1. General

OAM functions in a network are performed on hierarchical levels. Not all protocols support OAM, for example a physical layer based on SONET/SDH includes extensive OAM functions, while a physical layer based on Ethernet phys lacks OAM functions completely.
The OAM function in RPR is based on special frames sent between Stations. These frames correspond to flows. A flow is defined by the SA and DA. In some cases the flows may be further segmented using the Class Of Service, and the optional subscriber identification tag.
OAM frames are grouped in four groups:

- Fault Management
- Performance Management
- Protection Coordination
- Activation/Deactivation
- Topology Discovery

1.1 Fault Management

Fault Management frames are used to indicate components, Stations and ring failures, loss of continuity between ring Stations, and to perform Loopback operations.

1.2 Performance Management

Performance Management frames are used to measure packet loss between stations on a ring.

1.3 Protection Coordination

Protection Coordination frames are used to convey information regarding the protection states in a ring

1.4 Activation/Deactivation

Activation/Deactivation frames are used to Activate or Deactivate the transmission of Performance Management and Continuity Check frames. These frames allow coordinating the
transmission and reception of loss of continuity frames to avoid the generation of undesirable alarm indication.

1.5 Topology Discovery

TBD

2. OAM functions of the RPR layer

The OAM frame types of the RPR layer are:
AIS – For reporting defect indications in the forward direction on a flow level
RDI - For reporting defect indications in the backward direction on a flow level
CC – For monitoring continuity of flows
LB – For on demand connectivity monitoring and fault localization on flows
PM – For estimating performance monitoring on a flow level
Protection Coordination – For carrying ring protection switching information
Activation/Deactivation – For Activating/Deactivating CC and PM
Topology Discovery - TBD

2.1 Fault Management

Fault management includes alarm surveillance, fault localization, fault correction and testing. Alarm Surveillance provides the capability to monitor failures detected in NEs. In support of alarm surveillance RPR NEs should perform checks on hardware and software in order to detect failures, and generate alarms for such failures. Upon detecting a failure, in addition to generating and sending alarms to systems, NEs should also send AIS/RDI in the forward/backward directions, respectively, in order to notify downstream/upstream nodes that a failure has occurred (and some action is required).
Among others, Loss Of Continuity (LOC) is one defect that the NE has to detect. This is addressed by the use of a continuity check (CC) mechanism. CC also assists in fault localization, since it is possible to identify between which NEs the flow is interrupted. Another type of failure that RPR NEs may identify is software misconfiguration/failure. Such failure/misconfiguration can lead to invalid/unrecognizable header field value when the RPR frame is generated. Software checks can be performed on the RPR header to check for invalid/unrecognizable field value.
Fault Localization determines the root cause of a failure. In addition to the initial failure information, it may use failure information from other entities in order to correlate and localize the fault.
Fault Correction is responsible for the repair of a fault and for the control of procedures that use redundant resources to replace equipment or facilities that have failed. For RPR, in case of fiber cut or node failure, a protection switching is used to restore service.
Testing performs repair functions using some testing and diagnostic routines. Testing is characterized as the application of signals/messages and their measurement. Loopback is one example of a testing routine and can be activated upon request.
Fault Management frames include: AIS, RDI, LB and CC

2.1.1 AIS defect indication

The Station detecting a Loss Of Continuity (LOC) defect shall generate and send in the forward direction (same ringlet in which defect was detected) an AIS frame. The SA should be the detecting Station MAC address and the DA should be the MAC address of the Station sourcing the failed flow.
The AIS frame shall be generated and transmitted as soon as possible after detection of the LOC defect, and shall be periodically transmitted during the defect condition. The generation frequency of the AIS frame shall be one frame per second.
The AIS frame generation shall be stopped as soon as the defect indication is removed.
The AIS frames shall be detected at the respective flow sourcing Station. The AIS state shall be declared at the AIS frame detecting Station as soon as an AIS frame is received. The AIS state is released when AIS frames are absent for 2.5 ± 0.5 seconds.

