1. Introduction

1.1 Overview

This document describes the 802.17 resiliency mechanism.

1.2 Scope

The scope of this document is to define a proposal of resiliency mechanisms to be integrated into the draft for 802.17 RPR. The proposal is based on the Selective Steer Independent Wrap (SWIS) method.

1.3 Terms and definitions

2. Resiliency Background

One of the main objectives of RPR is to provide sub 50 msec protection for ring or Station failures, without wasting half of the bandwidth during normal operating conditions.
The basic methods to achieve this objective are: Wrap and Steer. Following is a description of each mode with its advantages and limitations.

2.1 Wrap

Stations using the Wrap protection method loop (or wrap) the signal on failure detection. As shown in Figure 1, the connection is wrapped by the two failure detecting Stations and is able to reach all the Stations in the ring. In other words, on failure the bidirectional counter rotating ring becomes a unidirectional ring.

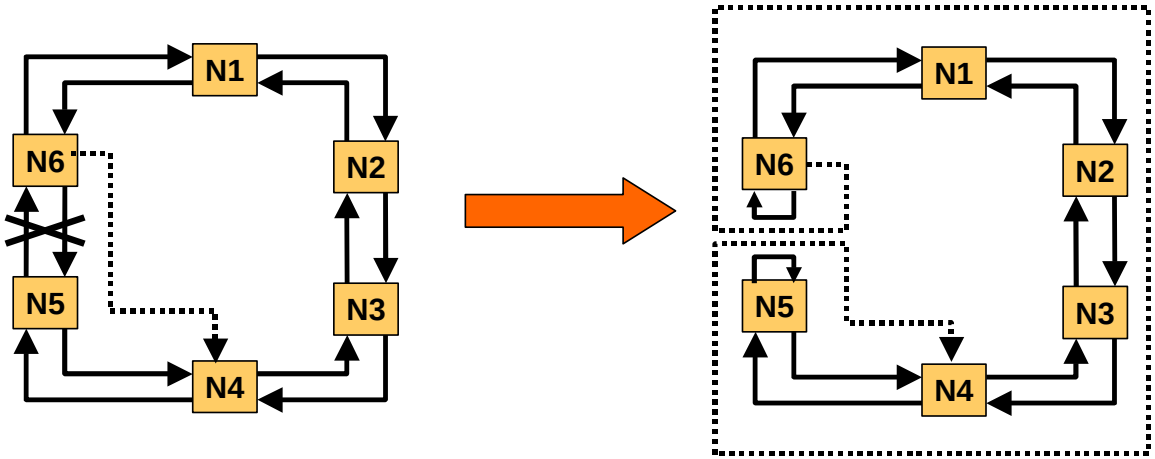

Figure 1: Wrap protection

Wrap advantages are:

- Fast
- Minimal packet loss
- Simple Broadcast/Multicast support
- Performed by hardware at MAC layer

2.1.1 Fast

The Stations involved in the protection operation are the ones adjacent to the failure, no indication has to be forwarded through the ring, the other Stations need not be aware of the failure to comply with the fast protection time.

2.1.2 Minimal packet loss

Packet loss is the main SLA parameter monitored by users and service providers. This parameter can be monitored in real time and with fairly good accuracy, so reducing packet loss is a desirable goal.
Since wrap achieves the fastest protection time, packet loss is minimal.

2.1.3 Simple Broadcast/Multicast support

Broadcast packets may be used in ring topologies for control purpose, such as fairness, maintenance, topology discovery. Furthermore Multicast and Broadcast RPR frames can be used to reduce the bandwidth consumed by higher layers performing these functions.
During normal operation the broadcast/multicast frame is transmitted through one of the rings (Inner or Outer) and will reach all Stations, until removed by the generating Station as shown in Figure 2. During failure conditions the wrap method allows the transmitting Station to transmit through the original ring, and still reach all Stations, as shown in Figure 2.

