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Pre-standard Linear Protection Switching in MPLS-TP
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Abstract

The IETF Standards Track solution for MPLS Transport Profile (MPLS-TP) Linear Protection is provided in RFC 6378, draft-ietf-mpls-psc-updates and draft-ietf-mpls-tp-psc-itu.

This document describes the pre-standard implementation of MPLS-TP Linear Protection that has been deployed by several network operators using equipment from multiple vendors. At the time of publication these pre-standard implementations were still in operation carrying live traffic.

The specified mechanism supports 1+1 unidirectional/bidirectional protection switching and 1:1 bidirectional protection switching. It is purely supported by MPLS-TP data plane, and can work without any control plane.

[Editor's note] The followings are to be included in "Status of Memo":

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Status of This Memo

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1. Introduction

The IETF Standards Track solution for MPLS Transport Profile (MPLS-TP) Linear Protection is provided in RFC 6378 [RFC6378], draft-ietf-mpls-psc-updates [I-D.ietf-mpls-psc-updates] and draft-ietf-mpls-tp-psc-itu [I-D.ietf-mpls-tp-psc-itu].

This document describes the pre-standard implementation of MPLS-TP Linear Protection that has been deployed by several network operators using equipment from multiple vendors. At the time of publication these pre-standard implementations were still in operation carrying live traffic.

This implementation was considered in the MPLS WG, however a different path was chosen.

This document might be useful in the future if a vendor is trying to interwork with a different vendor who has deployed the pre-standard implementation. It is also worth noting that the experience gained during deployment of the implementations of this document is used to refine draft-ietf-mpls-tp-psc-itu.

MPLS-TP is defined as transport profile of MPLS technology to fulfill the deployment in transport network. A typical feature of transport network is that it can provide fast protection switching for end-to-end or segments. The protection switching time is generally required to be less than 50ms according to the strict requirement of services such as voice, private line, etc.

The goal of linear protection switching mechanism is to satisfy the requirement of fast protection switching for MPLS-TP network. Linear protection switching means that, for one or more working transport entities (working paths), there is one protection transport entity (protection path), which is disjoint from any of working transport entities, ready for taking over the service transmission when a working transport entity failed.

This document specifies 1+1 unidirectional protection switching mechanism for unidirectional transport entity (either point-to-point or point-to-multipoint) as well as bidirectional point-to-point transport entity, and 1+1/1:1 bidirectional protection switching mechanism for point-to-point bidirectional transport entity. Since bidirectional protection switching needs the coordination of the two endpoints of the transport entity, this document also specifies Automatic Protection Switching (APS) protocol details which is used for this purpose.

The linear protection mechanism described in this document is applicable to both Label Switched Paths (LSPs) and Pseudowires (PWs).

The APS protocol specified in this document is based on the same principles and behavior of the APS protocol designed for Synchronous Optical Network (SONET)/Synchronous Digital Hierarchy (SDH) networks (i.e., it is mature and proven) and provides commonality with the established operation models utilized in other transport network technologies (e.g., SDH/SONET and Optical Transport Network (OTN)).

2. 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 [RFC2119].

3. Acronyms

This document uses the following acronyms:

APS	Automatic Protection Switching
DNR	Do not Revert
EXER	Exercise
G-ACh	Generic Associated Channel
FS	Forced Switch
LO	Lockout of Protection
LSP	Label Switched Path
MPLS-TP	MPLS Transport Profile
MS	Manual Switch
MS-P	Manual Switch to Protection transport entity
MS-W	Manual Switch to Working transport entity
NR	No Request
OAM	Operations, Administration, and Maintenance
OTN	Optical Transport Network
PDU	Protocol Data Unit
PW	Pseudowire
RR	Reverse Request
SD	Signal Degrade
SD-P	Signal Degrade on Protection transport entity
SD-W	Signal Degrade on Working transport entity
SDH	Synchronous Digital Hierarchy
SF	Signal Fail
SF-P	Signal Fail on Protection transport entity
SF-W	Signal Fail on Working transport entity
SONET	Synchronous Optical Network
WTR	Wait to Restore

4. Linear protection switching overview

To guarantee the protection switching time, for a working transport entity, its protection transport entity is always pre-configured before the failure occurs. Normally, the normal traffic will be transmitted and received on the working transport entity. The switching to protection transport entity is usually triggered by link /node failure, external commands, etc. Note that external commands are often used in transport network by operators, and they are very useful in cases of service adjustment, path maintenance, etc.

4.1. Protection architecture types

4.1.1. 1+1 architecture

In the 1+1 architecture, the protection transport entity is associated with a working transport entity. The normal traffic is permanently bridged onto both the working transport entity and the protection transport entity at the source endpoint of the protected domain. The normal traffic on working and protection transport entities is transmitted simultaneously to the sink endpoint of the protected domain where a selection between the working and protection transport entity is made, based on predetermined criteria, such as signal fail and signal degrade indications.

4.1.2. 1:1 architecture

In the 1:1 architecture, the protection transport entity is associated with a working transport entity. When the working transport entity is determined to be impaired, the normal traffic MUST be transferred from the working to the protection transport entity at both the source and sink endpoints of the protected domain. The selection between the working and protection transport entities is made based on predetermined criteria, such as signal fail and signal degrade indications from the working or protection transport entity.

The bridge at source endpoint can be realized in two ways: it is either a selector bridge or a broadcast bridge. With a selector bridge the normal traffic is connected either to the working transport entity or the protection transport entity. With a broadcast bridge the normal traffic is permanently connected to the working transport entity, and in case a protection switch is active also to the protection transport entity. Broadcast bridge is recommended to be used in revertive mode only.

4.1.3. 1:n architecture

Details for the 1:n protection switching architecture are out of scope of this document and will be provided in a different document in the future.

It is worth noting that the APS protocol defined here is ready to support 1:n operations.

4.2. Protection switching type

The linear protection switching types can be a unidirectional switching type or a bidirectional switching type.

- o Unidirectional switching type: Only the affected direction of working transport entity is switched to protection transport entity; the selectors at each endpoint operate independently. This switching type is recommended to be used for 1+1 protection in this document.

- o Bidirectional switching type: Both directions of working transport entity, including the affected direction and the unaffected direction, are switched to protection transport entity. For bidirectional switching, APS protocol is required to coordinate the two endpoints so that both have the same bridge and selector settings, even for a unidirectional failure. This type is applicable for 1+1 and 1:1 protection.

4.3. Protection operation type

The linear protection operation types can be a non-revertive operation type or a revertive operation type.

- o Non-revertive operation: The normal traffic will not be switched back to the working transport entity even after a protection switching cause has cleared. This is generally accomplished by replacing the previous switch request with a "Do not Revert (DNR)" request, which has a low priority.

- o Revertive operation: The normal traffic is restored to the working transport entity after the condition(s) causing the protection switching has cleared. In the case of clearing a command (e.g., Forced Switch), this happens immediately. In the case of clearing of a defect, this generally happens after the expiry of a "Wait to Restore (WTR)" timer, which is used to avoid chattering of selectors in the case of intermittent defects.

5. Protection switching trigger conditions

5.1. Fault conditions

Fault conditions mean the requests generated by the local Operations, Administration, and Maintenance (OAM) function.

- o Signal Failure (SF): If an endpoint detects a failure by OAM function or other mechanism, it will submit a local signal failure (local SF) to APS module to request a protection switching. The local SF could be on working transport entity (Signal Fail on Working transport entity (SF-W)) or protection transport entity (Signal Fail on Protection transport entity (SF-P)).

- o Signal Degrade (SD): If an endpoint detects signal degrade by OAM function or other mechanism, it will submit a local signal degrade (local SD) to APS module to request a protection switching. The local SD could be on working transport entity (Signal Degrade on Working transport entity (SD-W)) or protection transport entity (Signal Degrade on Protection transport entity (SD-P)).

5.2. External commands

The external command issues an appropriate external request on to the protection process.

5.2.1. End-to-end commands

These commands are applied to both local and remote nodes. When the APS protocol is present, these commands except Clear command are signaled to the far end of the connection. In bidirectional switching, these commands affect the bridge and selector at both ends.

- o Lockout of Protection (LO): This command is used to provide operator a tool for temporarily disabling access to the protection transport entity.

- o Manual switch (MS): This command is used to provide operator a tool for temporarily switching normal traffic to working transport entity (Manual Switch to Working transport entity (MS-W)) or protection transport entity (Manual Switch to Protection transport entity (MS-P)), unless a higher priority switch request (i.e., LO, FS, or SF) is in effect.

- o Forced switch (FS): This command is used to provide operator a tool for temporarily switching normal traffic from working transport entity to protection transport entity, unless a higher priority switch request (i.e., LO or SF-P is in effect.

- o Exercise (EXER): Exercise is a command to test if the APS communication is operating correctly. The EXER command SHALL NOT affect the state of the protection selector and bridge.

- o Clear: This command between management and local protection process is not a request sent by APS to other endpoints. It is used to clear the active near end external command or WTR state.

