# 1. Topology discovery and protection scenarios

**Editors' Notes:** To be removed prior to final publication.

The goal of this annex is to address the following comments:
1. Comment #560: Clarify the interworking of topology and protection. It will become clear through this exercise what the actual list of triggers is for generation of topology messages.
2. Comment #562: Illustrate the key scenarios for topology discovery. These include (for example) station initialization, addition of a station, removal of a station, isolation of a station, handling of bandwidth allocation, and handling of misconfigurations. Description will be included as to how topology interacts with protection and fairness.

## 1.1 Overview

This clause describes a variety of scenarios relevant to topology discovery and protection switching. The purpose of the scenarios is to clearly illustrate how the topology discovery and protection switching protocols respond to various events within an RPR ring.

## 1.2 Topology database generation

This subclause contains the following scenarios relating to the generation of the topology database at the stations making up an RPR ring:

1) Topology database generation in an RPR ring containing a single failed link.
2) Topology database generation in an RPR ring containing a station with two failed transmit links.
3) Topology database generation in an RPR ring containing a station with two failed receive links.
4) Topology database generation in an RPR ring containing a station with one failed receive link and one failed transmit link that are part of different spans.
5) Topology database generation in an RPR ring containing a station with two failed receive links and two failed transmit links.

### 1.2.1 Single failed link

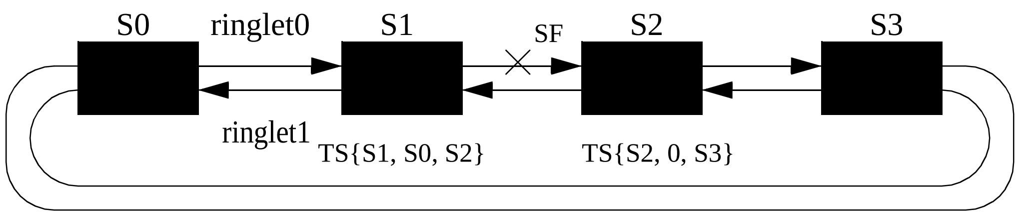
In this scenario, the link from S1 to S2 goes into signal fail state. Before the link went into signal fail state, S2 could determine that S1 was its west neighbor. After S2 detects a signal fail on its west interface, S2 clears S1 as its west neighbor but continues to report S3 as its east neighbor to the rest of the ring. The notation TS{S2, 0, S3} indicates that station S2 reports that its west neighbor is unknown, with zero MAC address.

On the other hand, S1 still detects S2 as its neighbor on its east interface. S1 will continue to report S2 as its east neighbor.

At all stations, the failure of the link from S1 to S2 results in modification of the topology database based on the fact that the span connecting S1 to S2 is no longer usable for data. The distance from each station to a given station contained in its topology database is maintained if a downstream path for data is maintained. For example, Figure 1.1shows that stations S0, S3, and S2 are reachable downstream from station S1 with hop count distances 1, 2, and 3 hops, respectively.

S2 reports a receive link status of signal fail on its west interface to the rest of the ring. Though the span connecting S1 and S2 is not usable for data, S1 reports a receive link status of idle on its east interface.

All stations continue to be reachable from all other stations for data, as denoted by the entries in the tables marked with a D.




| | | |
|---|---|---|
| 0 0 S0 S3 S1 I I D | 0 0 S1 S0 S2 I I D | 0 0 S2 00 S3 F I D |
| 1 X S1 S0 S2 I I D | X 3 S2 00 S3 F I D | 1 X S3 S2 S0 I I D |
| X 2 S2 00 S3 F I D | X 2 S3 S2 S0 I I D | 2 X S0 S3 S1 I I D |
| X 1 S3 S2 S0 I I D | X 1 S0 S3 S1 I I D | 3 X S1 S0 S2 I I D |

S0 Topology S1 Topology S2 Topology

**Figure 1.1—Single egress link failure.**

### 1.2.2 Two failed transmit links

> **Editors' Notes:** To be removed prior to final publication.
>
> This scenario needs further discussion. Based on the rule currently defined in 10.5.1.3 that topology messages shall be stripped from the ring by a station in wrapping state, the discovered topology in this case results in no messages from S3 being forwarded to S1, even though S0 and S2 refer to S3 as being one of their neighbors. Currently there is no such stipulation in 10.5.1.3 for steering rings, and as a result S3 would be visible to S1 for steering rings. The information visible in steering rings but not visible in wrappign rings is shown in italics.

