.8032v2 co-exists on an Ethernet ring, the sub-ring should be deployed with the R-APS virtual channel.

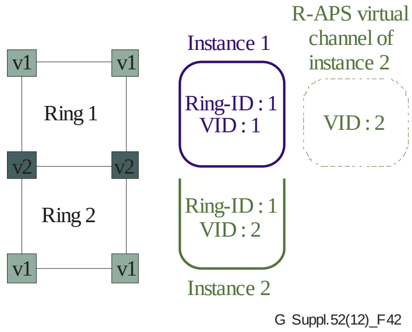


Figure 42 – Example 6: Co-existence of Ethernet ring nodes running ITU-T G.8032v1 and ITU-T G.8032v2 (with an R-APS virtual channel)

The model of the interconnection node depicted in Figure 42 is represented in Figure 9-8 (of [ITU-T G.8032]), and the behaviour of functions is the same as described in clause 12.1.2.

13 Minimizing segmentation in interconnected rings

13.1 Characterization of the segmentation issue

When considering traffic that is being transmitted over a network of interconnected rings, there are situations that have been identified that can cause segmentation of the network as a result of dual failures in one of the rings. While it is not possible to address all cases of segmentation that are caused by multiple failures and such situations should be addressed by the operator before they become problematic, there is a need to characterize the situations in which the resulting segmentation may be avoided for some portion of the traffic being transported.

13.1.1 Problem statement

Figure 43 shows a simplified network of two interconnected rings – the major ring includes nodes A, E, H, G and F, while the sub-ring includes nodes A, B, C, D and E. Nodes A and E are the interconnection nodes. The RPL for the major ring is the link G<->F and the RPL owner is Node G. The RPL for the sub-ring the link C<->B and the RPL owner is Node C.

Figure 43(a) shows that there is a service that is defined between Host X and Host Y that enters the major ring at Node G and must cross over into the sub-ring and exit at Node D. In the idle case (when there are no SF conditions in either ring) the traffic traverses through Nodes G-H-E in the major ring and then crosses over to the sub-ring and traverses E-D and connects to Host Y.

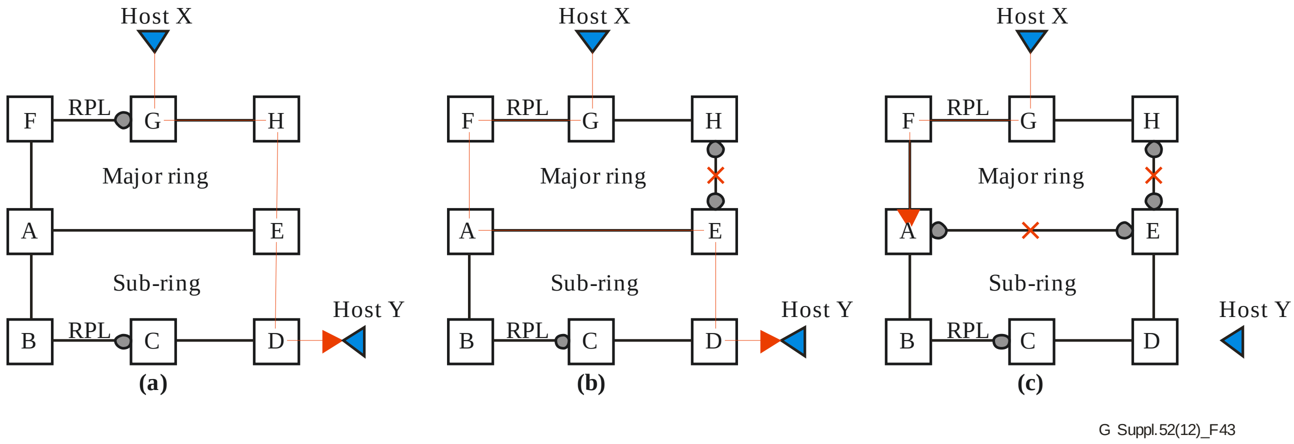


Figure 43 – Scenario showing loss of connectivity between major ring and sub-ring

Figure 43(b) shows the protection switching effect when an SF is identified on link H-E. Ring protection switching is invoked in the major ring, i.e., the RPL (G-F) is unblocked, and the service traffic is now rerouted over the path G-F-A-E in the major ring and then E-D in the sub-ring.