5.2.2. Local commands

These commands apply only to the near end (local node) of the protection group. Even when an APS protocol is supported, they are not signalled to the far end.

- Freeze: This command freezes the state of the protection group. Until the freeze is cleared, additional near end commands are rejected and condition changes and received APS information are ignored. When the Freeze command is cleared, the state of the protection group is recomputed based on the condition and received APS information.

  Because the freeze is local, if the freeze is issued at one end only, a failure of protocol can occur as the other end is open to accept any operator command or a fault condition.

- Clear Freeze: This command clears the local freeze.

6. Protection switching schemes

6.1. 1+1 unidirectional protection switching

```
     +-----------+                                       +-----------+
     |           |---------------------------------------|           |
     |          -+---------------------------------------+-          |
     |         / |---------------------------------------| \         |
     |        /  |       Working transport entity        |  \        |
   --+------->   |                                       |   --------+->
     |        \  |                                       |           |
     |         \ |---------------------------------------|           |
     |          -+---------------------------------------|           |
     |  source   |---------------------------------------|    sink   |
     +-----------+       Protection transport entity     +-----------+
                            (normal condition)

     +-----------+                                       +-----------+
     |           |---------------------------------------|           |
     |          -+------------------XX-------------------+           |
     |         / |---------------------------------------|           |
     |        /  |   Working transport entity (failure)  |           |
   --|------->   |                                       |   --------+->
     |        \  |                                       |  /        |
     |         \ |---------------------------------------| /         |
     |          -+---------------------------------------+-          |
     |  source   |---------------------------------------|    sink   |
     +-----------+     Protection transport entity       +-----------+
                           (failure condition)
```

         Figure 1: 1+1 unidirectional linear protection switching

1+1 unidirectional protection switching is the simplest protection switching mechanism. The normal traffic is permanently bridged on both the working and protection transport entities at the source endpoint of the protected domain. In normal condition, the sink endpoint receives traffic from the working transport entity. If the sink endpoint detects a failure on the working transport entity, it will switch to receive traffic from the protection transport entity. 1+1 unidirectional protection switching is recommended to be used for unidirectional transport entity.

Note that 1+1 unidirectional protection switching does not need APS coordination protocol since it only perform protection switching based on the local request.

6.2. 1+1 bidirectional protection switching

```
     +-----------+                                       +-----------+
     |           |---------------------------------------|           |
     |          -+<--------------------------------------+-          |
     |         / +-------------------------------------->+ \         |
     | sink   / /|---------------------------------------|\ \   sink |
   <-+-------/ / |        working transport entity       | --\-------+->
   --+-------->  |                                       |    <------+--
     | source  \ |                                       |   / Source|
     |          \|---------------------------------------|  /        |
     |           +-------------------------------------->| /         |
     |           |<--------------------------------------+-          |
     | APS <...................................................> APS |
     |           |---------------------------------------+           |
     +-----------+      Protection transport entity      +-----------+
                            (normal condition)

     +-----------+                                       +-----------+
     |           |---------------------------------------|           |
     |           +<----------------XX--------------------+-          |
     |           +-------------------------------------->+ \         |
     |          /|---------------------------------------|  \        |
     | source  / |   working transport entity (failure)  |   \ source|
   --+-------->  |                                       |    \<-----+--
   <-+-------  \ |                                       |  --/------+->
     | sink  \  \|---------------------------------------| / /  sink |
     |        \  +-------------------------------------->+- /        |
     |         --+<--------------------------------------+-/         |
     | APS <...................................................> APS |
     |           |---------------------------------------+           |
     +-----------+      Protection transport entity      +-----------+
                             (failure condition)
```

Figure 2: 1+1 bidirectional linear protection switching

In 1+1 bidirectional protection switching, for each direction, the normal traffic is permanently bridged on both the working and protection transport entities at the source endpoint of the protected domain. In normal condition, for each direction, the sink endpoint receives traffic from the working transport entity.

If the sink endpoint detects a failure on the working transport entity, it will switch to receive traffic from the protection transport entity. It will also send an APS message to inform the sink endpoint on another direction to switch to receive traffic from the protection transport entity.

APS mechanism is necessary to coordinate the two endpoints of transport entity and implement 1+1 bidirectional protection switching even for a unidirectional failure.

6.3. 1:1 bidirectional protection switching

```
     +-----------+                                       +-----------+
     |           |---------------------------------------|           |
     |          -+<--------------------------------------+-          |
     |         / +-------------------------------------->+ \         |
     | sink   / /|---------------------------------------|\ \  source|
   <-+-------/ / |        working transport entity       | \ <-------+--
   --+-------->  |                                       |  ---------+->
     | source    |                                       |      sink |
     |           |---------------------------------------|           |
     |           |                                       |           |
     |           |                                       |           |
     | APS <...................................................> APS |
     |           |---------------------------------------|           |
     +-----------+      Protection transport entity      +-----------+
                           (normal condition)

     +-----------+                                       +-----------+
     |           |---------------------------------------|           |
     |           |                 \/                    |           |
     |           |                 /\                    |           |
     |           |---------------------------------------|           |
     | source    |   working transport entity (failure)  |      sink |
   --+------->   |                                       |   --------+->
   <-+------- \  |                                       |  / <------+--
     | sink  \ \ |---------------------------------------| / / source|
     |        \ -+-------------------------------------->+- /        |
     |         --+<--------------------------------------+--         |
     | APS <...................................................> APS |
     |           |---------------------------------------+           |
     +-----------+      Protection transport entity      +-----------+
                           (failure condition)
```

Figure 3: 1:1 bidirectional linear protection switching

In 1:1 bidirectional protection switching, for each direction, the source endpoint sends traffic on either the working transport entity or the protection transport entity. The sink endpoint receives the traffic from the transport entity where the source endpoint sends on.

In normal condition, for each direction, the source endpoint and sink endpoint send and receive traffic from the working transport entity.

If the sink endpoint detects a failure on the working transport entity, it will switch to send and receive traffic from the protection transport entity. It will also send an APS message to inform the sink endpoint on another direction to switch to send and receive traffic from the protection transport entity.

APS mechanism is necessary to coordinate the two endpoints of transport entity and implement 1:1 bidirectional protection switching even for a unidirectional failure.

7. APS protocol

7.1. APS PDU format

APS packets MUST be sent over a Generic Associated Channel (G-ACh) as defined in RFC 5586 [RFC5586].

The format of APS Protocol Data Unit (PDU) is specified in Figure 4 below.

