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GMPLS Requirements for MS-SPRing support

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Abstract

GMPLS [1] provides ideally a robust and flexible control plane protocols set designed for application over generalized transport network. A typical application of GMPLS is, among others, the control of transport networks based on SDH/SONET [2] technology. In this scenario, the introduction of GMPLS based control plane should ensure support of and/or compatibility with the most important and widely exploited SDH/SONET features, making possible a seamless interworking with inherent data plane requirements. In this document we focus on one of the most attractive SDH/SONET protection mechanism, implemented through MS-SPRing (G.841 [3]), a widely deployed ITU standard for ring-shared protection.

In general, when setting up and configuring a data plane circuit traversing a MS-SPRing ring (or segments of it) via traditional management plane control, special constraints, which are specific to this kind of technology, have to be considered in order to ensure its correct operation. The same constraints have to be carefully taken into account when the data plane circuit is no more set up in a traditional way, but through a GMPLS based control plane.
The specific constraints imposed by MS-SPRing are related to:

. Time Slot Interchange (TSI)
. Ring Map filling in case of squelching

In this document a brief overview of MS-SPRing operation is introduced and its specific requirements are explained, putting in evidence the way they may impact when GMPLS is used as control plane.

Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [4].

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1. MS-SPRing Bird Eye Overview

The main reference for this Section is ITU-T G.841. G.841 defines two different kinds of MS-SPRing namely two fibers and four fibers.

Two-fiber MS switched rings require only two fibers for each span of the ring. Each fiber carries both working channels and protection channels. On each fiber, up to half the channels are defined as working channels and up to half are defined as protection channels.

It is possible that some channels are not protected at all, being defined as Non-pre-emptible Unprotected Traffic (NUT) channels.
The traffic carried on working channels inside one fiber is protected by channels going in the opposite direction around the ring. This allows for a bi-directional transport of normal traffic and makes possible a sharing of the protection resources when needed.

The following picture illustrates the two fibers case, no NUT in this example.
WPx links are 50% for worker traffic and 50% for protection traffic, e.g. and STM-16 links have 8 AU-4 timeslot for worker traffic and 8 AU-4 timeslot for protection.

```
         TNE A                     TNE B                     TNE C
    +------------+            +------------+            +------------+
    |            |            |            |            |            |
    |            |            |            |            |            |
    |            |            |            |            |            |
    |            |----------->|            |----------->|            |
    |            |    WP1     |            |     WP2    |            |
    |            |<-----------|            |<-----------|            |
    |            |            |            |            |            |
    |            |            |            |            |            |
    |            |            |            |            |            |
    +------------+            +------------+            +------------+
      ^     |                                               ^     |
      |     |                                               |     |
      |     |                                               |     |
      | WP3 |             WP Links Resources are            | WP4 |
      |     |                50% Worker                     |     |
      |     |                50% Protection                 |     |
      |     v                                               |     v
    +------------+            +------------+            +------------+
    |            |            |            |            |            |
    |            |            |            |            |            |
    |            |            |            |            |            |
```

```
   |            |----------->|            |----------->|            |
```

```
 |            |    WP5     |            |    WP6     |            |
 |            |<-----------|            |<-----------|            |
 |            |            |            |            |            |
 |            |            |            |            |            |
 |            |            |            |            |            |
 +------------+            +------------+            +------------+
     TNE F                     TNE E                      TNE D
```

Figure 1-1: MS-SPRing two fibers reference circuit

Four-fiber MS shared protection rings require four fibers for each span of the ring. As illustrated in Figure 1-2, working and protection channels are carried over different fibers: two multiplex sections transmitting in opposite directions carry the working channels while two multiplex sections, also transmitting in opposite directions, carry the protection channels. This enables the bi-directional transport of normal traffic, sharing as well the protection capability.