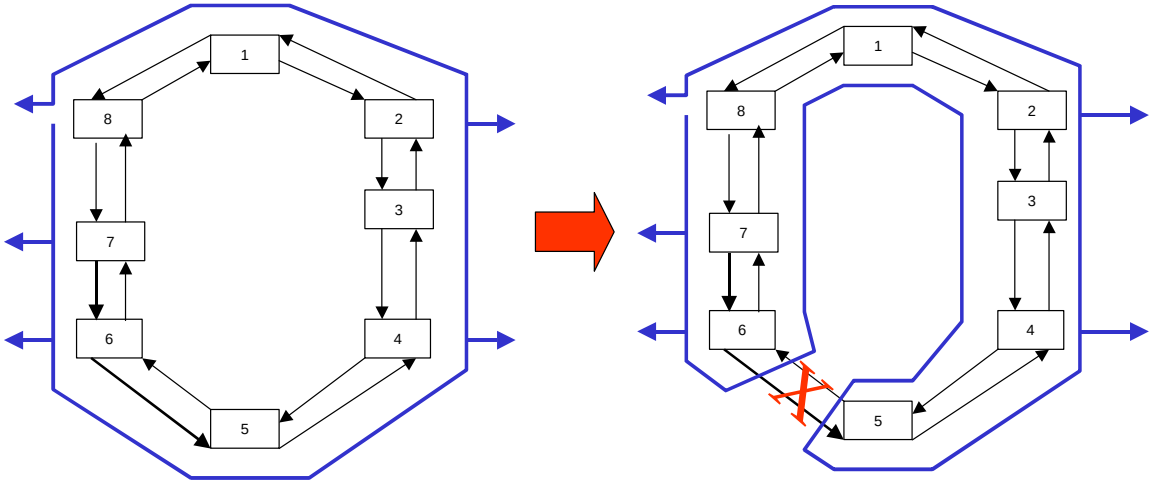

Figure 2: Broadcast/Multicast during normal and wrap conditions.

On contrast, for the steer method, once a failure is detected the ring is open, and the transmitting node has to evaluate the failure to decide what action should be performed. If the failure affects only the other ring, do nothing. If the failure affects the ring used for the broadcast transmission, then use other ring. If failure affects both rings, then transmit same frame through both rings. The different options are shown in Figure 3a.