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |0 0 0 1|0 0 0 0|0 0 0 0 0 0 0 0|     Channel Type (=0x7FFA)    |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | MEL | Version |    OpCode     |     Flags     |   TLV Offset  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                  APS Specific Information                     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |    End TLV    |
 +-+-+-+-+-+-+-+-+
```

Figure 4: APS PDU format

The following values MUST be used for APS PDU:

o Channel Type: The Channel Type MUST be configurable. During deployment the local system administrator provisioned the value 0x7FFA. This is a code point value in the range of experimental Channel Types as described in RFC 5586 section 10.

o MEL: The MEL value to set and check MUST be configurable. The DEFAULT value MUST be "111". With co-routed bidirectional transport paths, the configured MEL MUST be the same in both directions.

o Version: 0x00

o OpCode: 0x27 (=0d39)

o Flags: 0x00

o TLV Offset: 4

o End TLV: 0x00

The format of the APS-specific information is defined in Figure 5

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Request|Pr.Type|   Requested   |   Bridged     | |             |
|   /   |-+-+-+-|               |               |T|  Reserved(0)|
| State |A|B|D|R|    Signal     |    Signal     | |             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: APS specific information format

All bits defined as "Reserved" MUST be transmitted as 0 and ignored on reception.

o Request/State:

   The 4 bits indicate the protection switching request type. See Figure 6 for the code of each request/state type.

   In case that there are multiple protection switching requests, only the protection switching request with the highest priority MUST be processed.

Request/State	code/priority
Lockout of Protection (LO)	1111 (highest)
Signal Fail on Protection (SF-P)	1110
Forced Switch (FS)	1101
Signal Fail on Working (SF-W)	1011
Signal Degrade (SD)	1001
Manual Switch (MS)	0111
Wait to Restore (WTR)	0101
Exercise (EXER)	0100
Reverse Request (RR)	0010
Do Not Revert (DNR)	0001
No Request (NR)	0000 (lowest)

Figure 6: Protection switching request code/priority

o Protection type (Pr.Type):

   The 4 bits are used to specify the protection type.

   A: reserved (set by default to 1)
   B: 0 - 1+1 (permanent bridge)
   1 - 1:1 (no permanent bridge)
   D: 0 - Unidirectional switching
   1 - Bidirectional switching
   R: 0 - Non-revertive operation
   1 - Revertive operation

o Requested Signal:

   This byte is used to indicate the traffic that the near end requests to be carried over the protection entity.

   value = 0: Null traffic
   value = 1: Normal traffic 1
   value = 2˜255: Reserved

o Bridged Signal:

This byte is used to indicate the traffic that is bridged onto the protection entity.

value = 0: Null traffic
value = 1: Normal traffic 1
value = 2~255: Reserved

o Bridge Type (T):

This bit is used to further specify the type of non-permanent bridge for 1:1 protection switching.

value = 0: Selector bridge
value = 1: Broadcast bridge

o Reserved:

This field MUST be set to zero.

7.2. APS transmission

The APS message MUST be transported on protection transport entity by encapsulated with the protection transport entity label. If an endpoint receives APS-specific information from the working transport entity, it MUST ignore this information, and MUST report the Failure of Protocol defect (see Section 8.1) to the operator.

A new APS packet MUST be transmitted immediately when a change in the transmitted status occurs. The first three APS packets MUST be transmitted as fast as possible only if the APS information to be transmitted has been changed so that fast protection switching is possible even if one or two APS packets are lost or corrupted. The interval of the first three APS packets SHOULD be 3.3ms. APS packets after the first three MUST be transmitted with the interval of 5 seconds.

If no valid APS-specific information is received, the last valid received information remains applicable.

7.3. Hold-off timer

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

Each selector SHOULD have a provisioned hold-off timer. The suggested range of the hold-off timer is 0 to 10 seconds in steps of 100 ms (accuracy of +/-5 ms).

When a new defect or more severe defect occurs (new SF or SD) on the active transport entity (the transport entity that currently carries and selects traffic), this event will not be reported immediately to protection switching if the provisioned hold-off timer value is non-zero. Instead, the hold-off timer SHALL be started. When the hold-off timer expires, it SHALL be checked whether a defect still exists on the transport entity that started the timer. If it does, that defect SHALL be reported to protection switching. The defect need not be the same one that started the timer.

This hold-off timer mechanism SHALL be applied for both working and protection transport entities.

7.4. WTR timer

In revertive mode of operation, to prevent frequent operation of the protection switch due to an intermittent defect, a failed working transport entity MUST become fault-free. After the failed working transport entity meets this criterion, a fixed period of time SHALL elapse before a normal traffic signal uses it again. This period, called a WTR period, MAY be configured by the operator in 1 minute steps between 5 and 12 minutes; the default value is 5 minutes. An SF or SD condition will override the WTR. To activate the WTR timer appropriately, even when both ends concurrently detect clearance of SF-W and SD-W, when the local state transits from SF-W or SD-W to No Request (NR) with the requested signal number 1, the previous local state, SF-W or SD-W, MUST be memorized. If both the local state and far-end state are NR with the requested signal number 1, the local state transits to WTR only when the previous local state is SF-W or SD-W. Otherwise, the local state transits to NR with the requested signal number 0.

In revertive mode of operation, when the protection is no longer requested, i.e., the failed working transport entity is no longer in SF or SD condition (and assuming no other requesting transport entities), a local WTR state will be activated. Since this state becomes the highest in priority, it is indicated on the APS signal, and maintains the normal traffic signal from the previously failed working transport entity on the protection transport entity. This state SHALL normally time out and become a NR state. The WTR timer deactivates earlier when any request of higher priority request pre-empts this state.

7.5. Command acceptance and retention

The commands Clear, LO, FS, MS, and EXER are accepted or rejected in the context of previous commands, the condition of the working and protection entities in the protection group, and (in bidirectional switching only) the APS information received.

The Clear command MUST be only valid if a near end LO, FS, MS, or EXER command is in effect, or if a WTR state is present at the near end and rejected otherwise. This command will remove the near-end command or WTR state, allowing the next lower-priority condition or (in bidirectional switching) APS request to be asserted.

Other commands MUST be rejected unless they are higher priority than the previously existing command, condition, or (in bidirectional switching) APS request. If a new command is accepted, any previous, lower-priority command that is overridden MUST be forgotten. If a higher priority command overrides a lower-priority condition or (in bidirectional switching) APS request, that other request will be reasserted if it still exists at the time the command is cleared. If a command is overridden by a condition or (in bidirectional switching) APS request, that command MUST be forgotten.

7.6. Exercise operation

Exercise is a command to test if the APS communication is operating correctly. It is lower priority than any "real" switch request. It is only valid in bidirectional switching, since this is the only place where you can get a meaningful test by looking for a response.

The Exercise command SHALL issue the command with the same requested and bridged signal numbers of the NR, Reverse Request (RR) or DNR request that it replaces. The valid response will be an RR with the corresponding requested and bridged signal numbers. When Exercise commands are input at both ends, an EXER, instead of RR, MUST be transmitted from both ends. The standard response to DNR MUST be DNR rather than NR. When the exercise command is cleared, it MUST be replaced with NR or RR if the requested signal number is 0, and DNR or RR if the requested signal number is 1.

8. Protection switching logic

8.1. Principle of operation