However, if an additional SF is identified on link A-E in the major ring, then the service traffic will not be able to be transported. However, in theory it would be possible to reach Host-Y by following the route G-F-A-B-C-D, except that the sub-ring does not apply protection switching and the link B-C remains blocked to service traffic. As a result of this discontinuity, there are sub-ring nodes that are unreachable from the major ring, i.e., Nodes C and D in Figure 43(c). This situation is shown in Figure 43(c) above.

The problem that exists in the basic application of ring protection is a result of the simplicity of the general procedures. Since each ring in the network addresses the switching triggers locally without propagating the trigger to any neighbouring ring, there is no way to cause the sub-ring to unblock the RPL in the given situation.

The following clauses outline a possible way of overcoming the segmentation that is created in a restricted class of scenarios. The next clause characterizes the class of scenarios that are addressed and the following clause presents a method for propagating the switching trigger to the sub-ring for that particular class of scenarios.

13.1.2 Relationship to interconnection models

It should be clarified that these scenarios are relevant to both interconnection models presented in clause 9.7 of [ITU-T G.8032]. For the "Ring interconnection model with R-APS virtual channel", it should be noted that even though the R-APS virtual channel is used to transmit the R-APS control information, a loss of connectivity between the interconnection nodes within the major ring does not trigger protection switching within the sub-ring and the segmentation, described above, may occur. Protection for this loss of connectivity is assumed to be controlled by the ERP control process of the major ring exclusively. For the "Ring interconnection model without R-APS virtual channel", there is no correlation between the data path over the major ring and the ERP control process of the sub-ring, and therefore the segmentation may occur.

13.2 Class of double faults addressed

When considering the scenarios described in Figure 43, we can characterize the segmentation as occurring when there is a double fault in the major ring that causes a break in connectivity between the two interconnection nodes. If the interconnection nodes are still able to transport traffic between them, then there will always be a path to reach all of the sub-ring nodes from any major ring node that is still connected to one of the interconnection nodes. However, if there is no connected path between the two interconnection nodes, then there is a problem for traffic that arrives at one interconnection node to reach the nodes that are beyond the sub-ring RPL (from the perspective of the interconnection node).

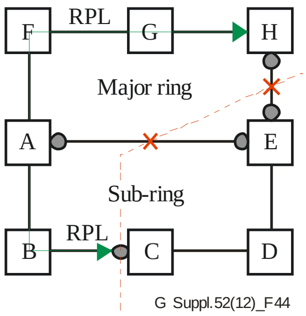


Figure 44 – No connectivity between interconnection nodes

For example, in Figure 44, if there is no connectivity between Nodes A and E, then traffic that arrives at Node A has no path to reach Node D and traffic that arrives at Node E has no path to reach Node B – because the RPL (link B-C) is blocked.

However, if the sub-ring were to perform protection switching and unblock the RPL and block traffic at one of the interconnection nodes, e.g., Node E, then all traffic that arrives at the non-blocked interconnection node, e.g., Node A, could reach all of the sub-ring nodes.

In this and the following clause we will present a methodology for identifying the cases where traffic segmentation can be avoided in spite of multiple failures.

13.2.1 Detection of interconnection segmentation

The first step in minimizing the segmentation effect is to identify that the major ring is currently disconnected from the sub-ring. To facilitate this identification it is recommended to use the available tools to determine the connectivity of the two paths, in the major ring, between the two interconnection nodes. For this one can use a unicast UP MEP (as defined in [IEEE 802.1ag]) from the sub-ring port of the interconnection node to the sub-ring port of the other interconnection node. This can use the VID used by the major ring R-APS channel with a higher MEL or use any one VID that is controlled by the Major Ring protection mechanism. It should be noted that in the Idle state, only one of these paths should be connected, the second path should be blocked by the RPL. In Figure 45, the two tandem connections [A-I-E] and [A-F-G-H-E] are tested for connectivity. The latter path will be blocked by the RPL (on link F-G).

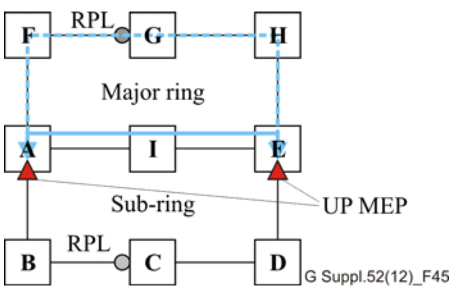


Figure 45 – Interconnected rings connectivity verification

13.3 Procedure for minimization of segmentation

13.3.1 Management configuration

To apply the procedure outline in the following subclause the operator should supply additional management information that will be used to determine the actions taken by the procedure.