The following picture illustrates the reference circuit (four fiber MS-SPRing) used in this Section.

```
      TNE A                     TNE B                     TNE C
 +------------+            +------------+            +------------+
 |            |            |            |            |            |
 |            |----------->|            |----------->|            |
 |            |     W1     |            |     W2     |            |
 |            |<-----------|            |<-----------|            |
 |            |            |            |            |            |
 |            |===========>|            |===========>|            |
 |            |     P1     |            |     P2     |            |
 |            |<===========|            |<===========|            |
 |            |            |            |            |            |
 +------------+            +------------+            +------------+
   ^  |  ^  l                                          ^  l  ^  |
   |  |  l  l                                          l  l  |  |
   |  |  l  l                                          l  l  |  |
   |W3|  lP3l       ------------ Working Link          lP4l  |W4|
   |  |  l  l       llll and === Protection Link       l  l  |  |
   |  |  l  l                                          l  l  |  |
   |  v  l  v                                          l  v  |  v
 +------------+            +------------+            +------------+
 |            |            |            |            |            |
 |            |===========>|            |===========>|            |
 |            |     P5     |            |     P6     |            |
 |            |<===========|            |<===========|            |
 |            |            |            |            |            |
 |            |----------->|            |----------->|            |
```

```
     |             |     W5     |            |     W6     |            |
```

```
  |            |<-----------|            |<-----------|            |
  |            |            |            |            |            |
  +------------+            +------------+            +------------+
       TNE F                    TNE E                      TNE D
```

Figure 1-2: Reference circuit for MS-SPRing, four fibers variant

1.1 Information needed by MS-SPRing

The MS-SPRing protection mechanism is implemented via a SDH signalling protocol known as Automatic Protection Switching (APS). This protocol makes use of SDH overhead bytes (K1 and K2, MS overhead bytes) as a means to transport its own information. APS is not detailed here as it is outside the scope of this document.

Each node on the ring shall be assigned an ID that is a number from 0 to 15, allowing a maximum of 16 nodes on the ring. Such ID value is not related to the position of corresponding node in the ring, i.e. the order of the nodes is not tied to nodes ID assignment.

Each node has a ring topology map that associates a nodeÆs ID with its address.

With respect to the Figures 1-1/2 the ring topology map is:

TNE-ID	TNE-Address
1	B
2	F
3	A
4	E
5	C
6	D

Table 1-1 Ring Topology map

The following tables represent the traffic matrix of the ring and the squelching (for definition of squelching please refer to Section 1.4) tables of the TNEs.

```
+-------------------------------------------------------------------+
|   AU    | <---- West               Nodes                East ---->|
| Number |  A          B           C         D        E        F     A|
+--------+----------------------------------------------------------+
|  1     |  <---------> <------------------->                        |
|  2     |  <------------------------------->                        |
|  3     |  <--------------------><------------------------->        |
+-------------------------------------------------------------------+
```

Table 1-2 Traffic Matrix

TNE-A					TNE-B				
AU	West		East		AU	West		East	
	Src	Dst	Src	Dst		Src	Dst	Src	Dst
1			A	B	1	B	A	B	D
2			A	D	2	D	A	A	D
3			A	C	3	C	A	C	F

TNE-C					TNE-D				
AU	West		East		AU	West		East	
	Src	Dst	Src	Dst		Src	Dst	Src	Dst
1	D	B	B	D	1	D	B	B	D
2	D	A	A	D	2	D	A	A	D
3	C	A	C	F	3	F	C	C	F

TNE-E					TNE-F				
AU	West		East		AU	West		East	
	Src	Dst	Src	Dst		Src	Dst	Src	Dst
1					1				
2					2				
3	F	C	C	F	3	F	C	C	F

Table 1-3 Squelching Table

When a node determines that a protection switch is required, it sources the appropriate bridge request using the APS protocol to the node at the far end of the affected MS (for more details on how APS carries that information please refer to G.841 [4]).

WeÆll call Ring Map the sum of the information contained in all the above Tables.