In this scenario, both of the transmit links of S1 (S1 to S0 and S1 to S2) go into signal fail state. When this occurs, S0 clears S1 as its east neighbor and S2 clears S1 as its west neighbor. S1 therefore disappears as a neighbor from all topology messages received at any station on the ring other than S1. S1 is also removed from the topology database at any station on the ring other than S1, as S1 is downstream of a failed span in both ring directions from any station on the ring other than S1.

At S1, topology messages from S0 and S2 can be received in wrapping rings. A topology message from S3 can additionally be received in steering rings. In all cases, any station on the ring other than S1 is not reachable for data from S1. Since topology messages can be received from other stations, from the perspective of S1 those other stations are considered control reachable and are marked with a C in the topology database.

The usage of signal fail and idle indications follows the equivalent behavior as in 1.2.1.

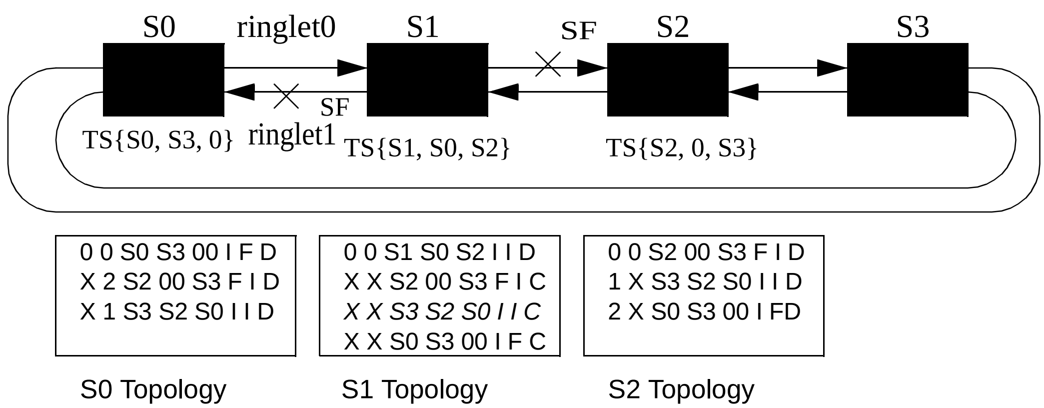



**Figure 1.2—Two egress links failure.**

### 1.2.3 Two failed receive links

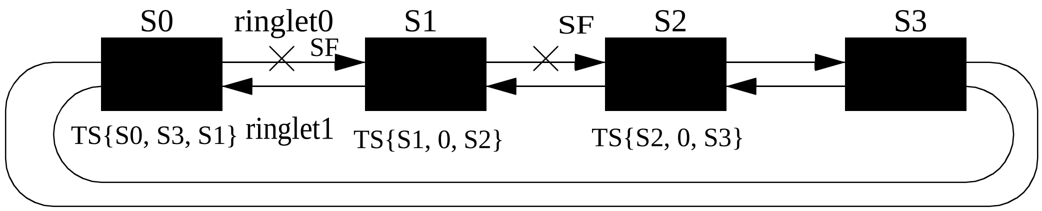
> **Editors' Notes:** To be removed prior to final publication.
>
> This scenario will be added later.

### 1.2.4 One failed receive link and one failed transmit link, different spans

> **Editors' Notes:** To be removed prior to final publication.
>
> This scenario needs further discussion. Based on the rule currently defined in 10.5.1.3 that topology messages shall be stripped from the ring by a station in wrapping state, the discovered topology in this case results in no messages from S3 being forwarded to S1, even though S0 and S2 refer to S3 as being one of their neighbors. Currently there is no such stipulation in 10.5.1.3 for steering rings, and as a result S3 would be visible to S1 for steering rings. The information visible in steering rings but not visible in wrappign rings is shown in italics.