```
                +-------------+ Persistent +----------+
    SF,SD       | Hold-off    | fault      | Local    |
    ----------->| timer logic |----------->| request  |
                +-------------+            | logic    |
    Other local requests ----------------->|          |
    (LO, FS, MS, EXER, Clear)              +----------+
                                               |
                                               | Highest
                                               | local request
                                               |
    Remote APS                                 V
    Message       +-------+ Remote APS    +----------------+
    ------------->|  APS  | request/state |  APS process   |
    (received     | check |-------------->|  logic         |
    from far end) +-------+               +----------------+
                    |   ^                   |            |
                    |   |                   | Signaled   |
                    |   |                   | APS        |
                    |   | Txed              |            |
                    |   | "Requested        V            |
                    |   | Signal"         +-----------+  |
                    |   +-----------------| APS mess. |  |
                    |                     | generator |  |
                    |                     +-----------+  |
                    |                       |            |
                    V                       |            |
                Failure of                  V            |
                Protocol                  APS Message    |
                Detection                                V
                                                    Set local
                                                    bridge/selector
```

Figure 7: Protection Switching Logic

Figure 7 describes the protection switching logic.

One or more local protection switching requests may be active. The "local request logic" determines which of these requests is highest using the order of priority given in Figure 6. This highest local request information SHALL be passed on to the "APS process logic". Note that an accepted Clear command, clearance of SF or SD or expiration of WTR timer SHALL NOT be processed by the local request logic, but SHALL be considered as the highest local request and submitted to the APS process logic for processing.

The remote APS message is received from the far end and is subjected to the validity check and mismatch detection in "APS check". Failure of Protocol situations are as follows:

o The "B" field mismatch due to incompatible provisioning;

o The reception of APS message from the working entity due to working/protection configuration mismatch;

o No match in sent "Requested Signal" and received "Requested Signal" for more than 50 ms;

o No APS message is received on the protection transport entity during at least 3.5 times the long APS interval (e.g. at least 17.5 seconds) and there is no defect on the protection transport entity.

Provided the "B" field matches:

o If "D" bit mismatches, the bidirectional side will fall back to unidirectional switching.

o If the "R" bit mismatches, one side will clear switches to WTR and the other will clear to DNR. The two sides will interwork and the traffic is protected.

o If the "T" bit mismatches, the side using a broadcast bridge will fall back to using a selector bridge.

The APS message with invalid information MUST be ignored, and the last valid received information remains applicable.

The linear protection switching algorithm SHALL commence immediately every time one of the input signals changes, i.e., when the status of any local request changes, or when a different APS specific information is received from the far end. The consequent actions of the algorithm are also initiated immediately, i.e., change the local bridge/selector position (if necessary), transmit a new APS specific information (if necessary), or detect the failure of protocol defect if the protection switching is not completed within 50 ms.

The state transition is calculated in the "APS process logic" based on the highest local request, the request of the last received "Request/State" information, and state transition tables defined in Section 9, as follows:

o If the highest local request is Clear, clearance of SF or SD, or expiration of WTR, a state transition is calculated first based on the highest local request and state machine table for local requests to obtain an intermediate state. This intermediate state is the final state in case of clearance of SF-P otherwise, starting at this intermediate state, the last received far end request and the state machine table for far end requests are used to calculate the final state.

- o If the highest local request is neither Clear, nor clearance of SF or of SD, nor expiration of WTR, the APS process logic compares the highest local request with the request of the last received "Request/State" information based on Figure 6.

  1. If the highest local request has higher or equal priority, it is used with the state transition table for local requests defined in Section 9 to determine the final state; otherwise

  2. The request of the last received "Request/State" information is used with the state transition table for far end requests defined in Section 9 to determine the final state.

The "APS message generator" generates APS specific information with the signaled APS information for the final state from the state transition calculation (with coding as described in Figure 5).

8.2. Equal priority requests

In general, once a switch has been completed due to a request, it will not be overridden by another request of the same priority (first-come, first-served policy). Equal priority requests from both sides of a bidirectional protection group are both considered valid, as follows:

- o If the local state is NR, with the requested signal number 1, and the far-end state is NR, with the requested signal number 0, the local state transits to NR with the requested signal number 0. This applies to the case when the remote request for switching to the protection transport entity has been cleared.

- o If both the local and far-end states are NR, with the requested signal number 1, the local state transits to the appropriate new state (DNR state for non-revertive mode and WTR state for revertive mode). This applies to the case when the old request has been cleared at both ends.

- o If both the local and far-end states are RR, with the same requested signal number, both ends transit to the appropriate new state according to the requested signal number. This applies to the case of concurrent deactivation of EXER from both ends.

- o In other cases, no state transition occurs, even if equal priority requests are activated from both ends. Note that if MSs are issued simultaneously to both working and protection transport entities, either as local or far-end requests, the MS to the working transport entity is considered as having higher priority than the MS to the protection transport entity.

8.3. Signal degrade of the protection transport entity

Signal degrade on protection transport entity has the same priority as signal degrade on working transport entity. As a result, if an SD condition affects both transport entities, the first SD detected MUST NOT overridden by the second SD detected. If the SD is detected simultaneously, either as local or far-end requests on both working and protection transport entities, then the SD on the standby transport entity MUST be considered as having higher priority than the SD on the active transport entity, and the normal traffic signal continues to be selected from the active transport entity (i.e., no unnecessary protection switching is performed).

In the preceding sentence, "simultaneously" relates to the occurrence of SD on both the active and standby transport entities at input to the protection switching process at the same time, or as long as a SD request has not been acknowledged by the remote end in bidirectional protection switching.

9. Protection switching state transition table

In this section, state transition tables for the following protection switching configurations are described.

- o 1:1 bidirectional (revertive mode, non-revertive mode);
- o 1+1 bidirectional (revertive mode, non-revertive mode);
- o 1+1 unidirectional (revertive mode, non-revertive mode).

Note that any other global or local request which is not described in state transition tables does not trigger any state transition.

The states specified in the state transition tables can be described as follows:

- o NR: NR is the state entered by the local priority under all conditions where no local protection switching requests (including WTR and DNR) are active. NR can also indicates that the highest local request is overridden by the far end request, whose priority is higher than the highest local request. Normal traffic signal is selected from the corresponding transport entity.

- LO, SF-P, SD-P: The access by the normal traffic to the protection transport entity is NOT allowed in this state. The normal traffic is carried by the working transport entity, regardless of the fault/degrade condition possibly present (due to the highest priority of the switching triggers leading to this state).

- FS, SF-W, SD-W, MS-W, MS-P: A switching trigger, NOT resulting in the protection transport entity unavailability is present. The normal traffic is selected either from the corresponding working transport entity or from the protection transport entity, according to the behavior of the specific switching trigger.

- WTR: In revertive operation, after the clearing of an SF-W or SD-W, maintains normal traffic as selected from the protection transport entity until the WTR timer expires or another request with higher priority, including Clear command, is received. This is used to prevent frequent operation of the selector in the case of intermittent failures.

- DNR: In non-revertive operation, this is used to maintain a normal traffic to be selected from the protection transport entity.

- EXER: Exercise of the APS protocol.

- RR: The near end will enter and signal Reverse Request only in response to an EXER from the far end.

[State transition tables are shown at the end of the PDF form of this document.]

10. Security considerations

MPLS-TP is a subset of MPLS and so builds upon many of the aspects of the security model of MPLS. MPLS networks make the assumption that it is very hard to inject traffic into a network and equally hard to cause traffic to be directed outside the network. The control-plane protocols utilize hop-by-hop security and assume a "chain-of-trust" model such that end-to-end control-plane security is not used. For more information on the generic aspects of MPLS security, see RFC 5920 [RFC5920].

This document describes a protocol carried in the G-ACh [RFC5586], and so is dependent on the security of the G-ACh, itself. The G-ACh is a generalization of the Associated Channel defined in [RFC4385]. Thus, this document relies heavily on the security mechanisms provided for the Associated Channel and described in those two documents.

11. IANA considerations

There are no IANA actions requested.

12. Acknowledgements

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Appendix A. Operation examples of APS protocol

The sequence diagrams shown in this section are only a few examples of the APS operations. The first APS message which differs from the previous APS message is shown. The operation of hold-off timer is omitted. The fields whose values are changed during APS packet exchange are shown in the APS packet exchange. They are Request/State, requested traffic, and bridged traffic. For an example, SF(0,1) represents an APS packet with the following field values: Request/State = SF, Requested Signal = 0, and Bridged Signal = 1. The values of the other fields remain unchanged from the initial configuration. The signal numbers 0 and 1 refer to null signal and normal traffic signal, respectively. W(A->Z) and P(A->Z) indicate the working and protection paths in the direction of A to Z, respectively.

Example 1. 1:1 bidirectional protection switching (revertive mode) - Unidirectional SF case

```
                    A                  Z
                    |                  |
                (1) |---- NR(0,0)----->|
                    |<----- NR(0,0)----|
                    |                  |
                    |                  |
                (2) | (SF on W(Z->A))  |
                    |---- SF(1,1)----->| (3)
                    |<----- NR(1,1)----|
                (4) |                  |
                    |                  |
                (5) | (Recovery)       |
                    |---- WTR(1,1)---->|
                   /|                  |
          WTR timer |                  |
                   \|                  |
                (6) |---- NR(0,0)----->| (7)
                (8) |<----- NR(0,0)----|
                    |                  |
```

(1) The protected domain is operating without any defect, and the working entity is used for delivering the normal traffic.

(2) Signal Fail occurs on the working entity in the Z to A direction. Selector and bridge of node A select protection entity. Node A generates SF(1,1) message.

(3) Upon receiving SF(1,1), node Z sets selector and bridge to protection entity. As there is no local request in node Z, node Z generates NR(1,1) message.

(4) Node A confirms that the far end is also selecting protection entity.

(5) Node A detects clearing of SF condition, starts the WTR timer, and sends WTR(1,1) message.

(6) At expiration of the WTR timer, node A sets selector and bridge to working entity and sends NR(0,0) message.

(7) Node Z is notified that the far end request has been cleared, and sets selector and bridge to working entity.

(8) It is confirmed that the far end is also selecting working entity.

Example 2. 1:1 bidirectional protection switching (revertive mode) - Bidirectional SF case

```
                    A                  Z
                    |                  |
                (1) |---- NR(0,0)----->| (1)
                    |<----- NR(0,0)----|
                    |                  |
                    |                  |
                (2) | (SF on W(Z<->A)) | (2)
                    |<---- SF(1,1)---->|
                (3) |                  | (3)
                    |                  |
                (4) |    (Recovery)    | (4)
                    |<---- NR(1,1)---->|
                (5) |<--- WTR(1,1)---->| (5)
                   /|                  |\
          WTR timer |                  | WTR timer
                   \|                  |/
                (6) |<---- NR(1,1)---->| (6)
                (7) |<----- NR(0,0)--->| (7)
                (8) |                  | (8)
```

(1) The protected domain is operating without any defect, and the working entity is used for delivering the normal traffic.

(2) Nodes A and Z detect local Signal Fail conditions on the working entity, set selector and bridge to protection entity, and generate SF(1,1) messages.

(3) Upon receiving SF(1,1), each node confirms that the far end is also selecting protection entity.

(4) Each node detects clearing of SF condition, and sends NR(1,1) message as the last received APS message was SF.

(5) Upon receiving NR(1,1), each node starts the WTR timer and sends WTR(1,1).

(6) At expiration of the WTR timer, each node sends NR(1,1) as the last received APS message was WTR.

(7) Upon receiving NR(1,1), each node sets selector and bridge to working entity and sends NR(0,0) message.

(8) It is confirmed that the far end is also selecting working entity.

Example 3. 1:1 bidirectional protection switching (revertive mode) - Bidirectional SF case - Inconsistent WTR timers

```
                       A                  Z
                       |                  |
                   (1) |---- NR(0,0)----->| (1)
                       |<----- NR(0,0)----|
                       |                  |
                       |                  |
                   (2) | (SF on W(Z<->A)) | (2)
                       |<---- SF(1,1)---->|
                   (3) |                  | (3)
                       |                  |
                   (4) |    (Recovery)    | (4)
                       |<---- NR(1,1)---->|
                   (5) |<--- WTR(1,1)---->| (5)
                      /|                  |\
             WTR timer |                  | |
                      \|                  | WTR timer
                   (6) |----- NR(1,1)---->| | (7)
                       |                  |/
                   (9) |<----- NR(0,0)----| (8)
                       |---- NR(0,0)----->| (10)
```

(1) The protected domain is operating without any defect, and the working entity is used for delivering the normal traffic.

(2) Nodes A and Z detect local Signal Fail conditions on the working entity , set selector and bridge to protection entity, and generate SF(1,1) messages.

(3) Upon receiving SF(1,1), each node confirms that the far end is also selecting protection entity.

(4) Each node detects clearing of SF condition, and sends NR(1,1) message as the last received APS message was SF.

(5) Upon receiving NR(1,1), each node starts the WTR timer and sends WTR(1,1).

(6) At expiration of the WTR timer in node A, node A sends NR(1,1) as the last received APS message was WTR.

(7) At node Z, the received NR(1,1) is ignored as the local WTR has a higher priority.

(8) At expiration of the WTR timer in node Z, node Z node sets selector and bridge to working entity, and sends NR(0,0) message.

(9) Upon receiving NR(0,0), node A sets selector and bridge to working entity and sends NR(0,0) message.

(10) It is confirmed that the far end is also selecting working entity.

Example 4. 1:1 bidirectional protection switching (non-revertive mode) - Unidirectional SF on working followed by unidirectional SF on protection