1.2 MS-SPRing Example

The worker circuit follows this path (4_fibers/2_fibers):

TNE-A <-Link W1/WP1-> TNE-B <-Link W2/WP2-> TNE-C <-Link W4/WP4->
TNE-D : AU Timeslot 1

In four fibers scenario failure of Links W2 and P2 triggers the MS-SPRing protection.

Traffic is protected using this path:

TNE-A <-Link W1-> TNE-B [Internal Bridge] <-Link P1-> TNE-A <-Link P3-> TNE F <-Link P5-> TNE-E <-Link P6-> TNE-D <-Link P4-> TNE-C [Internal Bridge] <- Link W4 -> TNE-D: AU Timeslot 1.

The following picture illustrates the state of the network after the recovery, by means of MS-SPRing, of the failure.

```
            1
     TNE A  v                  TNE B                      TNE C
 +----------|-+            +------------+            +------------+
 |          | |            |            |            |            |
 |          +------------->----->----+  |XXXXXXXXXXXX| +--------+ |
 |            |     W1     |         |  |     W2     | |        | |
 |            |<-----------|         |  |XXXXXXXXXXXX| |        | |
 |            |            |         v  |            | ^        v |
 |            |===========>|         |  |XXXXXXXXXXXX| |        | |
 |            |     P1     |         |  |     P2     | |        | |
 |          +--<===========-----<----+  |XXXXXXXXXXXX| |        | |
 |          | |            |            |            | |        | |
 +----------|-+            +------------+            +-|--------|-+
   ^  |  ^  l                                          ^  l  ^  |
   |  |  l  l                                          l  l  |  |
   |  |  l  l                                          l  l  |  |
   |W3|  lP3l       ------------ Working Link          lP4l  |W4|
   |  |  l  l       llll and === Protection Link       l  l  |  |
   |  |  l  l                                          l  l  |  |
   |  v  l  v                                          l  v  |  v
 +----------|-+            +------------+            +-|--------|-+
 |          | |            |            |            | |        | |
 |          +--===========>------->------===========>--+        | |
 |            |     P5     |            |     P6     |          | |
 |            |<===========|            |<===========|          | |
 |            |            |            |            |          v |
 |            |----------->|            |----------->|          | |
 |            |     W5     |            |     W6     |          | |
 |            |<-----------|            |<-----------|          | |
 |            |            |            |            |          | |
 +------------+            +------------+            +----------|-+
  TNE F                     TNE E                     TNE D     v
                                                                1
```

Figure 1-3: MS-SPRing four fibers ring-switching

The extra traffic in spans P1, P3, P4, P5 and P6 is affected.

Note that in this case working traffic passes the same section two times, i.e. link W1 and link P1, link P4 and link W4.
If these sections are very long, e.g. in trans-oceanic applications, the propagation delay is affected considerably and will result in a degradation of performance.
For trans-oceanic applications intermediate nodes, not adjacent to an affected section, will switch bridges as well.

Traffic is now protected using this path:

TNE-A [Internal Bridge] TNE-A <-Link P3-> TNE F <-Link P5-> TNE-E <-Link P6-> TNE-D [Internal Bridge] TNE-D: AU Timeslot 1.