In this scenario, one of the transmit links of S1 (S1 to S2) and one of the receive links of S1 (S0 to S1) go into signal fail state. When this occurs, S1 clears S0 as its west neighbor and S2 clears S1 as its west neighbor. S1 is no longer data reachable from other stations on the ring, but remains control reachable (see editorial note above).

The usage of signal fail and idle indications follows the equivalent behavior as in 1.2.1.




| | | |
|---|---|---|
| 0 0 S0 S3 S1 I I D | 0 0 S1 S0 S2 F I D | 0 0 S2 00 S3 F I D |
| X X S1 00 S2 F I C | X X S2 00 S3 F I C | 1 X S3 S2 S0 I I D |
| X 2 S2 00 S3 F I D | *X X S3 S2 S0 I I C* | 2 X S0 S3 S1 I I D |
| X 1 S3 S2 S0 I I D | X X S0 S3 S1 I I C | X X S1 00 S2 F I C |
| S0 Topology | S1 Topology | S2 Topology |

**Figure 1.3—One egress and ingress link failure.**

### 1.2.5 Two failed receive links and two failed transmit links

> **Editors' Notes:** To be removed prior to final publication.
>
> This scenario will be added later.

## 1.3 Insertion and removal of stations

This subclause contains the following scenarios relating to the insertion and removal of stations to/from an RPR ring:

> **Editors' Notes:** To be removed prior to final publication.
>
> Scenario 5 will be added by the PAH if pass-through mode is an allowed mode of operation.
>
> The PAH needs to add insertion of information for topology extended status messages into these scenarios.
>
> In the scenarios below, transmissions of IDLE status by a station will be modified to use only short path message identification (S rather than L) in an upcoming version of the draft.

1) Replacement of one or more stations without use of operator commands to change the protection status of links in the ring. The basic scenarios for insertion and/or removal of a station to/from an RPR ring are subsets of this scenario.
2) Replacement of one or more stations with use of operator commands to change the protection status of links in the ring.
3) Scenario 1), with existing ring being a wrapping ring and the newly inserted station being only steering-capable.
4) Removal of the only steering-only station from a wrapping-capable ring.

5) Addition or deletion of one or more stations using a mechanism such as electrical passthrough that will not trigger any change of protection status on any link in the ring during the replacement.

### 1.3.1 Replacement of stations without use of operator commands

The initial configuration of the ring is shown in Figure 1.4. Station B is replaced with a new station G. G is fully connected into the ring prior to being powered up. In the case of a wrapping ring, station G is assumed to be wrapping capable. The final configuration of the ring is shown in Figure 1.5.

This scenario is written for a single station replacement. The scenario can be directly extended for replacement of multiple adjacent stations.

The protection switching specific portions of this scenario are different for steering and wrapping rings. The topology specific portions of this scenario do not vary for steering and wrapping.