2.1.2 RDI defect indication

The Station detecting a Loss Of Continuity (LOC) defect shall generate and send in the backward direction (opposite to the ringlet in which defect was detected) a RDI frame. The SA should be the detecting Station MAC address and the DA should be the MAC address of the Station sourcing the failed flow.
The RDI frame shall be generated and transmitted as soon as possible after detection of the LOC defect, and shall be periodically transmitted during the defect condition. The generation frequency of the RDI frame shall be one frame per second.
The RDI frame generation shall be stopped as soon as the defect indication is removed.
The RDI frames shall be detected at the respective flow sourcing Station. The RDI state shall be declared at the RDI frame detecting Station as soon as a RDI frame is received. The RDI state is released when RDI frames are absent for 2.5±0.5 seconds.

2.1.3 Continuity Check

Continuity Check allows detecting per flow failures, such as one Station “stealing” the frames from another Station. It can also be used to verify connectivity in the protection path.
Continuity Check frames transmission and reception can be activated using Activation/Deactivation frames or by configuration. CC frames are sent with a periodicity of nominally 1 frame per second.
When the sink Station does not receive any CC frame within a time interval of 3.5+0.5 seconds, it will declare a Loss Of Continuity (LOC) defect. LOC shall be removed when a CC frame is detected.
Each side of the Station shall have separate CC capability, LOC declaration shall be per ringlet.

2.1.4 Loopback capability

The RPR Loopback capability allows for a frame to be inserted at one Station in the ring, and returned back by another Station through the opposite ringlet, without impairing the normal flow operation. Loopback frames can be activated for each Class Of Service.
The Loopback source Station shall set the DA to the Loopback target MAC address and the SA to its own MAC address, and it shall set the Loopback indication to 00000001. The target Station shall perform the following operations:

- Clear the Loopback indication
- Change the SA to its MAC address
- Set the DA to the original Loopback frame SA
- Change the ring ID
- Loopback the resulting frame including all other unmodified fields.

The waiting time between the transmission of consecutive Loopback frames on a flow shall be 5 seconds. The Loopback shall be considered unsuccessful if the Loopback frame is not returned to the source Station within 5 seconds.

2.2 Performance Management

Performance Monitoring is one of the function groups in Performance Management. Performance Monitoring (PM) is the process of non-intrusive collection, analysis, and reporting of performance data. This data is used to assess and maintain the network as well as to document the quality of service to customers. Indications of service affecting degradation are used by Fault Management functions.
Performance Monitoring can be used in RPR to:

- Detect signal degradation
- Service restoration triggering

- Count delivered and lost packets (SLA monitoring)

Service restoration can be triggered by fault management (failed signal/node) and also by performance monitoring (signal degradation). Signal degradation and service restoration triggered by Performance Monitoring are going to be addressed in another contribution.

Packet loss (or misrouted packets) detection at the RPR level is performed by inserting monitoring frames at the source Station of a flow. The Performance Monitoring function is performed per Class Of Service. The Performance Monitoring frame uses the same Class Of Service as the correspondent flow.

Performance Monitoring Frames indicate the number of user frames transmitted between two consecutive Performance Monitoring frames. A Performance Monitoring frame is inserted every N±N/2 user frames, where N is the nominal block size.

Performance Monitoring frames transmission and reception can be activated using Activation/Deactivation frames or by configuration.

2.3 Protection Coordination

Protection coordination functions are defined in paragraph TBD.

2.4 Activation/Deactivation procedures

Performance Monitoring and Continuity Check can be activated at any time, an initialization procedure is needed between the two endpoints of the flow to properly initialize the OAM process. Specifically, this initialization procedure may serve the following purposes:

- To coordinate the beginning or end of the transmission and reception of PM or CC
- To establish the type of procedure (CC or PM)
- To specify relevant parameters (Block size for PM)

The initialization procedure may be performed either via configuration, or using the Activation/Deactivation frames.

If no response is received for an Activation/Deactivation frame within 5 seconds, the frame shall be resend. If no response is received after 3 attempts the operation shall be declared as failed.

A Station that does not support Continuity Check and/or Performance Monitoring functions shall respond to the relevant Activation messages with Activation Request Denied.

2.5 Topology Discovery

TBD

3. OAM frame handling during failures

Two protection schemes are used to protect the rings: Steer and Wrap.