The following picture illustrates the state of the network after the recovery, by means of trans-oceanic MS-SPRing, of the failure.

```
            1
     TNE A  v                  TNE B                      TNE C
 +----------|-+            +------------+            +------------+
 |          | |            |            |            |            |
 |          | |----------->|            |XXXXXXXXXXXX|            |
 |          | |     W1     |            |     W2     |            |
 |          | |<-----------|            |XXXXXXXXXXXX|            |
 |          v |            |            |            |            |
 |          | |===========>|            |XXXXXXXXXXXX|            |
 |          | |     P1     |            |     P2     |            |
 |          | |<===========|            |XXXXXXXXXXXX|            |
 |          | |            |            |            |            |
 +----------|-+            +------------+            +------------+
   ^  |  ^  l                                          ^  l  ^  |
   |  |  l  l                                          l  l  |  |
   |  |  l  l                                          l  l  |  |
   |W3|  lP3l      ------------ Working Link            lP4l  |W4|
   |  |  l  l      llll and === Protection Link        l  l  |  |
   |  |  l  l                                          l  l  |  |
   |  v  l  v                                          l  v  |  v
 +----------|-+            +------------+            +------------+
 |          | |            |            |            |            |
 |          +--===========>------->-----===========>------>----+ |
 |            |     P5     |            |     P6     |          | |
 |            |<===========|            |<===========|          | |
 |            |            |            |            |          v |
 |            |----------->|            |----------->|          | |
 |            |     W5     |            |     W6     |          | |
 |            |<-----------|            |<-----------|          | |
 |            |            |            |            |          | |
```

```
    +------------+              +------------+              +----------|-+
```

```
  TNE F                     TNE E                     TNE D     v
                                                                1
```

Figure 1-4: MS-SPRing four fibers trans-oceanic ring-switching

Only the extra traffic in spans P3, P5 and P6 is affected.

Instead of bridging all working traffic to the protections channels in the nodes adjacent to the failure in trans-oceanic ring-switching the individual AU tributaries are switched in their ingress and egress nodes using ring maps and APS information. Due to the transfer and evaluation of the information more time is required for the protection switch to complete, the objective is 300 ms or less. Because tributaries are switched in their ingress and egress nodes no squelching is required and protection channels not required for protection may carry pre-empted extra traffic.
A mechanism is required to auto-provision the ring maps and maintain their consistency.

In two fibers scenario failure of Links W2 and P2 triggers the MS-SPRing protection.

Traffic is protected using this path:

TNE-A <-Link WP1-> TNE-B [Internal Bridge] <-Link WP1-> TNE-A <-Link WP3-> TNE F <-Link WP5-> TNE-E <-Link WP6-> TNE-D <-Link WP4-> TNE-C [Internal Bridge] <- Link WP4 -> TNE-D: AU Timeslot 1 is used on all the links.

The following picture illustrates the state of the network after the recovery from the failure done by means of MS-SPRing mechanism.

```
            |
   TNE A    v                    TNE B                     TNE C
 +------------+            +------------+            +------------+
 |          | |            |            |            |            |
 |          | |            |            |            |            |
 |          | |            |            |            |            |
 |          +-|----------->|------+     |xxxxxxxxxxx>|   +-----+  |
 |            |   WP1      |      |     |    WP2     |   |     |  |
 |       +----|<-----------|------+     |<-----------|   ^     v  |
 |       |    |            |            |            |   |     |  |
 |       |    |            |            |            |   |     |  |
 |       |    |            |            |            |   |     |  |
 +------------+            +------------+            +------------+
   ^     |                                               ^     |
   |     |                                               |     |
   |     |                                               |     |
   | WP3 |             WP Links Resources are            | WP4 |
```

```
   |     |                50% Worker                     |     |
   |     |                50% Protection                 |     |
   |     v                                               |     v
 +------------+            +------------+            +------------+
 |       |    |            |            |            |   |     |  |
 |       |    |            |            |            |   |     |  |
 |       |    |            |            |            |   |     |  |
 |       +----|----------->|------------|----------->|---+     |  |
 |            |    WP5     |            |    WP6     |         |  |
 |            |<-----------|            |<-----------|         |  |
 |            |            |            |            |         |  |
 |            |            |            |            |         |  |
 |            |            |            |            |         |  |
 +------------+            +------------+            +------------+
     TNE F                     TNE E                    TNE D  v
```

Figure 1-5: MS-SPRing two fibers ring-switching

Figure 1-3 and 1-5 illustrates the so-called ôring-switchingö protection.