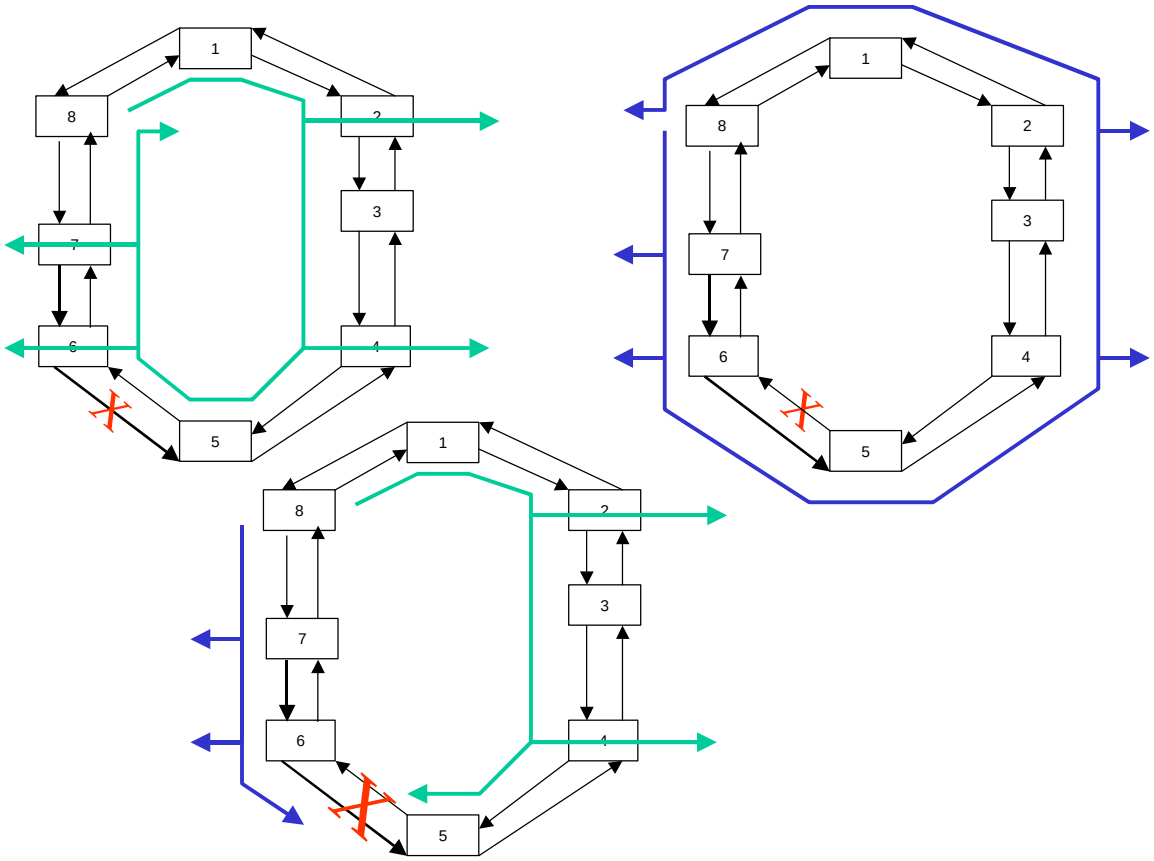

Figure 3a: Steer Broadcast/Multicast protection options

2.1.4 Performed at MAC layer

The wrap activation can be triggered by hardware or software indications, and easily implemented as a loop by the MAC hardware, no need to change routing tables.

2.2 Steer

On failure, the detecting node sends an indication to all the Stations in the ring. Stations using the Steer protection method use anothe other ring to transmit the signal on failure detection. As shown in Figure 4, the connection is steered by the transmitting Station and is able to reach all the destination Station in the ring. In other words, on failure, the failed ring becomes a linear Network.

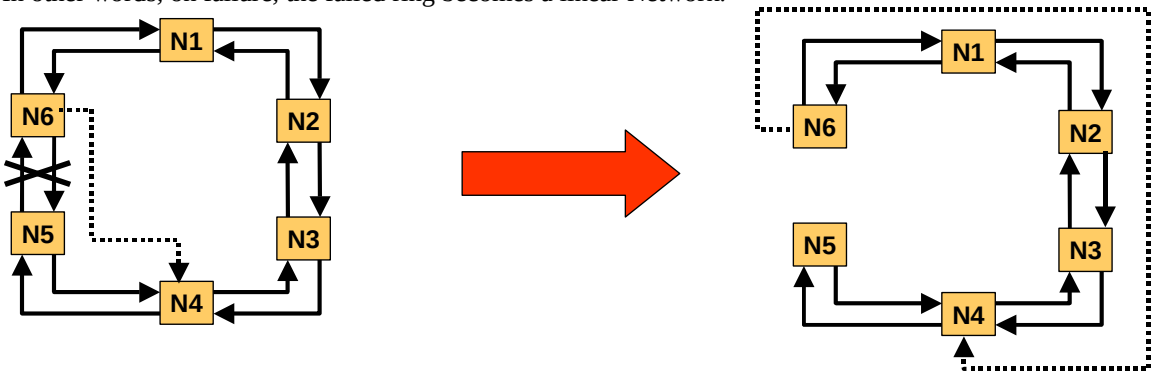

Figure 4: Steer protection

Steer advantages are:

- Single operation
- Supports both: Revertive and non-Revertive schemes
- Optimal Bandwidth utilization (during failure and for Revertive mode)
- Lower delay for data flows during protection
- Supports both: Unidirectional and Bidirectional protection

2.2.1 Single operation

Steer optimizes resources allocation during failures, so no further action should be performed. If wrap is used as the protection method resources are not used optimally during wrap, so usually a slow reroute is performed as a second step.