3.1 Steer protection

During a single failure of the ring all the affected flows that are using CC, will declare LOC. Depending on the failure type, RDI will reach the source Station (Unidirectional failure) or not (Bidirectional failure). AIS will always reach the source Station.
The LOC state will remain until the ring failure is repaired, Activation/Deactivation frames can not deactivate CC automatically, since the affected side is unreachable by the source Station.
If SWIS is used, then the OAM frames can be marked with the wrap flag “on” and in that case the behavior will be as described in the next paragraph.

3.2 Wrap protection

During a single failure of the ring the OAM frames are wrapped, so they will reach their original destination. No LOC will be declared.

4. OAM frame

The OAM frame includes a common part and a function specific part. Figure 1 shows the general frame format.

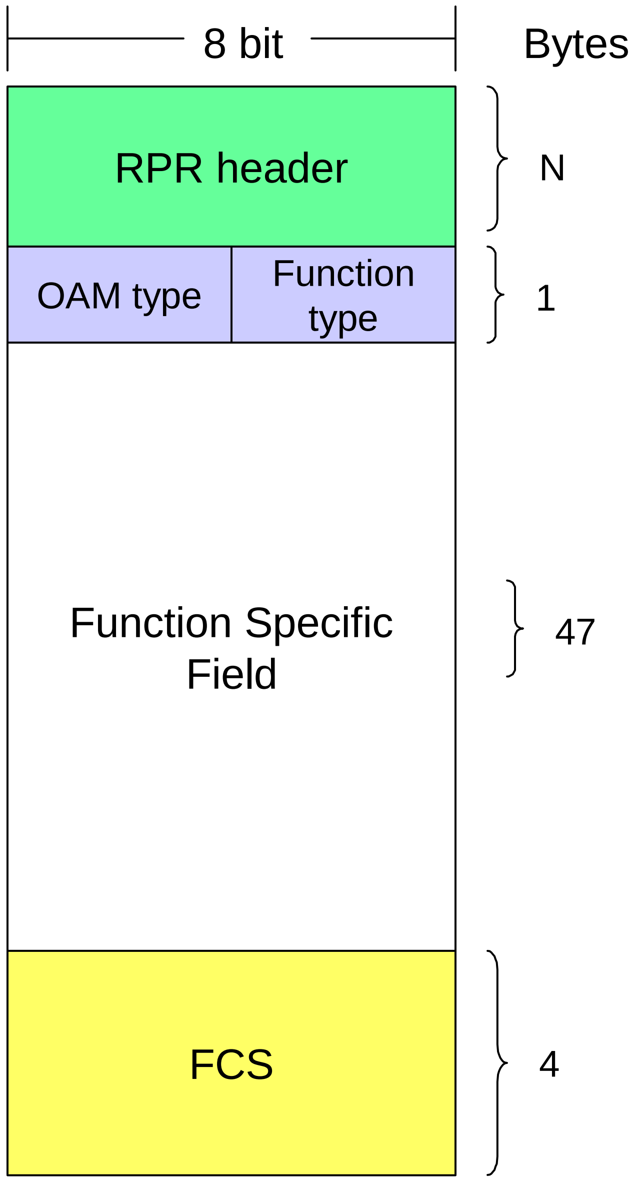


Figure 1: OAM frame format

The OAM frames length is fixed.

4.1 RPR Header

The exact format of the RPR header is TBD. The required fields for the OAM frames are:

- Source Address – MAC address of source Station
- Destination Address – MAC address of sink Station
- Frame type. In the case of OAM frames it will indicate “OAM frame”
- Class Of Service
- Separation tag - Optional

4.1.1 OAM Class Of Service

OAM CoS depends on the OAM frame type.
The following OAM frames use the highest priority class:

- AIS
- RDI
- CC
- Activation/Deactivation
- Protection Coordination

Loopback frames use the CoS defined by the operation.
Performance Monitoring frames use the same CoS as the correspondent flow

4.2 OAM Type

The OAM type identifies the OAM group of the OAM frame. Table 1 shows the possible values of the OAM type field.

4.3 Function Type

This field indicates the actual function performed by this frame within the group indicated by the OAM Type. Table 1 shows the possible values of the Function Type field.