In four-fiber MS-SPRing there exists also ôspan-switchingö and in this case only the working fibers are cut while the protection fibers remain intact. See figure 1-6. The protection switch affects the extra traffic in span P2.

```
            1
     TNE A  v                   TNE B                     TNE C
 +----------|-+            +------------+            +------------+
 |          | |            |            |            |            |
 |          +------------->----->----+  |XXXXXXXXXXXX| +--------+ |
 |            |     W1     |         |  |     W2     | |        | |
 |            |<-----------|         v  |XXXXXXXXXXXX| ^        | |
 |            |            |         |  |            | |        | |
 |            |===========>|         +---===========>--+        v |
 |            |     P1     |            |     P2     |          | |
 |            |<===========|            |<===========|          | |
 |            |            |            |            |          | |
 +------------+            +------------+            +----------|-+
   ^  |  ^  l                                          ^  l  ^  |
   |  |  l  l                                          l  l  |  |
   |  |  l  l                                          l  l  |  |
   |W3|  lP3l       ------------ Working Link          lP4l  |W4|
   |  |  l  l       llll and === Protection Link       l  l  |  |
   |  |  l  l                                          l  l  |  |
   |  v  l  v                                          l  v  |  v
 +------------+            +------------+            +----------|-+
 |            |            |            |            |          | |
```

```
     |             |===========>|            |===========>|          | |
```

```
       |            |     P5     |            |     P6     |          | |
       |            |<===========|            |<===========|          | |
       |            |            |            |            |          v |
       |            |----------->|            |----------->|          | |
       |            |     W5     |            |     W6     |          | |
       |            |<-----------|            |<-----------|          | |
       |            |            |            |            |          | |
       +------------+            +------------+            +----------|-+
          TNE F                     TNE E                     TNE D   v
                                                                      1
```

Figure 1-6: MS-SPRing span-switch

1.3 Time Slot Interchange (TSI)

TSI is the connection function capability of changing the time slot position of through-connected traffic (i.e. traffic that is not added or dropped from the node). At present there is no TSI capability specified in nodes belonging to a MS-SPRing sub network. Channels at MS-SPRing nodeÆs egress are nailed to the same timeslot used by the same channels at nodeÆs ingress. This is a currently required condition to ensure MS-SPRing correct operation.

1.4 Squelching

Squelching is defined as the process of inserting AU-AIS in order to prevent misconnections. The squelching process application over traffic results in an ôall 1Æsö signal.

1.4.1 Squelching to avoid misconnected traffic

To perform a ring switch, the protection channels are essentially shared among each span of the ring. Also, extra traffic may reside in the protection channels when the protection channels are not currently being used to restore normal traffic transported on the working channels. Thus, each protection channel time slot is subject to use by multiple services (services from the same time slot but on different spans, and service from extra traffic). With no extra traffic on the ring, under certain multiple point failures, such as those that cause node(s) isolation, services (from the same time slot but on different spans) may contend for access to the same protection channel time slot. This yields a potential for misconnected traffic. With extra traffic on the ring, even under single point failures, normal traffic on the working channels may contend for access to the same protection channel time slot that carries the extra traffic. This also yields a potential for misconnected traffic.

Without a mechanism to prevent misconnection, the following failure scenario would yield misconnections.

Referring to Figure 1-1, two circuits traverse the MS-SPRing namely circuit Q and R the path that they traverse is:

Circuit R: TNE-A <-Link WP3 AU 1-> TNE-F
Circuit Q: TNE-A <-Link WP1 AU 1-> TNE-B <-Link WP2 AU 1-> TNE-C

Suppose a cut in both the spans between nodes A and F and between nodes A and B (isolating node A, that is the same as a TNE A failure) causes circuits Q and R to attempt to access time slot #1P on the protection channels. The mechanism for the MS-SPRing protection is as depicted in previous sub-section.