2.2.2 Revertive and non-Revertive

Once the ring failure is fixed the system can decide if the connection has to return to the original path, or it can remain in the steered path until it fails. Non-Revertive mode avoids a second hit on the connection during the restoration to the original path.
Note that wrap is always Revertive, since the loop is open once the failure is fixed. If slow reroute is performed, then protection can be non-Revertive, but anyway a second hit is present during the slow reroute.

2.2.3 Optimal Bandwidth utilization during protection

During failure the connection is routed through the next best path, it does not transverse any segments that could be avoided.
In wrap method the connection transverses the whole opposite ring.

2.2.4 Lower delay during protection

The same reasons as described in the previous paragraph for both methods.

2.2.5 Unidirectional and Bidirectional

Failure on a ring affects only connections that transverse that ring, connections that use the other ring are not disturbed.
Note that wrap is always Bidirectional since the wrap operation affects both rings.

3. SWIS

RPR uses Selective Wrap Independent Steer (SWIS) as the preferred resiliency method. A Wrap on failure (WOF) mark is defined in the Standard RPR frame header, and Stations mark their sourced frames to indicate what is the desired behavior to be applied to the frame by the defect detecting Station. Depending on the mark the defect detecting Station may wrap the frame or discard it.

Note that each Station in a ring can mark all its frames, not mark all its frames, or mark some. Usually a Station designed for Steer protection mechanism will not mark all its sourced frames and a Station designed for Wrap protection mechanism will mark all its sourced frames, but its is also envisioned that some Stations will not mark some of its sourced frames (i.e. unicast traffic) and mark other sourced frames (i.e. multicast traffic)

3.1 SWIS Principles

The WOF bit in the frame header is used to indicate the desired behavior to be applied to the frame by a failure detecting Station. WOF shall be set or clear by the frame sourcing Station for all sourced frames during normal and ring failure operation.
Protection may be initiated either manually by user command, or automatically by a ring failure.

3.1.1 Station operation during ring failures

A Station detecting a ring failure shall operate as follows:

- Wrap all frames with the WOF indication set
- Discard all frames with the WOF indication clear
- Transmit alarm indications to the other Stations in the ring

Other Stations in the ring may use the alarm indication to perform a steer operation.
Once the ring failure is cleared the Station shall operate as follows:

- Stop wrapping frames regardless of WOF
- Stop discarding frames regardless of WOF
- Stop sending the alarm indication

Other Stations in the ring may detect the clearance of the alarm indication to revert from the protection path to the original path.

3.2 Protection switch operating modes

Stations supporting steer method for some or all its sourced frames shall support non-revertive protection steer. In non-revertive protection steer a switch to the protection path (steer operation) is maintained even after the working path has recovered from the failure that caused the protection steer. Stations supporting steer method for some or all its sourced frames may be required to support revertive protection steer. In revertive protection steer the traffic is steered back to the working path after the working path has recovered from the failure that caused the protection steer.

The wrap operation implemented on WOF marked frames by a failure detecting Station shall always be Revertive.

Protection mode shall be bi-directional a failure affecting one direction of the ring segment renders the whole segment as failed. Unidirectional protection mode is for further study.

3.3 Protection Initiation and completion criteria

Two automatic protection initiation criteria are defined.

Signal Failure (SF): A hard failure detected on the incoming signal. Failure of the phy layer, Unicast Protection Coordination frame with SF received or BER exceeding 10e-3 shall be detected as SF. The SF BER threshold should be user provisionable over the range of 10e-3 to 10e-5.