OAM type	**Coding**	**Function Type**	**Coding**
Fault Management	0001	AIS	0000
		RDI	0001
		CC	0100
		LB	1000
Performance Management	0010	PM	0000
Protection Coordination	0101	APS	0000
Activation/Deactivation	1000	PM	0000
		CC	0001
Topology Discovery	TBD		

Table 1: OAM type field values

5. OAM frame detection procedure

OAM frames are detected through the following procedure (no specific ordering is implied):

- Check RPR header to determine if it is an OAM frame, and if it is for this Station
- Check the OAM type and Function type values according to Table 1 to determine the type of OAM frame received
- Check the FCS to determine if the received OAM frame is valid. Invalid OAM frames should not be further processed

6. Specific fields for OAM frames

The definition of the specific fields for the different OAM frames are provided in the sub clauses that follow.

6.1 Fault Management frame

The Function Type field for the Fault Management frame will be used to identify the following possible functions: AIS, RDI, CC and LB.

6.1.1 AIS/RDI Fault Management frame

The function specific fields for AIS/RDI fault management frames are illustrated in Figure 2.

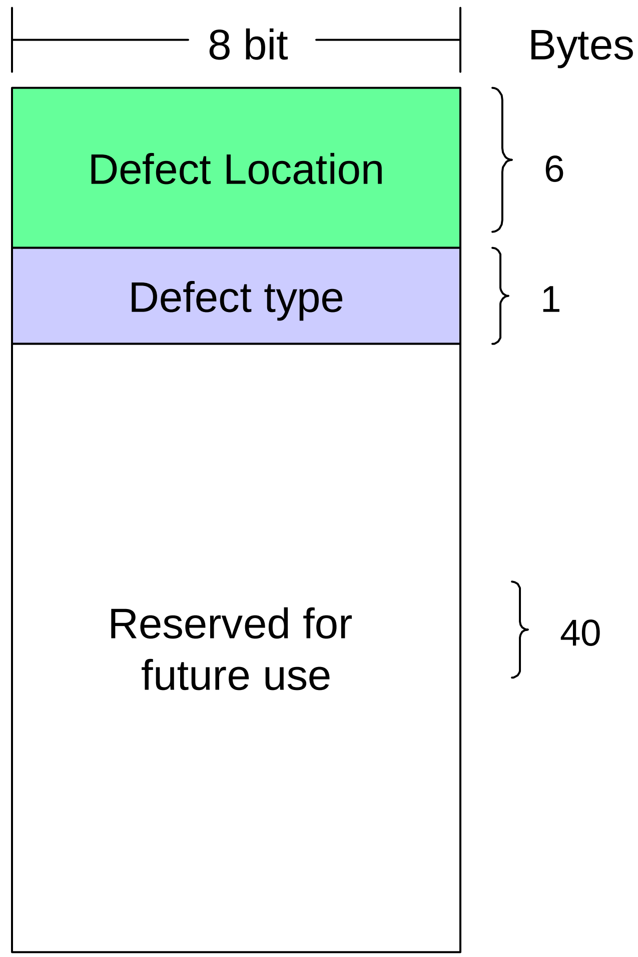


Figure 2: AIS/RDI fault management frame

6.1.1.1 Defect Location

This field carries the MAC address of the Station that detected the failure.

6.1.1.2 Defect type

Optional field used to provide further information about the nature of the failure. Examples of this information are:

- Defect not specified
- Defect in the RPR layer. For example loss of continuity.

6.1.2 Continuity Check Fault Management frame

No fields are specified for the Continuity Check Fault Management frame

6.1.3 Loopback Frame

The function specific fields for Loopback frames are illustrated in Figure 3.