The following management information items should be configured for each interconnection node of the sub-ring ERP control process:

- ETH_C_MI_RAPS_Interconnection_Node
  - Values: "primary", "secondary", or "none"
  - Default value: "none"
- ETH_C_MI_RAPS_Multiple_Failure
  - Values: "primary", "secondary", or "disabled"
  - Default value: "disabled"

In addition, the management system should configure a tandem connection between the two interconnection nodes. If the ETH_C_MI_RAPS_Interconnection_Node is set to either "primary" or "secondary", then an UP-MEP (as defined in [IEEE 802.1ag]) should be configured at the sub-ring port of the interconnection node.

13.3.2 Block indication logic procedure

The following procedure will be used to minimize the segmentation of the traffic from the major ring to the sub-ring.

1) Employ connectivity verification for the tandem connection between the two UP MEPs. If there is connectivity, continue.
2) If there is a loss of connectivity between the two interconnection nodes, the UP MEP sends an indication to the block indication logic through the ETH_CI_SSF (see Figure 46 and Figure 47).
3) The block indication logic (see Figure 48) of the interconnection node sub-ring port accepts the two management information items as input compare the values of the two items:
   a) If the two values are identical (either both "primary" or both "secondary") – then perform MS command to the sub-ring port.
   b) If the two values are different – then ignore.
4) When the connectivity of the tandem connection is restored, the UP MEP sends an indication through the ETH_CI_SSF to the block indication logic and the block indication logic should again compare the values of the two management information items.
   a) If the two values are identical (either both "primary" or both "secondary") – then clear MS to the sub-ring port (either port 0 or port 1 as the case may be).
   b) If the two values are different – then ignore.