The exact definition of the phy layer failures defined as SF depends on the specific phy used and are for further study. The exact method of computing BER is for further study.

Signal Degraded (SD): A soft failure detected on the incoming signal. Unicast Protection Coordination frame with SD received or BER exceeding 10e-6 shall be detected as SD. The SD BER threshold should be user provisionable over the range of 10e-5 to 10e-9.

BER for SD may be computed by the phy layer by the RPR layer or both. The exact method of computing BER is for further study.

Protection time is the time it takes a Station to detect a SF or a SD. SF shall be detected within 8 msec. SD detection time is for further study.

For frames that are wrapped during failure conditions, protection completion time includes the time between the declaration of the SF or SD and the actual wrap of such frames. For frames that are not wrapped during failure conditions, protection completion time includes the time between the declaration of the SF or SD and the time the frames are actually steered by the source Station.

Protection switch completion time shall be less than 50 msec.

3.4 Restoral of SF and SD conditions

For BER initiated protection switches, a hysteresis method of clearing SF and SD conditions is used. The SF and SD clearing thresholds shall be 10 times lower than the SF and SD declaration thresholds.

The exact performance of the BER clearing method is for further study.

For Unicast Protection Coordination initiated protection, the SF or SD shall be cleared if a Unicast Protection Coordination frame indicating the idle condition is received.

For Stations using Revertive mode a Wait To Restore (WTR) time of 12 minutes shall be provided after the condition that caused the protection switch clears. The length of the WTR shall be user provisionable over the range of 5 to 12 minutes.

3.5 Protection Coordination frame

Protection Coordination frames are OAM type frames used to signalize the ring protection states. The Protection Coordination common and specific fields along with the detection procedure is described in paragraph TBD (refer to OAM proposal).

Two types of Protection Coordination frames are defined. A Broadcast Protection Coordination (BPCF) frame that shall be transmitted by a failure detecting Station and a Unicast Protection Coordination (UPCF) frame that shall be used to convey protection status information between peer Stations as long as the BPCF is not received. Both types of frames use the same frame specific fields.

3.5.1 Message ID filed

The code values for the Message ID are shown in the following table. Priority of message is in descending order.

Message	**Coding**
Forced Switch	00001101
Signal Fail	00001011
Signal Degrade	00001000
Manual Switch	00000110
Wait To Restore	00000101
No Request	00000000

Note that for the BPCF the Message ID filed can indicate either SF or SD only.

3.5.2 Path ID filed

The code values for the Path ID are:

- BPCF coded as Long
- UPCF coded as Short

3.5.3 BPCF generation

A Station detecting an SF or SD, or receiving a switch command, shall evaluate the ring status as indicated by any existing BPCF received and generate a BPCF in the upstream direction indicating its state if:

- The ring state priority as indicated by the Protection Coordination frames is lower than its local state
- The local state is Forced Switch or SF

BFCP shall be generated every TBD msec as long as the conditions for its generation exist.

3.5.4 UPCF generation

Every Station shall generate a UPCF in the upstream and downstream direction as long as the ring is in the Idle state. A Station transmitting BPCF in the upstream direction shall generate UPCF in the downstream direction with the same Message ID as indicated in the BPCF.

UPCF shall be transmitted every TBD msec. UPCF upstream generation shall be inhibited immediately if a BPCF is received.

3.5.5 Protection Coordination frames troubles

A Protection Coordination frame defect shall be declared if no UPCF or BPCF is received within TBD msec, or if the contents of the Message ID or Status fields in the Protection Coordination frame, are invalid. A Protection Coordination frame defect shall not be declared if a lower layer (i.e. phy) defect is detected.

The Protection Coordination frame defect shall be terminated if 3 consecutive valid UPCF or BPCF are received.

A Protection Coordination mismatch defect shall be declared if while generating BPCF in the upstream direction a BPCF with a lower priority state is received from the same ringlet during TBD msec.