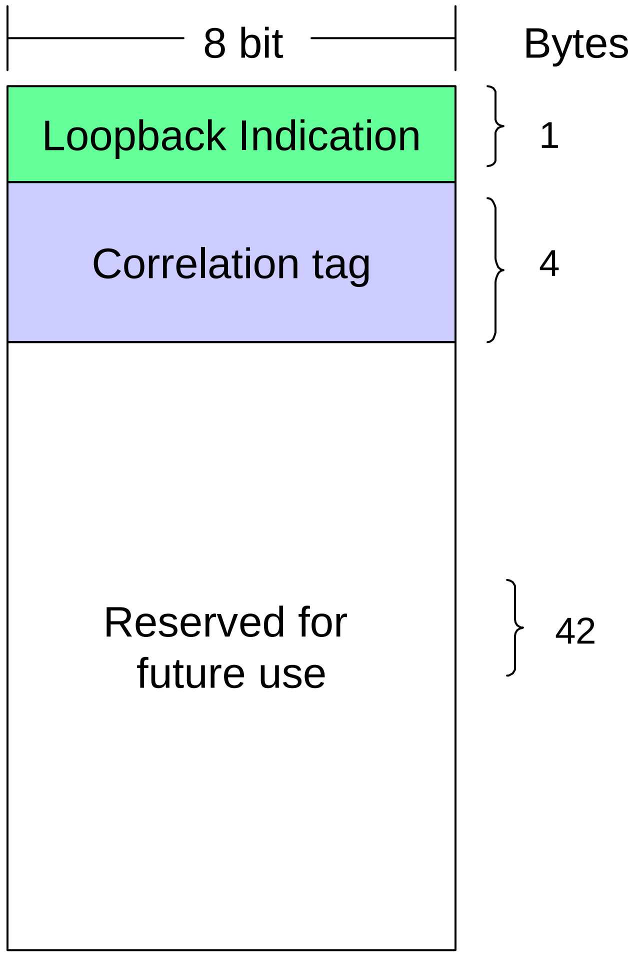


Figure 3: Loopback frame

6.1.3.1 Loopback Indication

The least significant bit of this field provides a Boolean indication as to whether or not the frame has already been looped back. The source Station encodes this field as 00000001. The Loopback Station changes the encoding to 00000000.

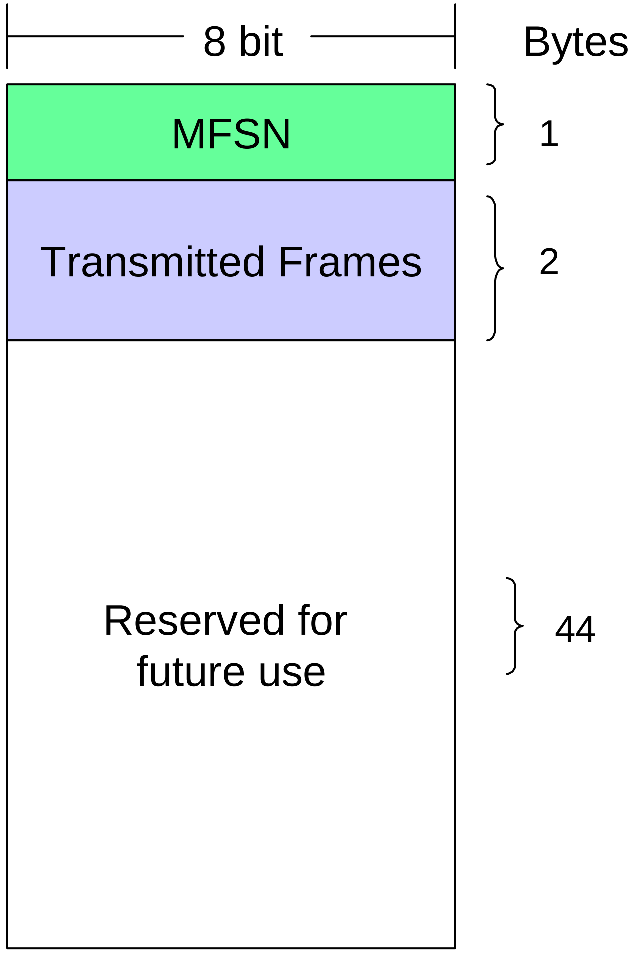
6.1.3.2 Correlation tag

A correlation tag is generated for each Loopback process so Stations can correlate Loopback commands with Loopback responses. The correlation tag in a response must match the correlation tag in the associated command. Consecutively generated correlation tags should be different, in order to correctly correlate commands with responses.

6.2 Performance Management frame

The function specific fields for the Performance Management frame are illustrated in Figure 4.