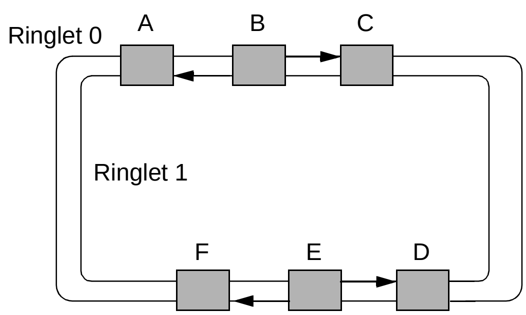



**Figure 1.4—An RPR ring with six stations.**

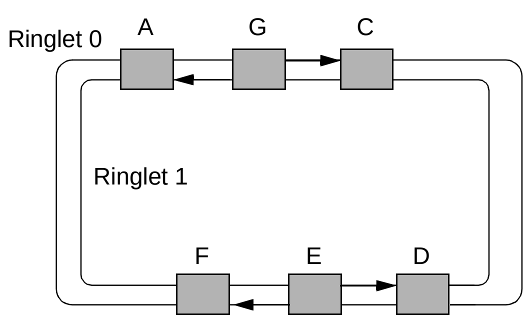



**Figure 1.5—An RPR ring with six stations after replacement of B by G.**

### 1.3.1.1 Steering ring

The configuration of the ring during the replacement of station B with station G is shown in Figure 1.6. Station B is disconnected from the ring via manual unplugging of fibers. Station G is then fully connected into the ring while powered down. Station G is then powered up. The final configuration of the ring is shown in Figure 1.5.

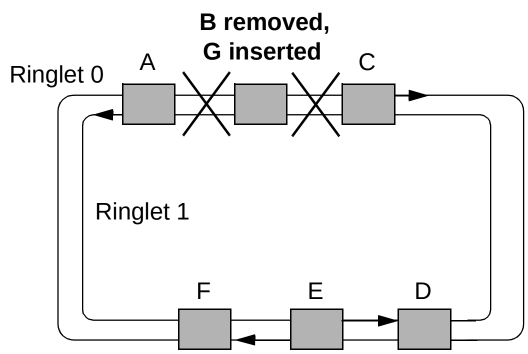



**Figure 1.6—Replacement of a station in a steering RPR ring**

#### 1.3.1.1.1 Removal of station B

The removal of station B may be done via one fiber removal at a time, via bidirectional fiber removal on the east and west interfaces of B, or via simultaneous bidirectional fiber removal, e.g. power-down of B.

Single fiber removal (fiber from A->B):

Actions at A and B:

1) Station B detects SF on ringlet 0, transmits {SF, B, I, S} towards A on ringlet 1, and transmits {SF, B, I, L}on ringlet 0.
2) [Topology database at B is updated.]
3) Station B steers traffic appropriately.
4) Just after transmission of protection messages, station B transmits a topology message on each ringlet. This is done as the identity of B’s neighbor on its west interface has changed.
5) Station A receives a protection request on ringlet 1.
6) [Topology database at A is updated. ]
7) Station A steers traffic appropriately.
8) Station A receives a protection request on ringlet 0. As it is a duplicate request, A takes no additional action.

Actions at other stations on ring:

1) Each station receives a protection request from station B.
2) [Topology database at the station is updated.]

3) Each station steers traffic appropriately.

Simultaneous bidirectional fiber removal (e.g. power-down of station B):

Actions at A and C:

1) A detects SF on ringlet 1, transmits {SF, A, I, S} towards B on ringlet 0, and transmits {SF, A, I, L} on ringlet 1.
2) C detects SF on ringlet 0, transmits {SF, C, I, S} towards B on ringlet 1, and transmits {SF, C, I, L} on ringlet 0.
3) [Topology database at A is updated.]
4) Station A steers traffic appropriately.
5) [Topology database at C is updated.]
6) Station C steers traffic appropriately.
7) Just after transmission of protection messages, stations A and C transmit a topology message on each ringlet.
8) Station A receives a protection request on ringlet 0.
9) Station C receives a protection request on ringlet 1.
10) [Topology database at A is updated. ]
11) Station A steers trafffic appropriately.
12) [Topology database at C is updated. ]
13) Station C steers traffic appropriately.

Actions at other stations on ring:

1) Each station receives protection requests from stations A and C.
2) [Topology database at the station is updated. For illustration, this is what occurs. The entries for link availability are updated to SF on links A->B, B->A, B->C, and C->B. The entries for B in the topology database are deleted, as are the east neighbor value for the A entry, and the west neighbor value for the C entries. All fields in the topology database showing upstream distances on ringlet 1 beyond A are cleared. All fields in the topology database showing upstream distances on ringlet 0 beyond C are cleared.]
3) Each station steers traffic appropriately.