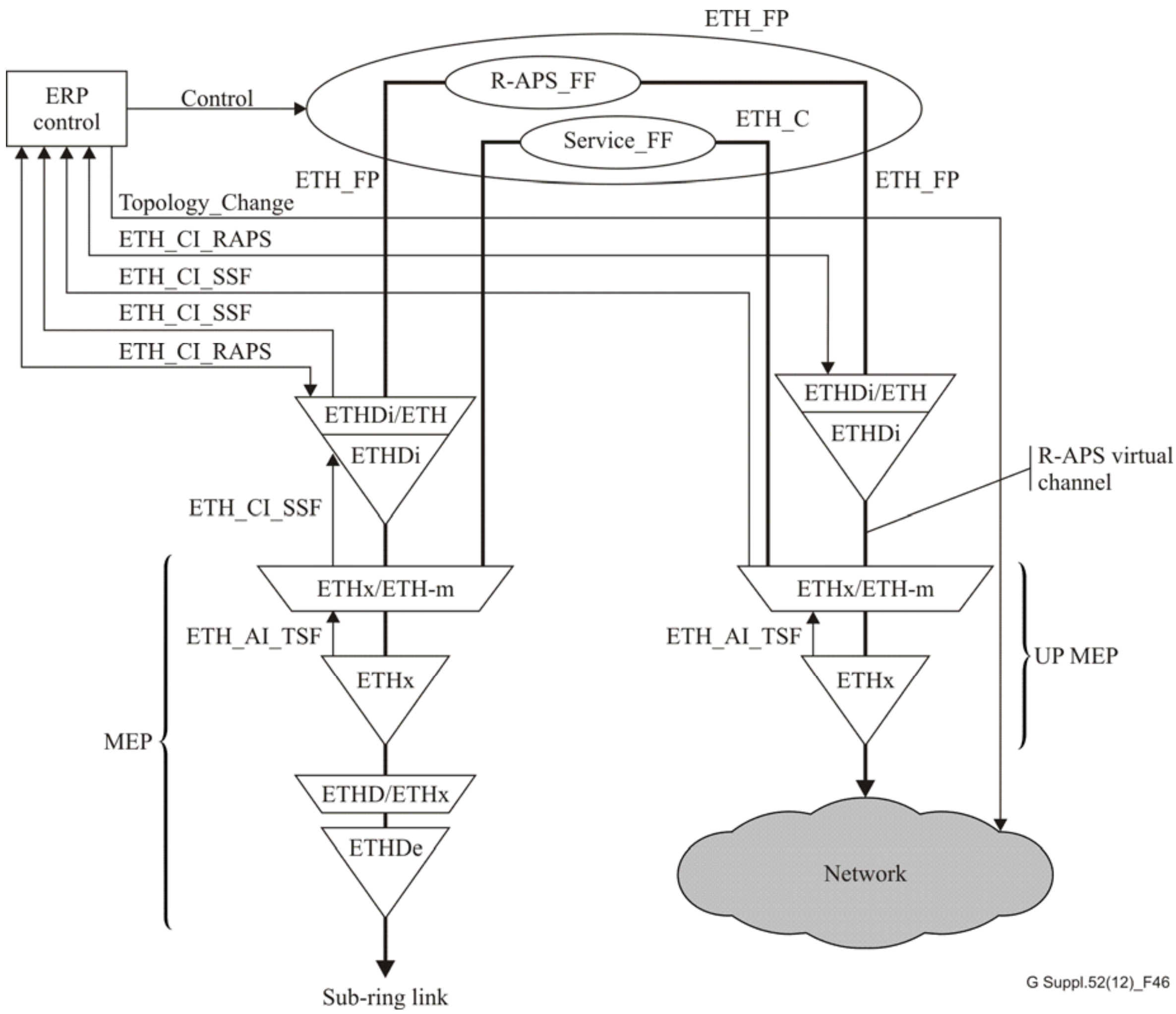


Figure 46 – MEPs and R-APS insertion function in interconnection node for minimization of ring segmentation in interconnected rings

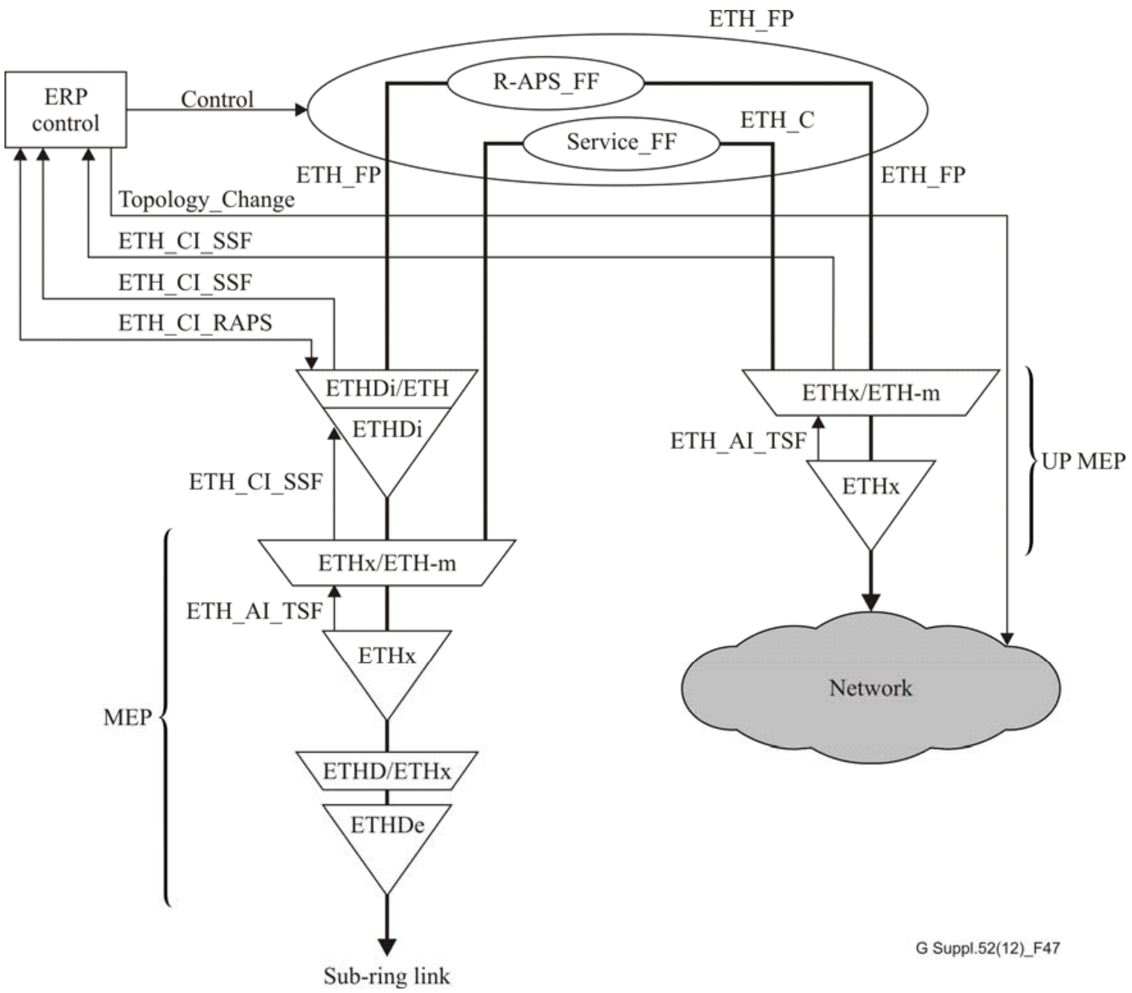


Figure 47 – MEPs and R-APS insertion function in interconnection node without R-APS virtual channel for minimization of ring segmentation in interconnected rings