Figure 4: Performance Management frame



6.2.1 MFSN

The Monitoring Frame Sequence Number (MFSN) indicates the current value of a running counter modulo 256 of the Performance Monitoring frame sequence.

6.2.2 Transmitted Frames

This field indicates the current value of a running counter related to the total number (modulo 65536) of transmitted user frames from the source Station to the destination Station.

6.3 Protection Coordination frame

The function specific fields for the Protection Coordination frame are illustrated in Figure 5.

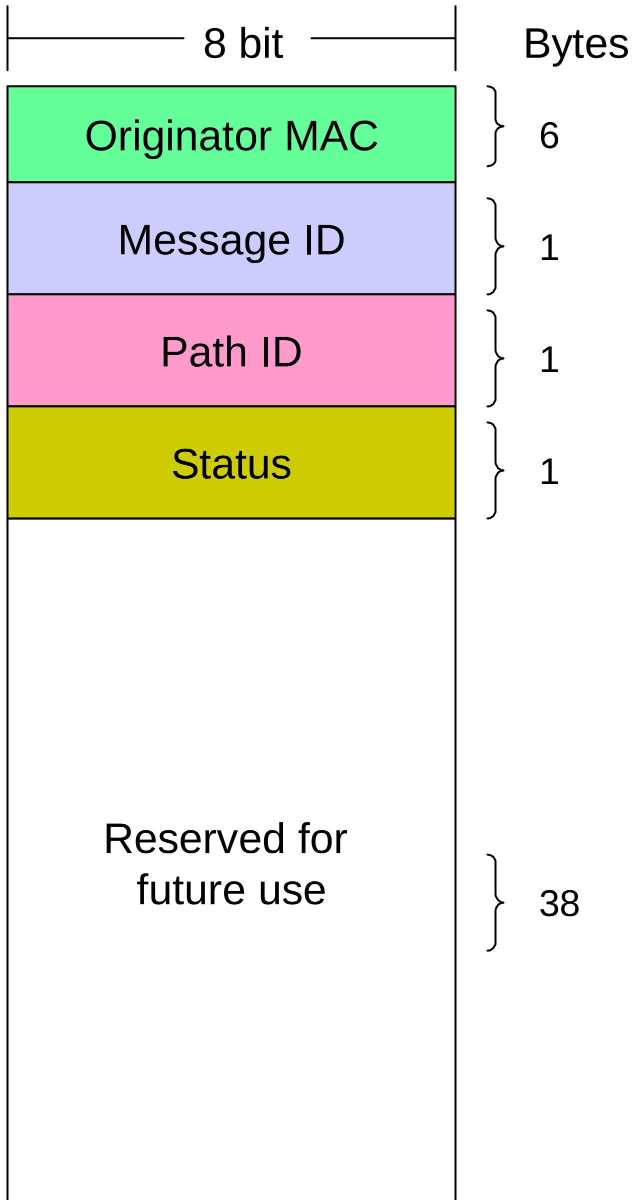

8 bit
Bytes
Originator MAC
6
Message ID
1
Path ID
1
Status
1
Reserved for future use
38

Figure 5: Protection Coordination frame

6.3.1 Originator MAC

MAC address of Station sourcing the Coordination Frame

6.3.2 Message ID

This field indicates the Message ID conveyed by the Protection Coordination frame. Code values for this field are shown in Table 2.

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

Table 2: Message ID values

6.3.3 Path ID

This field indicates the direction relative to the segment for which the request is initiated. Long indicates the path away from the segment for which the request is initiated, and short indicates the path on the segment for which the request is initiated.
Short coding is 00000000 and Long coding is 00000001

6.3.4 Status

Indicates the status of the protection process. Protection Switch Completed coding is 00000010 and Idle coding is 00000000

6.4 Activation/Deactivation frame

The Function Type field for the Activation/Deactivation frame will be used to identify the following possible functions: Performance Monitoring activation/deactivation and Continuity Check activation/deactivation.
The function specific fields for the Activation/Deactivation frame are illustrated in Figure 6.