The bidirectional fiber removal scenario on a single span (such as between A and B) follows the same steps as for the simultaenous bidirectional fiber removal, except that references to station C are replaced by station B. Modifications to the topology databases will also not result in the deletion of entries for station B.

#### 1.3.1.1.2 Insertion of station G

Note: A station will usually return to service with one segment coming up after the other (with the time delta potentially close to 0). In this scenario, a station is powered up with the links connected and fault free.

Actions at G:

1) G is attached to the ring.
2) G is powered up.
3) Station G and the span between A and G return to service (SF on both links between A and G disappears).
4) Station G and the span between Cand G return to service (SF on both links between C and G disappears).

5) Station G, not seeing any faults, transmits idle messages {IDLE, G, I, S} and {IDLE, G, I, L} on both ringlets.
6) Just after transmission of protection messages, station G transmits a topology message on each ringlet.
7) The messages are forwarded through A and C to the rest of the ring.
8) All other stations on the ring respond to the topology message from station G with their own transmitted topology messages. G updates its topology database.
9) All other stations on the ring respond to the topology message from station G with their own transmitted protection messages. (necessary?) G updates its topology database.

Actions at A:

1) The fault disappears on A, and A enters WTR state (briefly).
2) [Station A updates its topology database.]
3) Station A steers traffic appropriately.
4) Station A transmits {WTR, A, I, S} on ringlet 0 and {WTR, A, I, L} on ringlet 1.
5) Station A receives an idle protection message from station G. Station A receives a topology message from station G.
6) [Topology database at A is updated with new entry for G. When full bidirectional connectivity is restored, A updates its topology database as it sees topology discovery messages arrive from stations upstream on ringlet 1.]
7) [Protection learns from the topology database that A's neighbor has changed to G.]
8) Based on G being different from the previously connected neighbor, station A drops the WTR. Station A transmits {Idle, A, I, S} on ringlet 0 and {Idle, A, I, L} on ringlet 1.
9) [Station A updates its topology database.]
10) Station A steers traffic appropriately.

Actions at C:

1) The fault disappears on C, and C enters WTR state (briefly).
2) [Station C updates its topology database.]
3) Station C steers traffic appropriately.
4) Station C transmits {WTR, C, I, S} on ringlet 0 and {WTR, C, I, L} on ringlet 1.
5) Station C receives an idle protection message from station G. Station C receives a topology message from station G.
6) [Topology database at C is updated with new entry for G. When full bidirectional connectivity is restored, C updates its topology database as it sees stations appear upstream on ringlet 0.]
7) [Protection learns from the topology database that C's neighbor has changed to G.]
8) Based on G being different from the previously connected neighbor, , station C drops the WTR. Station C transmits {Idle, C, I, S} on ringlet 0 and {Idle, C, I, L} on ringlet 1.
9) [Station C updates its topology database.]
10) Station C steers traffic appropriately.

Actions at other stations:

1) At all other stations, protection and topology messages from A, C, and G are received.

2) [Topology database at each station is updated appropriately based on modified information from A and C, new information from station G, and restoration of full bidirectional connectivity.]
3) Stations steer traffic appropriately.

### 1.3.1.2 Wrapping ring

The configuration of the ring during the replacement of station B with station G is shown in Figure 1.7. Station B is disconnected from the ring via manual unplugging of fibers. Stations A and C wrap as a result. Station G is then fully connected into the ring while powered down. Station G is then powered up. The final configuration of the ring is shown in Figure 1.5.

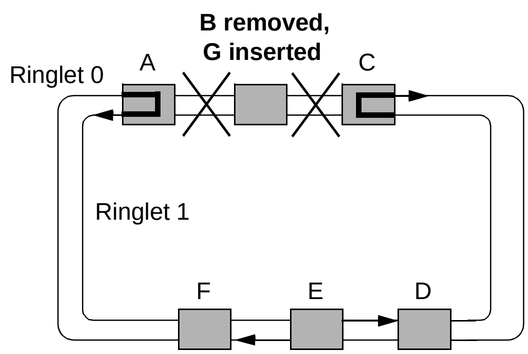



**Figure 1.7—Replacement of a station in a wrapping RPR ring**

#### 1.3.1.2.1 Removal of station B

The removal of station B may be done via one fiber removal at a time, via bidirectional fiber removal on the east and west interfaces of B, or via simultaneous bidirectional fiber removal, e.g. power-down of B.