```
                      A                   Z
                      |                   |
                  (1) |---- NR(0,0)------>| (1)
                      |<----- NR(0,0)-----|
                      |                   |
                      |                   |
                  (2) | (SF on W(Z->A))   |
                      |----- SF(1,1)----->| (3)
                  (4) |<----- NR(1,1)-----|
                      |                   |
                      |                   |
                  (5) |    (Recovery)     |
                      |----- DNR(1,1)---->| (6)
                      |<--- DNR(1,1)----->|
                      |                   |
                      |                   |
                      | (SF on P(A->Z))   | (7)
                  (8) |<--- SF-P(0,0)-----|
                      |---- NR(0,0)------>|
                      |                   |
                      |                   |
                      |     (Recovery)    | (9)
                      |<----- NR(0,0)-----|
                      |                   |
```

(1) The protected domain is operating without any defect, and the working entity is used for delivering the normal traffic.

(2) Signal Fail occurs on the working entity in the Z to A direction. Selector and bridge of node A select the protection entity. Node A generates SF(1,1) message.

(3) Upon receiving SF(1,1), node Z sets selector and bridge to protection entity. As there is no local request in node Z, node Z generates NR(1,1) message.

(4) Node A confirms that the far end is also selecting protection entity.

(5) Node A detects clearing of SF condition, and sends DNR(1,1) message.

(6) Upon receiving DNR(1,1), node Z also generates DNR(1,1) message.

(7) Signal Fail occurs on the protection entity in the A to Z direction. Selector and bridge of node Z select the working entity. Node Z generates SF-P(0,0) message.

(8) Upon receiving SF-P(0,0), node A sets selector and bridge to working entity, and generates NR(0,0) message.

(9) Node Z detects clearing of SF condition, and sends NR(0,0) message.

Exmaple 5. 1:1 bidirectional protection switching (non-revertive mode) - Bidirectional SF on working followed by bidirectional SF on protection