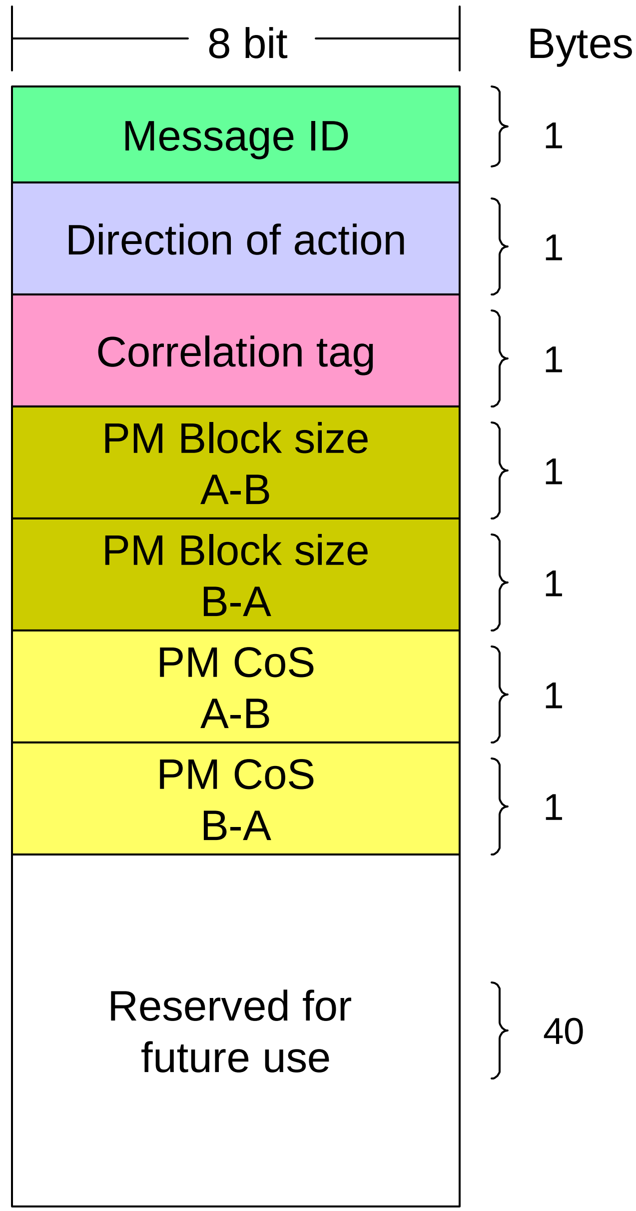


Figure 6: Activation/Deactivation frame

6.4.1 Message ID

This field indicates the Message ID for activating or deactivating specific OAM functions. Code values for this field are shown in Table 3.

Message	Command/Response	Coding
Activate	Command	00000001
Activation Confirmed	Response	00000010
Activation Request Denied	Response	00000011
Deactivate	Command	00000101
Deactivation Confirmed	Response	00000110

Table 3: Message ID values

6.4.2 Direction of Action

This field identifies the direction, or directions, of transmission to activate/deactivate OAM functions. The A-B and B-A notation is used to differentiate between the direction of transmission away or towards the activator/deactivator, respectively. This field is used as a parameter for the Activate and Deactivate messages. This field shall be encoded as shown in Table 4.

Direction	Coding
A-B	00000010
B-A	00000001
Two-way	00000011
Not applicable	00000000

Table 4: Direction values

6.4.3 Correlation tag

A correlation tag is generated for each message so Stations can correlate commands with responses. The correlation tag in a response must match the correlation tag in the associated command. Consecutively generated correlation tags should be different, in order to correctly correlate commands with responses.

6.4.4 PM Block size

These fields specify the block size for Performance Monitoring required by the activator. Values for this field are shown in Table 5. This field is used for the Activate and Activation Confirmed messages. It should be 00000000 for all other performance monitoring related messages and for all Continuity Check messages.

PM Block Size	Coding
65536	00000110
32768	00000111
16384	00001011
8192	00000011
4096	00000101
2048	00001001
1024	00000001
512	00000010
256	00000100
128	00001000

Table 5: Block size values

6.4.5 PM CoS

These fields specify the Class Of Service of the flow for which the Performance Monitoring function is required by the activator. This field is used for the Activate and Activation Confirmed messages. It should be 00000000 for all other performance monitoring related messages and for all Continuity Check messages.

6.5 Topology Discovery

TBD