Single fiber removal (fiber from A->B):

Actions at A and B:

1) Station B detects SF on ringlet 0, transitions to Wrapped state (performs a wrap) on its west interface, transmits {SF, B, W, S} towards A on ringlet 1, and transmits {SF, B, W, L}on ringlet 0.
2) [Topology database at B is updated.]

3) Just after transmission of protection messages, station B transmits a topology message on each ringlet. This is done as the identity of B's neighbor on its west interface has changed.
4) Station A receives a protection request on ringlet 1, and transitions to Wrapped state on its east interface.
5) [Topology database at A is updated. ]
6) Station A receives a protection request on ringlet 0. As it is a duplicate request, A takes no additional action.

Actions at other stations on ring:

1) Each station receives a protection request from station B.
2) [Topology database at the station is updated.]

Simultaneous bidirectional fiber removal (e.g. power-down of station B):

Actions at A and C:

1) A detects SF on ringlet 1, transitions to Wrapped state (performs a wrap), transmits {SF, A, W, S} towards B on ringlet 0, and transmits {SF, A, W, L} on ringlet 1.
2) C detects SF on ringlet 0, transitions to Wrapped state (performs a wrap), transmits {SF, C, W, S} towards B on ringlet 1, and transmits {SF, C, W, L} on ringlet 0.
3) [Topology database at A is updated.]
4) [Topology database at C is updated.]
5) Just after transmission of protection messages, stations A and C transmit a topology message on each ringlet.
6) Station A receives a protection request on ringlet 0. Station A should already be wrapped on its east interface due to local detect of SF.
7) Station C receives a protection request on ringlet 1. Station C should already be wrapped on its west interface due to local detect of SF.
8) [Topology database at A is updated. ]
9) [Topology database at C is updated. ]

Actions at other stations on ring:

1) Each station receives protection requests from stations A and C.
2) [Topology database at the station is updated. For illustration, this is what occurs. The entries for link availability are updated to SF on links A->B, B->A, B->C, and C->B. The entries for B in the topology database are deleted, as are the east neighbor value for the A entry, and the west neighbor value for the C entries. All fields in the topology database showing upstream distances on ringlet 1 beyond A are cleared. All fields in the topology database showing upstream distances on ringlet 0 beyond C are cleared.]

The bidirectional fiber removal scenario on a single span (such as between A and B) follows the same steps as for the simultaenous bidirectional fiber removal, except that references to station C are replaced by station B. Modifications to the topology databases will also not result in the deletion of entries for station B.

#### 1.3.1.2.2 Insertion of station G

Note: A station will usually return to service with one segment coming up after the other (with the time delta potentially close to 0). In this scenario, a station is powered up with the links connected and fault free.

Actions at G:

1) G is attached to the ring.
2) G is powered up.
3) Depending on timing of transmission of protection messages, G may receive a message {SF, A, W, S} from A or a message {SF, C, W, S} from C while it is coming up. This will cause G to wrap. When A or C determines that the incoming link from G has now transitioned to idle status (and that G is a new neighbor), then the standard unwrapping sequence will take place, as described in 11.8.2.2.
4) Station G and the span between A and G return to service (SF on both links between A and G disappears).
5) Station G and the span between C and G return to service (SF on both links between C and G disappears).
6) Station G, not seeing any faults, transmits idle messages {IDLE, G, I, S} and {IDLE, G, I, L} on both ringlets.
7) Prior to A, C, and G unwrapping, topology discovery messages from G are stripped from the ring at A and C. Topology discovery messages from A and C are received at G, but topology discovery messages from other stations are stripped by A or C and do not reach G.
8) [A, C, and G update their topology databases appropriately.]
9) After A, C, and G unwrap, station G transmits a topology message on each ringlet. All other stations on the ring respond to the topology message from station G with their own transmitted topology messages.
10) [G updates its topology database.]
11) All other stations on the ring respond to the topology message from station G with their own transmitted protection messages. (necessary?) G updates its topology database.