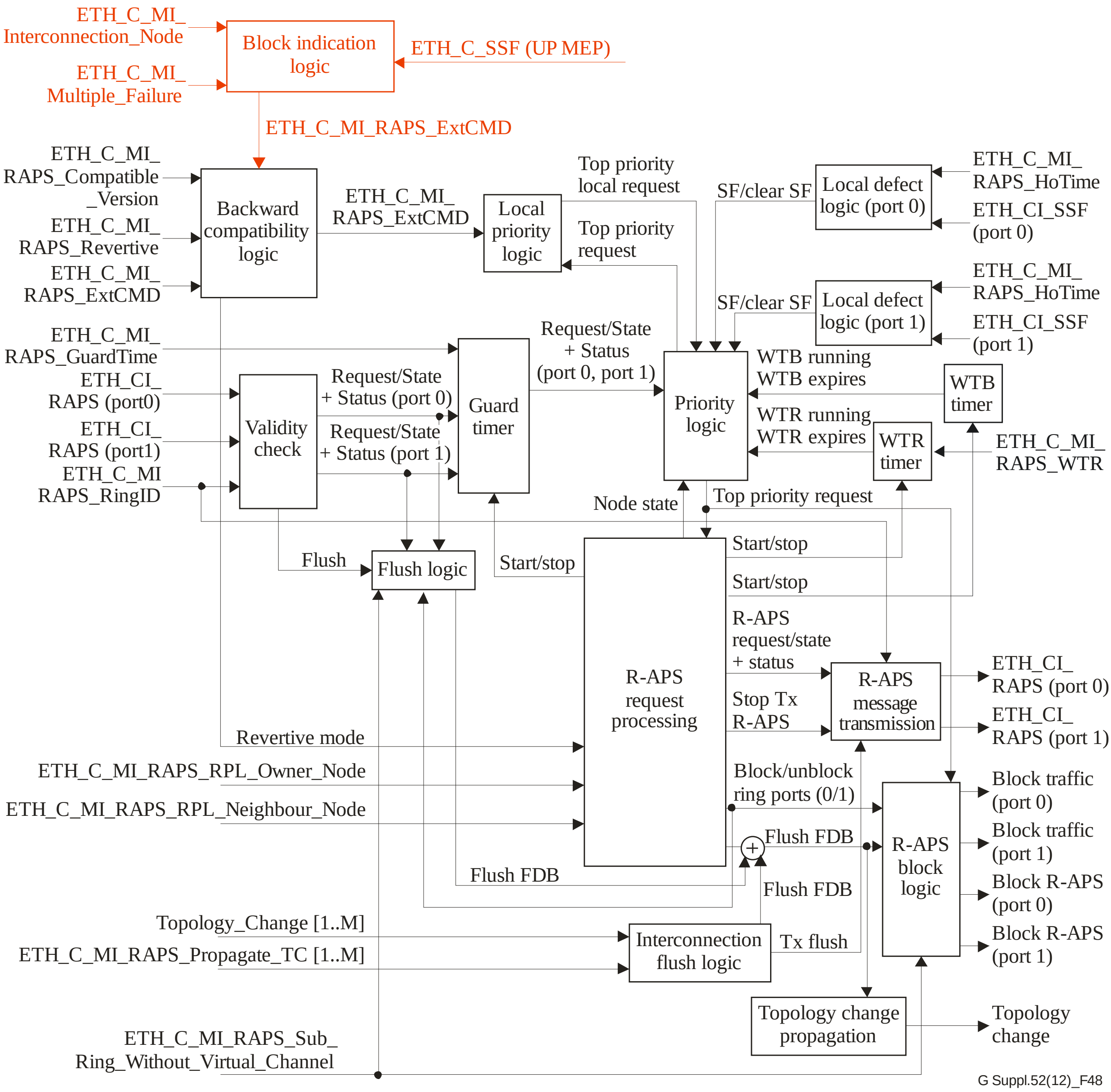


Figure 48 – ERP control process for minimization of ring segmentation in interconnected rings

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