```
          A                  Z
          |                  |
      (1) |---- NR(0,0)----->| (1)
          |<----- NR(0,0)----|
          |                  |
          |                  |
      (2) | (SF on W(A<->Z)) | (2)
      (3) |<---- SF(1,1)---->| (3)
          |                  |
          |                  |
      (4) |    (Recovery)    | (4)
      (5) |<---- NR(1,1)---->| (5)
          |<--- DNR(1,1)---->|
          |                  |
          |                  |
      (6) | (SF on P(A<->Z)) | (6)
      (7) |<--- SF-P(0,0)--->| (7)
          |                  |
          |                  |
      (8) |     (Recovery)   | (8)
          |<---- NR(0,0)---->|
          |                  |
```

(1) The protected domain is operating without any defect, and the working entity is used for delivering the normal traffic.

(2) Nodes A and Z detect local Signal Fail conditions on the working entity, set selector and bridge to protection entity, and generate SF(1,1) messages.

(3) Upon receiving SF(1,1), each node confirms that the far end is also selecting protection entity.

(4) Each node detects clearing of SF condition, and sends NR(1,1) message as the last received APS message was SF.

(5) Upon receiving NR(1,1), each node sends DNR(1,1).

(6) Signal Fail occurs on the protection entity in both directions. Selector and bridge of each node selects the working entity. Each node generates SF-P(0,0) message.

(7) Upon receiving SF-P(0,0), each node confirms that the far end is also selecting working entity

(8) Each node detects clearing of SF condition, and sends NR(0,0) message.

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7.1 State transition for 1:1 bidirectional switching with revertive mode

Table 7.1 - State transition by local requests (1:1, bidirectional, revertive mode)

			Local request														
			a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**
	State	**Signalled APS**	**Lockout**	**Forced switch**	**SF on working** [a)]	**Working recovers from SF**	**SF on protection** [a)]	**Protection recovers from SF**	**SD on working** [a)]	**Working recovers from SD**	**SD on protection** [a)]	**Protection recovers from SD**	**Manual switch to protection**	**Manual switch to working**	**Clear**	**Exercise**	**WTR timer expires**
A	No Request Working/Active Protection/Standby	NR [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K	N/A
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→C	→D	→E	O	→F	N/A	→P	O	→Q	N/A	→G	→H	N/A	O	N/A
C	Lockout Working/Active Protection/Standby	LO [r/b=null]	O	O	O	O	O	O	O	O	O	O	O	O	→A or →E [b)] or →F [c)] or →P [d)] or →Q [e)]	O	N/A
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→C	O	O	O	→F	N/A	O	O	O	O	O	O	→A or →E [b)] or →P [d)] or →Q [e)]	O	N/A
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→C	→D	N/A	→I or →P [d)] or →Q [e)]	→F	N/A	O	O	O	O	O	O	N/A	O	N/A
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r/b=null]	→C	O	O	O	N/A	→A or →E [b)] or →P [d)] or →Q [e)]	O	O	O	O	O	O	N/A	O	N/A
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→C	→D	→E	N/A	→F	N/A	N/A	→I or →Q [e)]	O	O	O	O	N/A	O	N/A
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r/b=null]	→C	→D	→E	N/A	→F	N/A	O	O	N/A	→A or →P [d)]	O	O	N/A	O	N/A
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	O	N/A
H	Manual Switch Working/Active Protection/Standby	MS [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	O	N/A

			Local request														
			a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
	State	**Signalled APS**	**Lockout**	**Forced switch**	**SF on working** a)	**Working recovers from SF**	**SF on protection** a)	**Protection recovers from SF**	**SD on working** a)	**Working recovers from SD**	**SD on protection** a)	**Protection recovers from SD**	**Manual switch to protection**	**Manual switch to working**	**Clear**	**Exercise**	**WTR timer expires**
I	Wait to Restore Working/Standby Protection/Active	WTR [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→A	O	→A
K	Exercise Working/Active Protection/Standby	EXER [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→A	O	N/A
M	Reverse Request Working/Active Protection/Standby	RR [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K	N/A

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→**X**)" represents that the state is not changed and remains the same state.
a) Signal Fail or Signal Degrade on working or protection is input to the local priority logic only if the Signal Fail or Signal Degrade still exists after hold-off timer expires.
b) If SF is reasserted.
c) If SF-P is reasserted.
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.

Table 7.2 - State transition by far end requests (1:1, bidirectional, revertive mode)

			Received far end request													
			p	q	r	s	t	u	v	w	x	y	z	aa	ab	ac
	State	**Signalled APS**	**LO [r/b= null]**	**SF-P [r/b= null]**	**FS [r/b= normal]**	**SF [r/b= normal]**	**SD [r/b= normal]**	**SD [r/b= null]**	**MS [r/b= normal]**	**MS [r/b= null]**	**WTR [r/b= normal]**	**EXER [r/b= null]**	**RR [r/b= null]**	**NR [r/b= null]**	**NR [r/b= normal]**	**DNR [r/b= normal]**
A	No Request Working/Active Protection/Standby	NR [r/b=null]	(→A)	(→A)	→B	→B	→B	(→A)	→B	(→A)	→B	→M	(→A)	(→A) or →E[a)] or →F[b)] or →P[d)] or →Q[e)]	(→A)	→B
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→A	→A	(→B)	(→B)	(→B)	→A	(→B)	→A	(→B)	N/A	N/A	→A or →E[a)] or →P[d)]	→A or →I[c)]	(→B)
C	Lockout Working/Active Protection/Standby	LO [r/b=null]	(→C)	O	O	O	O	O	O	O	O	O	O	O	O	O

			Received far end request													
			p	q	r	s	t	u	v	w	x	y	z	aa	ab	ac
	State	Signalled APS	LO [r/b= null]	SF-P [r/b= null]	FS [r/b= normal]	SF [r/b= normal]	SD [r/b= normal]	SD [r/b= null]	MS [r/b= normal]	MS [r/b= null]	WTR [r/b= normal]	EXER [r/b= null]	RR [r/b= null]	NR [r/b= null]	NR [r/b= normal]	DNR [r/b= normal]
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→A	→A	(→D)	O	O	O	O	O	O	O	O	O	O	O
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→A	→A	→B	(→E)	O	O	O	O	O	O	O	O	O	O
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r/b=null]	→A	(→F)	O	O	O	O	O	O	O	O	O	O	O	O
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→A	→A	→B	→B	(→P)	O	O	O	O	O	O	O	O	O
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r/b=null]	→A	→A	→B	→B	O	(→Q)	O	O	O	O	O	O	O	O
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→A	→A	→B	→B	→B	→A	(→G)	(→G) or →A[f)]	O	O	O	O	O	O
H	Manual Switch Working/Active Protection/Standby	MS [r/b=null]	→A	→A	→B	→B	→B	→A	O	(→H)	O	O	O	O	O	O
I	Wait to Restore Working/Standby Protection/Active	WTR [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	(→I)	O	O	N/A	O	O
K	Exercise Working/Active Protection/Standby	EXER [r/b=null]	→A	→A	→B	→B	→B	→A	→B	→A	N/A	(→K)	(→K)	O	N/A	O
M	Reverse Request Working/Active Protection/Standby	RR [r/b=null]	→A	→A	→B	→B	→B	→A	→B	→A	N/A	(→M)	→A	→A	N/A	O

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→X)" represents that the state is not changed and remains the same state.

a) If SF is reasserted.
b) If SF-P is reasserted.
c) If the previous local state is SF (or SD (W) if applicable, see clause 11.13).
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.
f) Only if the far end request is due to the simultaneous application of a manual switch to working command at the far end (i.e. no NR request acknowledging the local MS state received previously from the far end)

7.2 State transition for 1:1 bidirectional switching with non-revertive mode

Table 7.3 – State transition by local requests (1:1, bidirectional, non-revertive mode)

			Local request													
			a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**
	State	**Signalled APS**	**Lockout**	**Forced switch**	**SF on working** [a)]	**Working recovers from SF**	**SF on protection** [a)]	**Protection recovers from SF**	**SD on working** [a)]	**Working recovers from SD**	**SD on protection** [a)]	**Protection recovers from SD**	**Manual switch to protection**	**Manual switch to working**	**Clear**	**Exercise**
A	No Request Working/Active Protection/Standby	NR [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→C	→D	→E	O	→F	N/A	→P	O	→Q	N/A	→G	→H	N/A	O
C	Lockout Working/Active Protection/Standby	LO [r/b=null]	O	O	O	O	O	O	O	O	O	O	O	O	→A or →E[b)] or →F[c)] or →P[d)] or →Q[e)]	O
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→C	O	O	O	→F	N/A	O	O	O	O	O	O	→J or →E[b)] or →P[d)] or →Q[e)]	O
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→C	→D	N/A	→J or →P[d)] or →Q[e)]	→F	N/A	O	O	O	O	O	O	N/A	O
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r/b=null]	→C	O	O	O	N/A	→A or →E[b)] or →P[d)] or →Q[e)]	O	O	O	O	O	O	N/A	O
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→C	→D	→E	N/A	→F	N/A	N/A	→J or →Q[e)]	O	O	O	O	N/A	O
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r/b=null]	→C	→D	→E	N/A	→F	N/A	O	O	N/A	→A or →P[d)]	O	O	N/A	O
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→J	O

			Local request													
			a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**
	State	**Signalled APS**	**Lockout**	**Forced switch**	**SF on working** a)	**Working recovers from SF**	**SF on protection** a)	**Protection recovers from SF**	**SD on working** a)	**Working recovers from SD**	**SD on protection** a)	**Protection recovers from SD**	**Manual switch to protection**	**Manual switch to working**	**Clear**	**Exercise**
H	Manual Switch Working/Active Protection/Standby	MS [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	O
J	Do Not Revert Working/Standby Protection/Active	DNR [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→L
K	Exercise Working/Active Protection/Standby	EXER [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→A	O
L	Exercise Working/Standby Protection/Active	EXER [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→J	O
M	Reverse Request Working/Active Protection/Standby	RR [r/b=null]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K
N	Reverse Request Working/Standby Protection/Active	RR [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→L

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→**X**)" represents that the state is not changed and remains the same state.
a) Signal Fail or Signal Degrade on working or protection is input to the local priority logic only if the Signal Fail or Signal Degrade still exists after hold-off timer expires.
b) If SF is reasserted.
c) If SF-P is reasserted.
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.