A potential misconnection is determined by identifying the nodes that will act as the switching nodes for a bridge request, and by examining the traffic that will be affected by the switch. The switching nodes can be determined from the node addresses in the K1 and K2 bytes. The switching nodes determine the traffic affected by the protection switch from the information contained in their ring maps and from the identifications of the switching nodes. Potential misconnections shall be squelched by inserting the appropriate AU-AIS in those time slots where misconnected traffic could occur. Specifically, the traffic that is sourced or dropped at the node(s) isolated from the ring by the failure shall be squelched. For rings operating at an AU-4 level, this squelching occurs at the switching nodes. AU level squelching occurs for the normal or extra traffic into or out of the protection channels (i.e. normal traffic into or out of working channels is never squelched).

For example, consider a segment of a ring consisting of three nodes, A, B, and C where B has failed. In a typical scenario, both A and C will send bridge requests destined for B. When A sees the bridge request from C, and sees that B is between A and C (from the node map) it can deduce that B is isolated from the ring. A and C will use their respective maps to find out which channels are added or dropped by B. A and C will squelch these channels before the ring switch is performed by inserting AU-AIS. Thus, any node on the ring that was connected to B will now receive AIS on those channels.

Each of the ring maps, then, shall contain at minimum:

1. a ring map that contains information regarding the order in which the nodes appear on the ring;
2. a cross-connect map that contains the AU-4 time-slot assignments for traffic that is both terminated at that node and passed-through that node;
3. a squelch table that contains, for each of these AU-4 time slots, the node addresses at which the traffic enters and exits the ring; and

4. an optional indication of whether the AU is being accessed at the lower order VC level somewhere on the ring (not covered by this Document)

An example of such ring maps and squelching table is given in Section 1.1.

2. GMPLS requirements imposed by MS-SPRing

When setting up (either via traditional management plane actions or via GMPLS control plane protocols) a data plane circuit going across parts of the network that include MS-SPRing based protection mechanism, it MUST be done according to MS-SPRing specific needs as explained in previous sections.

2.1 LSP Set-Up

When GMPLS is used for circuit setup, the presence of MS-SPRing rings in the network results in a set of requirements that have to be handled at control plane level.
Basically when setting up an LSP over a data plane that includes TNEs connected in MS-SPRing scheme, the control plane taking care of routing and signaling of such LSP has to behave in a way that

1. the label(corresponding to a SDH/SONET timeslot) must not be changed within the MS-SPRing ring traversed;
2. involved TNE MUST have all the information necessary to fill the Ring Map.

From the NMS point of view it is important to be able to univocally identify a ring in the network, this leads to the Ring Identifier (RingId) concept. Even if the RingId is not needed for the MS-SPRing operation it is needed for management issues.
Given the above there is the requirement to add the RingId information to the information stored when an LSP traverses a node that is part of a MS-SPRing.

The above requirements can be satisfied either via signaling only or signaling plus routing.

2.2 Data Plane and Control Plane misalignment

When a failure affects an LSP that traverse an MS-SPRing protected ring the data plane scenario is the same as in Figure 1-3.

Data Traffic is flowing through:
Node-A<-->Node-B<-->Node-A<-->Node-F<-->Node-E<-->Node-D<-->Node-C<-->Node-D while from a control plane perspective traffic is still flowing through Node-A<-->Node-B<-->Node-C<-->Node-D.
It may be noted that the loop Node-A<-->Node-B<-->Node-A can be

bridged and releases the protection channels for use by extra traffic thus increasing the availability of extra traffic, however this requires an update to the Ring map.

The misalignment between control and data plane arises because the control plane is un-aware of the failure.

In this case there is the need for a control plane data plane re-alignment.

When, without the intervention of the control plane, inherent protection scheme changes some characteristic of an LSP there should be a communication mechanism that re-aligns control plane and data plane information.

2.3 Interworking between GMPLS restoration and MS-SPRing Protection

A hold-off timer e.g. 50 ms should be provided in order to allow MS-SPRing protection to react firstly to a failure.

In case of failures unrecoverable by MS-SPRing the hold-off elapse triggering the control plane recovery mechanism, of course in order to recover the traffic control plane and data plane must be aligned, see above Section about control plane and data plane misalignment.

3. Security Considerations

This document does not introduce any additional Security issues.

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