Actions at A:

1) The fault disappears on A, and A enters WTR state (briefly).
2) [Station A updates its topology database.]
3) Station A transmits {WTR, A, W, S} on ringlet 0 and {WTR, A, W, L} on ringlet 1.
4) Station A receives an idle protection message from station G. Station A receives a topology message from station G.
5) [Topology database at A is updated with new entries for G. When full bidirectional connectivity is restored, A updates its topology database as it sees topology discovery messages from stations upstream on ringlet 1.]
6) [Protection learns from the topology database that A's neighbor has changed to G.]
7) Based on G being different from the previously connected neighbor, station A drops the WTR. Station A unwraps. Station A transmits {Idle, A, I, S} on ringlet 0 and {Idle, A, I, L} on ringlet 1.
8) [Station A updates its topology database.]

Actions at C:

1) The fault disappears on C, and C enters WTR state (briefly).
2) [Station C updates its topology database.]
3) Station C transmits {WTR, C, W, S} on ringlet 0 and {WTR, C, W, L} on ringlet 1.
4) Station C receives an idle protection message from station G. Station C receives a topology message from station G.
5) [Topology database at C is updated with new entries for G. When full bidirectional connectivity is restored, C updates its topology database as it sees topology discovery messages from stations upstream on ringlet 0.]

6) [Topology informs protection that C's neighbor has changed to G.]
7) Based on G being different from the previously connected neighbor, station C drops the WTR. Station C unwraps. Station C transmits {Idle, C, I, S} on ringlet 0 and {Idle, C, I, L} on ringlet 1.
8) [Station C updates its topology database.]

Actions at other stations:

1) At all other stations, protection and topology messages from A, C, and G are received (after A, C, and G unwrap).
2) [Topology database at each station is updated appropriately based on modified information from A and C, new information from station G, and restoration of full bidirectional connectivity.]

### 1.3.2 Replacement of stations using operator commands

Consider the scenario of 1.3.1. For removal of a station, the only difference is that spans are commanded down via, for example, a forced switch (FS) command. This command is reported from the management station or command line interface to the OAM module via the MLME interface. The OAM module informs the protection module of the change in link status. From this point forward, the scenarios behave identically to the scenarios of 1.3.1 for steering and wrapping rings, except that the link status being reported is FS rather than SF.

For insertion of a station via clearing of FS, once the protection module finds out about the management command, again the scenarios behave identically to the scenarios of 1.3.1 for steering and wrapping rings, except that the link status being cleared to Idle is FS rather than SF.

### 1.3.3 Insertion of a steering-only station in a wrapping ring

Consider the scenario of 1.3.1. For insertion of a steering station into a ring where all other stations are wrapping-capable and the ring is configured to prefer wrapping, the following additional steps are inserted, keeping all other steps the same:

1) G sends out topology messages on both ringlets indicating that it is not wrapping capable.
2) The neighbors of G (A and C) unwrap immediately upon finding out that G is not wrapping capable.
3) After A and C unwrap, topology messages from G are forwarded to the rest of the stations on the ring. Upon receipt of these messages, all other stations on the ring proceed to steer their traffic.

### 1.3.4 Removal of the only steering-only station from a wrapping-capable ring

Consider the scenario of 1.3.1. For removal of a steering station from a ring where all other stations are wrapping-capable and the ring is configured to prefer wrapping, the following additional steps are inserted, keeping all other steps the same:

1) When other stations remove the entry for G from their topology databases, those stations check at that time if all remaining stations on the ring are wrapping capable and the ring is configured to prefer wrapping.
2) If so, A and C (neighbors of G) then wrap immediately.
3) If so, other stations on the ring re-steer their traffic appropriately (back to the default directions for the traffic).