Table 7.4 – State transition by far end requests (1:1, bidirectional, non-revertive mode)

			Received far end request															
			o	**p**	**q**	**r**	**s**	**t**	**u**	**v**	**w**	**x**	**y**	**z**	**aa**	**ab**	**ac**	**ad**
	State	**Signalled APS**	**LO [r/b= null]**	**SF-P [r/b= null]**	**FS [r/b= normal]**	**SF [r/b= normal]**	**SD [r/b= normal]**	**SD [r/b= null]**	**MS [r/b= normal]**	**MS [r/b= null]**	**WTR [r/b= normal]**	**EXER [r/b= null]**	**EXER [r/b= normal]**	**RR [r/b= null]**	**RR [r/b= normal]**	**NR [r/b= null]**	**NR [r/b= normal]**	**DNR [r/b= normal]**
A	No Request Working/Active Protection/Standby	NR [r/b=null]	(→A)	(→A)	→B	→B	→B	(→A)	→B	(→A)	→B	→M	N/A	(→A)	N/A	(→A) or →E[a)] or →F[b)] or →P[c)] or →Q[d)]	(→A)	→J
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→A	→A	(→B)	(→B)	(→B)	→A	(→B)	→A	(→B)	N/A	N/A	N/A	N/A	→A or →E[a)] or →P[c)]	→J	→J
C	Lockout Working/Active Protection/Standby	LO [r/b=null]	(→C)	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→A	→A	(→D)	O	O	O	O	O	O	O	O	O	O	O	O	O
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→A	→A	→B	(→E)	O	O	O	O	O	O	O	O	O	O	O	O
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r/b=null]	→A	(→F)	O	O	O	O	O	O	O	O	O	O	O	O	O	O
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→A	→A	→B	→B	(→P)	O	O	O	O	O	O	O	O	O	O	O
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r/b=null]	→A	→A	→B	→B	O	(→Q)	O	O	O	O	O	O	O	O	O	O
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→A	→A	→B	→B	→B	→A	(→G)	(→G) or →A[e)]	O	O	O	O	O	O	O	O
H	Manual Switch Working/Active Protection/Standby	MS [r/b=null]	→A	→A	→B	→B	→B	→A	O	(→H)	O	O	O	O	O	O	O	O
J	Do Not Revert Working/Standby Protection/Active	DNR [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	N/A	→N	N/A	(→J)	O	O	(→J)

	State	Signalled APS	Received far end request															
			o	**p**	**q**	**r**	**s**	**t**	**u**	**v**	**w**	**x**	**y**	**z**	**aa**	**ab**	**ac**	**ad**
			LO [r/b= null]	**SF-P [r/b= null]**	**FS [r/b= normal]**	**SF [r/b= normal]**	**SD [r/b= normal]**	**SD [r/b= null]**	**MS [r/b= normal]**	**MS [r/b= null]**	**WTR [r/b= normal]**	**EXER [r/b= null]**	**EXER [r/b= normal]**	**RR [r/b= null]**	**RR [r/b= normal]**	**NR [r/b= null]**	**NR [r/b= normal]**	**DNR [r/b= normal]**
K	Exercise Working/Active Protection/Standby	EXER [r/b=null]	→A	→A	→B	→B	→B	→A	→B	→A	→B	(→K)	N/A	(→K)	N/A	O	N/A	N/A
L	Exercise Working/Standby Protection/Active	EXER [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	N/A	(→L)	N/A	(→L)	N/A	O	O
M	Reverse Request Working/Active Protection/Standby	RR [r/b=null]	→A	→A	→B	→B	→B	→A	→B	→A	→B	(→M)	N/A	→A	N/A	→A	N/A	N/A
N	Reverse Request Working/Standby Protection/Active	RR [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	N/A	(→N)	N/A	→J	N/A	N/A	→J

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→X)" represents that the state is not changed and remains the same state.
a) If SF is reasserted.
b) If SF-P is reasserted.
c) If SD (W) is reasserted.
d) If SD (P) is reasserted.
e) Only if the far end request is due to the simultaneous application of a manual switch to working command at the far end (i.e. no NR request acknowledging the local MS state received previously from the far end)

7.3 State transition for 1+1 bidirectional switching with revertive mode

Table 7.5 – State transition by local requests (1+1, bidirectional, revertive mode)

	State	Signalled APS	Local request														
			a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
			Lockout	**Forced switch**	**SF on working** [a)]	**Working recovers from SF**	**SF on protection** [a)]	**Protection recovers from SF**	**SD on working** [a)]	**Working recovers from SD**	**SD on protection** [a)]	**Protection recovers from SD**	**Manual switch to protection**	**Manual switch to working**	**Clear**	**Exercise**	**WTR timer expires**
A	No Request Working/Active Protection/Standby	NR [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K	N/A
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→C	→D	→E	O	→F	N/A	→P	O	→Q	N/A	→G	→H	N/A	O	N/A
C	Lockout Working/Active Protection/Standby	LO [r=null, b=normal]	O	O	O	O	O	O	O	O	O	O	O	O	→A or →E[b)] or →F[c)] or →P[d)] or →Q[e)]	O	N/A
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→C	O	O	O	→F	N/A	O	O	O	O	O	O	→A or →E[b)] or →P[d)] or →Q[e)]	O	N/A
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→C	→D	N/A	→I or →P[d)] or →Q[e)]	→F	N/A	O	O	O	O	O	O	N/A	O	N/A
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r=null, b=normal]	→C	O	O	O	N/A	→A or →E[b)] or →P[d)] or →Q[e)]	O	O	O	O	O	O	N/A	O	N/A
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→C	→D	→E	N/A	→F	N/A	N/A	→I or →Q[e)]	O	O	O	O	N/A	O	N/A
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	O	O	N/A	→A or →P[d)]	O	O	N/A	O	N/A
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	O	N/A
H	Manual Switch Working/Active Protection/Standby	MS [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	O	N/A

State		Signalled APS	Local request a Lockout	b Forced switch	c SF on working [a)]	d Working recovers from SF	e SF on protection [a)]	f Protection recovers from SF	g SD on working [a)]	h Working recovers from SD	i SD on protection [a)]	j Protection recovers from SD	k Manual switch to protection	l Manual switch to working	m Clear	n Exercise	o WTR timer expires
I	Wait to Restore Working/Standby Protection/Active	WTR [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→A	O	→A
K	Exercise Working/Active Protection/Standby	EXER [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→A	O	N/A
M	Reverse Request Working/Active Protection/Standby	RR [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K	N/A

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(**→X**)" represents that the state is not changed and remains the same state.
a) Signal Fail or Signal Degrade on working or protection is input to the local priority logic only if the Signal Fail or Signal Degrade still exists after hold-off timer expires.
b) If SF is reasserted.
c) If SF-P is reasserted.
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.

Table 7.6 - State transition by far end requests (1+1, bidirectional, revertive mode)

State		Signalled APS	Received far end request p LO [r=null, b=normal]	q SF-P [r=null, b=normal]	r FS [r/b= normal]	s SF [r/b= normal]	t SD [r/b= normal]	u SD [r=null, b=normal]	v MS [r/b= normal]	w MS [r=null, b=normal]	x WTR [r/b= normal]	y EXER r=null, b=normal]	z RR r=null, b=normal]	aa NR r=null, b=normal]	ab NR [r/b= normal]	ac DNR [r/b= normal]
A	No Request Working/Active Protection/Standby	NR [r=null, b=normal]	(→A)	(→A)	→B	→B	→B	(→A)	→B	(→A)	→B	→M	(→A)	(→A) or →E[a)] or →F[b)] or →P[d)] or →Q[e)]	(→A)	→B
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→A	→A	(→B)	(→B)	(→B)	→A	(→B)	→A	(→B)	N/A	N/A	→A or →E[a)] or →P[d)]	→A or →I[c)]	(→B)
C	Lockout Working/Active Protection/Standby	LO [r=null, b=normal]	(→C)	O	O	O	O	O	O	O	O	O	O	O	O	O

State		Signalled APS	Received far end request													
			p	**q**	**r**	**s**	**t**	**u**	**v**	**w**	**x**	**y**	**z**	**aa**	**ab**	**ac**
			LO [r=null, b=normal]	**SF-P** [r=null, b=normal]	**FS** [r/b= normal]	**SF** [r/b= normal]	**SD** [r/b= normal]	**SD** [r=null, b=normal]	**MS** [r/b= normal]	**MS** [r=null, b=normal]	**WTR** [r/b= normal]	**EXER** r=null, b=normal]	**RR** r=null, b=normal]	**NR** r=null, b=normal]	**NR** [r/b= normal]	**DNR** [r/b= normal]
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→A	→A	(→D)	O	O	O	O	O	O	O	O	O	O	O
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→A	→A	→B	(→E)	O	O	O	O	O	O	O	O	O	O
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r=null, b=normal]	→A	(→F)	O	O	O	O	O	O	O	O	O	O	O	O
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→A	→A	→B	→B	(→P)	O	O	O	O	O	O	O	O	O
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r=null, b=normal]	→A	→A	→B	→B	O	(→Q)	O	O	O	O	O	O	O	O
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→A	→A	→B	→B	→B	→A	(→G)	(→G) or →A[f)]	O	O	O	O	O	O
H	Manual Switch Working/Active Protection/Standby	MS [r=null, b=normal]	→A	→A	→B	→B	→B	→A	O	(→H)	O	O	O	O	O	O
I	Wait to Restore Working/Standby Protection/Active	WTR [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	(→I)	O	O	N/A	O	O
K	Exercise Working/Active Protection/Standby	EXER [r=null, b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	N/A	(→K)	(→K)	O	N/A	O
M	Reverse Request Working/Active Protection/Standby	RR [r=null, b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	N/A	(→M)	→A	→A	N/A	O

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→X)" represents that the state is not changed and remains the same state.
a) If SF is reasserted.
b) If SF-P is reasserted.
c) If the previous local state is SF (or SD (W) if applicable, see clause 11.13).
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.
f) Only if the far end request is due to the simultaneous application of a manual switch to working command at the far end (i.e. no NR request acknowledging the local MS state received previously from the far end)

7.4 State transition for 1+1 bidirectional switching with non-revertive mode

Table 7.7 - State transition by local requests (1+1, bidirectional, non-revertive mode)

			Local request													
			a	b	c	d	e	f	g	h	i	j	k	l	m	n
	State	Signalled APS	Lockout	Forced switch	SF on working a)	Working recovers from SF	SF on protection a)	Protection recovers from SF	SD on working a)	Working recovers from SD	SD on protection a)	Protection recovers from SD	Manual switch to protection	Manual switch to working	Clear	Exercise
A	No Request Working/Active Protection/Standby	NR [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→C	→D	→E	O	→F	N/A	→P	O	→Q	N/A	→G	→H	N/A	O
C	Lockout Working/Active Protection/Standby	LO [r=null, b=normal]	O	O	O	O	O	O	O	O	O	O	O	O	→A or →E[b)] or →F[c)] or →P[d)] or →Q[e)]	O
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→C	O	O	O	→F	N/A	O	O	O	O	O	O	→J or →E[b)] or →P[d)] or →Q[e)]	O
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→C	→D	N/A	→J or →P[d)] or →Q[e)]	→F	N/A	O	O	O	O	O	O	N/A	O
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r=null, b=normal]	→C	O	O	O	N/A	→A or →E[b)] or →P[d)] or →Q[e)]	O	O	O	O	O	O	N/A	O
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→C	→D	→E	N/A	→F	N/A	N/A	→J or →Q[e)]	O	O	O	O	N/A	O
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	O	O	N/A	→A or →P[d)]	O	O	N/A	O
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→J	O