The Protection Coordination mismatch defect shall be terminated if no such BPCF are received during TBD msec.

3.6 Switch Commands

The control layer issues switch commands. Only wrap switch commands shall influence the Message ID of the Protection Coordination frames. Switch commands that were preempted by higher priority commands shall not be retained.

Switch Commands that were rejected shall not be retained.

3.6.1 Wrap Switch Commands

The following switch commands shall be provided:

- Forced Switch: Forces a Selective Wrap operation at the Station where the command was received and at the adjacent Station regardless of the ring status.

- Manual Switch: Forces a Selective Wrap operation at the Station where the command was received and at the adjacent Station unless the ring status priority is higher or equal to Manual Switch.

- Clear Switch: Clears Force or Manual commands from the stack of the Station receiving the command

3.6.2 Steer Switch Commands

The following switch commands shall be provided:

- Forced Steer: Forces a Steer operation at the Station where the command was received regardless of the ring status.

- Manual Steer: Forces a Steer operation at the Station where the command was received unless the ring status priority is higher or equal to Manual Switch.

- Clear Steer: Clears Force or Manual commands from the stack of the Station receiving the command

3.7 SWIS Operation

This section provides some examples of the SWIS operation under different conditions. Assume A, B and C are adjacent Stations in a ring, with B laying between A and C.

The following table gives an example of a unidirectional failure between A and B. Steer operation is assumed to be nonrevertive..

Failure Condition	**A to B**			**A to C**			**Action**		
	Frame type	**Message ID**	**Status ID**	**Frame type**	**Message ID**	**Status ID**	**At Station A**	**At Station B**	**At Station C**
No failure	UPCF	No Request	Idle	UPCF	No Request	Idle			
SF in B to A	UPCF	SF	PS completed	BPCF	SF	PS completed	Selective Wrap, Steer relevant traffic	Selective Wrap, Steer relevant traffic, send BPCF towards C and UPCF towards A with same fields as the ones sent by A	Steer relevant traffic, stop sending UPCF
Failure clear WTR not expired	UPCF	WTR	PS completed	BPCF	WTR	PS completed	Selective Wrap, Steer relevant traffic	Selective Wrap, Steer relevant traffic, send BPCF towards C and UPCF towards A with same fields as the ones sent by A	Steer relevant traffic, stop sending UPCF
WTR expires	UPCF	No request	Idle	UPCF	No Request	Idle	Release Wrap	Release Wrap. Send Idle UPCF to A and C	Send Idle UPCF to A and B

The following table illustrates an example of a unidirectional SD followed by a SF:

Failure Condition	**A to B**			**A to C**			**Action**		
	Frame type	**Message ID**	**Status ID**	**Frame type**	**Message ID**	**Status ID**	**At Station A**	**At Station B**	**At Station C**
No failure	UPCF	No Request	Idle	UPCF	No Request	Idle			
SD in B to A	UPCF	SD	PS completed	BPCF	SD	PS completed	Selective Wrap B side, Steer relevant traffic	Selective Wrap A side, Steer relevant traffic, send BPCF towards C and UPCF towards A with same fields as the ones sent by A	Steer relevant traffic, stop sending UPCF
SF in B to C	BPCF from C	SF	PS completed	BPCF from B	SF	PS completed	Unwrap, Steer relevant traffic	Unwrap A side and wrap C side, Steer relevant traffic, send BPCF towards A and UPCF towards C with same fields as the ones sent by C	Selective Wrap B side, Steer relevant traffic, send BPCF towards A and UPCF towards B
SF clear WTR not expired	BPCF from C	WTR	PS completed	BPCF from B	WTR	PS completed			
WTR expires	UPCF	SD	PS completed	BPCF	SD	PS completed	Selective Wrap B side	Unwrap C side, Selective Wrap A side, send BPCF towards C and UPCF towards A with same fields as the ones sent by A	Unwrap B side