	State	Signalled APS	Local request a Lockout	b Forced switch	c SF on working a)	d Working recovers from SF	e SF on protection a)	f Protection recovers from SF	g SD on working a)	h Working recovers from SD	i SD on protection a)	j Protection recovers from SD	k Manual switch to protection	l Manual switch to working	m Clear	n Exercise
H	Manual Switch Working/Active Protection/Standby	MS [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	O
J	Do Not Revert Working/Standby Protection/Active	DNR [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→L
K	Exercise Working/Active Protection/Standby	EXER [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→A	O
L	Exercise Working/Standby Protection/Active	EXER [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→J	O
M	Reverse Request Working/Active Protection/Standby	RR [r=null, b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→K
N	Reverse Request Working/Standby Protection/Active	RR [r/b=normal]	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	→L

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→X)" represents that the state is not changed and remains the same state.
a) Signal Fail or Signal Degrade on working or protection is input to the local priority logic only if the Signal Fail or Signal Degrade still exists after hold-off timer expires.
b) If SF is reasserted.
c) If SF-P is reasserted.
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.

Table 7.8 - State transition by far end requests (1+1 bidirectional, non-revertive mode)

			Received far end request											
			o	**p**	**q**	**r**	**s**	**t**	**u**	**v**	**w**	**x**	**y**	**z**
	State	**Signalled APS**	**LO [r=null, b=normal]**	**SF-P [r=null, b=normal]**	**FS [r/b= normal]**	**SF [r/b= normal**	**SD [r/b= normal]**	**SD [r=null, b=normal]**	**MS [r/b= normal]**	**MS [r=null, b=normal]**	**WTR [r/b= normal]**	**EXER [r=null, b=normal]**	**EXER [r/b= normal]**	**RR [r=null, b=normal]**
A	No Request Working/Active Protection/Standby	NR [r=null, b=normal]	(→A)	(→A)	→B	→B	→B	(→A)	→B	(→A)	→B	→M	N/A	(→A)
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	→A	→A	(→B)	(→B)	(→B)	→A	(→B)	→A	(→B)	N/A	N/A	N/A
C	Lockout Working/Active Protection/Standby	LO [r= null, b=normal]	(→C)	O	O	O	O	O	O	O	O	O	O	O
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	→A	→A	(→D)	O	O	O	O	O	O	O	O	O
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	→A	→A	→B	(→E)	O	O	O	O	O	O	O	O
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r= null, b=normal]	→A	(→F)	O	O	O	O	O	O	O	O	O	O
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	→A	→A	→B	→B	(→P)	O	O	O	O	O	O	O
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r= null, b=normal]	→A	→A	→B	→B	O	(→Q)	O	O	O	O	O	O
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	→A	→A	→B	→B	→B	→A	(→G)	(→G) or →A[e)]	O	O	O	O
H	Manual Switch Working/Active Protection/Standby	MS [r= null, b=normal]	→A	→A	→B	→B	→B	→A	O	(→H)	O	O	O	O
J	Do Not Revert Working/Standby Protection/Active	DNR [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	N/A	→N	N/A

	State	Signalled APS	Received far end request			
			aa	**ab**	**ac**	**ad**
			RR [r/b= normal]	**NR [r=null, b=normal]**	**NR [r/b= normal]**	**DNR [r/b= normal]**
A	No Request Working/Active Protection/Standby	NR [r=null, b=normal]	N/A	(→A) or →E[a)] or →F[b)] or →P[c)] or →Q[d)]	(→A)	→J
B	No Request Working/Standby Protection/Active	NR [r/b=normal]	N/A	→A or→E[a)] or →P[c)]	→J	→J
C	Lockout Working/Active Protection/Standby	LO [r= null, b=normal]	O	O	O	O
D	Forced Switch Working/Standby Protection/Active	FS [r/b=normal]	O	O	O	O
E	Signal Fail (W) Working/Standby Protection/Active	SF [r/b=normal]	O	O	O	O
F	Signal Fail (P) Working/Active Protection/Standby	SF-P [r= null, b=normal]	O	O	O	O
P	Signal Degrade (W) Working/Standby Protection/Active	SD [r/b=normal]	O	O	O	O
Q	Signal Degrade (P) Working/Active Protection/Standby	SD [r= null, b=normal]	O	O	O	O
G	Manual Switch Working/Standby Protection/Active	MS [r/b=normal]	O	O	O	O
H	Manual Switch Working/Active Protection/Standby	MS [r= null, b=normal]	O	O	O	O
J	Do Not Revert Working/Standby Protection/Active	DNR [r/b=normal]	(→J)	O	O	(→J)

State		Signalled APS	o LO [r=null, b=normal]	p SF-P [r=null, b=normal]	q FS [r/b= normal]	r SF [r/b= normal	s SD [r/b= normal]	t SD [r=null, b=normal]	u MS [r/b= normal]	v MS [r=null, b=normal]	w WTR [r/b= normal]	x EXER [r=null, b=normal]	y EXER [r/b= normal]	z RR [r=null, b=normal]
K	Exercise Working/Active Protection/Standby	EXER [r=null, b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	(→K)	N/A	(→K)
L	Exercise Working/Standby Protection/Active	EXER [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	N/A	(→L)	N/A
M	Reverse Request Working/Active Protection/Standby	RR [r=null, b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	(→M)	N/A	→A
N	Reverse Request Working/Standby Protection/Active	RR [r/b=normal]	→A	→A	→B	→B	→B	→A	→B	→A	→B	N/A	(→N)	N/A

State		Signalled APS	aa RR [r/b= normal]	ab NR [r=null, b=normal]	ac NR [r/b= normal]	ad DNR [r/b= normal]
K	Exercise Working/Active Protection/Standby	EXER [r=null, b=normal]	N/A	O	N/A	N/A
L	Exercise Working/Standby Protection/Active	EXER [r/b=normal]	(→L)	N/A	O	O
M	Reverse Request Working/Active Protection/Standby	RR [r=null, b=normal]	N/A	→A	N/A	N/A
N	Reverse Request Working/Standby Protection/Active	RR [r/b=normal]	→J	N/A	N/A	→J

(Column group heading for both tables: Received far end request)

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→X)" represents that the state is not changed and remains the same state.
a) If SF is reasserted.
b) If SF-P is reasserted.
c) If SD (W) is reasserted.
d) If SD (P) is reasserted.
e) Only if the far end request is due to the simultaneous application of a manual switch to working command at the far end (i.e. no NR request acknowledging the local MS state received previously from the far end)

7.5 State transition for 1+1 unidirectional switching with revertive mode

Table 7.9 – State transition by local requests (1+1, unidirectional, revertive mode)

		Local request														
		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
State		Lockout	Forced switch	SF on working [a)]	Working recovers from SF	SF on protection [a)]	Protection recovers from SF	SD on working [a)]	Working recovers from SD	SD on protection [a)]	Protection recovers from SD	Manual switch to protection	Manual switch to working	Clear	Exercise	WTR timer expires
A	No Request Working/Active Protection/Standby	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	N/A	N/A
C	Lockout Working/Active Protection/Standby	O	O	O	O	O	O	O	O	O	O	O	O	(→A) or →E[b)] or→F[c)] or →P[d)] or →Q[e)]	N/A	N/A
D	Forced Switch Working/Standby Protection/Active	→C	O	O	O	→F	N/A	O	O	O	O	O	O	(→A) or →E[b)] or →P[d)] or →Q[e)]	N/A	N/A
E	Signal Fail (W) Working/Standby Protection/Active	→C	→D	N/A	→I or →P[d)] or →Q[e)]	→F	N/A	O	O	O	O	O	O	N/A	N/A	N/A
F	Signal Fail (P) Working/Active Protection/Standby	→C	O	O	O	N/A	→A or →E[b)] or →P[d)] or →Q[e)]	O	O	O	O	O	O	N/A	N/A	N/A
P	Signal Degrade (W) Working/Standby Protection/Active	→C	→D	→E	N/A	→F	N/A	N/A	→I or →Q[e)]	O	O	O	O	N/A	N/A	N/A
Q	Signal Degrade (P) Working/Active Protection/Standby	→C	→D	→E	N/A	→F	N/A	O	O	N/A	→A or →P[d)]	O	O	N/A	N/A	N/A
G	Manual Switch Working/Standby Protection/Active	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	N/A	N/A
H	Manual Switch Working/Active Protection/Standby	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	N/A	N/A
I	Wait to Restore Working/Standby Protection/Active	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	→A	N/A	→A

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
NOTE 3 – "(→X)" represents that the state is not changed and remains the same state.

a) Signal Fail or Signal Degrade on working or protection is input to the local priority logic only if the Signal Fail or Signal Degrade still exists after hold-off timer expires.
b) If SF is reasserted.
c) If SF-P is reasserted.
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.

7.6 State transition for 1+1 unidirectional switching with non-revertive mode

Table 7.10 – State transition by local requests (1+1, unidirectional, non-revertive mode)

State		Local request													
		a	b	c	d	e	f	g	h	i	j	k	l	m	n
		Lockout	**Forced switch**	**SF on working** a)	**Working recovers from SF**	**SF on protection** a)	**Protection recovers from SF**	**SD on working** a)	**Working recovers from SD**	**SD on protection** a)	**Protection recovers from SD**	**Manual switch to protection**	**Manual switch to working**	**Clear**	**Exercise**
A	No Request Working/Active Protection/Standby	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	N/A
C	Lockout Working/Active Protection/Standby	O	O	O	O	O	O	O	O	O	O	O	O	→A or →E b) or →F c) or →P d) or →Q e)	N/A
D	Forced Switch Working/Standby Protection/Active	→C	O	O	O	→F	N/A	O	O	O	O	O	O	→J or →E b) or →P d) or →Q e)	N/A
E	Signal Fail (W) Working/Standby Protection/Active	→C	→D	N/A	→J or →P d) or →Q e)	→F	N/A	O	O	O	O	O	O	N/A	N/A
F	Signal Fail (P) Working/Active Protection/Standby	→C	O	O	O	N/A	→A or →E b) or →P d) or →Q e)	O	O	O	O	O	O	N/A	N/A
P	Signal Degrade (W) Working/Standby Protection/Active	→C	→D	→E	N/A	→F	N/A	N/A	→J or →Q e)	O	O	O	O	N/A	N/A
Q	Signal Degrade (P) Working/Active Protection/Standby	→C	→D	→E	N/A	→F	N/A	O	O	N/A	→A or →P d)	O	O	N/A	N/A

State		Local request													
		a	b	c	d	e	f	g	h	i	j	k	l	m	n
		Lockout	Forced switch	SF on working a)	Working recovers from SF	SF on protection a)	Protection recovers from SF	SD on working a)	Working recovers from SD	SD on protection a)	Protection recovers from SD	Manual switch to protection	Manual switch to working	Clear	Exercise
G	Manual Switch Working/Standby Protection/Active	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→J	N/A
H	Manual Switch Working/Active Protection/Standby	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	O	O	→A	N/A
J	Do Not Revert Working/Standby Protection/Active	→C	→D	→E	N/A	→F	N/A	→P	N/A	→Q	N/A	→G	→H	N/A	N/A

NOTE 1 – "N/A" means that the event is not expected to happen for the State. However if it does happen, the event should be ignored.
NOTE 2 – "O" means that the request shall be overruled by the existing condition because it has an equal or a lower priority.
a) Signal Fail or Signal Degrade on working or protection is input to the local priority logic only if the Signal Fail or Signal Degrade still exists after hold-off timer expires.
b) If SF is reasserted.
c) If SF-P is reasserted.
d) If SD (W) is reasserted.
e) If SD (P) is reasserted.