



GROUP SPECIFICATION

Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; Interface and Information Model Specification for Multi-Site Connectivity Services

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Reference

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Foreword

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Modal verbs terminology

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1 Scope

The present document specifies the interfaces for management of multi-site connectivity services. The services are produced by a WAN Infrastructure Manager (WIM). The present document also describes the operations and the information elements that are exchanged over these interfaces.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

- [1] ETSI GS NFV-IFA 010: "Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; Functional requirements specification".
- [2] ETSI GS NFV-SEC 012 (V3.1.1): "Network Functions Virtualisation (NFV) Release 3; Security; System architecture specification for execution of sensitive NFV components".
- [3] Recommendation ITU-T X.733: "Information technology - Open Systems Interconnection - Systems Management: Alarm reporting function".

2.2 Informative references

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ETSI GS NFV 003: "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".
- [i.2] ETSI GS NFV-MAN 001: "Network Functions Virtualisation (NFV); Management and Orchestration".
- [i.3] ETSI GR NFV-IFA 022: "Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; Report on Management and Connectivity for Multi-Site Services".
- [i.4] IETF RFC 8453: "Framework for Abstraction and Control of TE Networks (ACTN)".

NOTE: Available at <https://tools.ietf.org/html/rfc8453>.

- [i.5] IETF RFC 8454: "Information Model for Abstraction and Control of TE Networks (ACTN)".

NOTE: Available at <https://tools.ietf.org/html/rfc8454>.

- [i.6] ETSI GS NFV-SEC 006 (V1.1.1): "Network Functions Virtualisation (NFV); Security Guide; Report on Security Aspects and Regulatory Concerns".
- [i.7] ETSI GS NFV-SEC 014 (V3.1.1): "Network Functions Virtualisation (NFV) Release 3; NFV Security; Security Specification for MANO Components and Reference Points".
- [i.8] ETSI GS NFV-IFA 031 (V3.2.1): "Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; Requirements and interfaces specification for management of NFV-MANO".
- [i.9] ETSI GS NFV-IFA 005 (V3.2.1): "Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; Or-Vi reference point - Interface and Information Model Specification".
- [i.10] ISO/IEC 9646-7: "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 7: Implementation Conformance Statements".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GS NFV 003 [i.1] and the following apply:

NOTE: A term defined in the present document takes precedence over the definition of the same term, if any, in ETSI GS NFV 003 [i.1].

Multi-site Connectivity Service (MSCS): connectivity service abstracting the details of information regarding the connections between two or more NFVI-PoP (site) network endpoints

Multi-site Network Connection (MSNC): provisioned multi-site network connectivity enabling the data forwarding between two or more network edge points

NOTE: In the present document, the network edge points represent the ingress/egress ports of the network(s) in between the NFVI-PoPs (sites).

Multi-Site Network Service (MSNS): network service whose constituent Network Functions/Network Services are deployed in more than one site

site: NFVI Point of Presence (NFVI-PoP), as defined in ETSI GS NFV 003 [i.1].

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GS NFV 003 [i.1] and the following apply:

NOTE: An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in ETSI GS NFV 003 [i.1].

Mscs	Multi-site connectivity service
MSNC	Multi-site Network Connection

4 Overview of interfaces and information elements for multi-site connectivity services

4.1 Introduction

This clause provides an overview of interfaces and information elements exposed or consumed by the WIM.

Clause 5.2 of ETSI GR NFV-IFA 022 [i.3] introduces the concept of multi-site service spanning a Wide Area Network (WAN).

Figure 4.1-1 illustrates an example of such multi-site service, composed of 2 VNFs, each one located in a different NFVI-PoP. The NS VL connecting those 2 VNFs is made of a virtual network in each NFVI-PoP and a Multi-site connectivity service (MSCS) provided by the WIM that enables connecting virtualised network resources in each NFVI-PoP to create an overall multi-site Virtual Link.

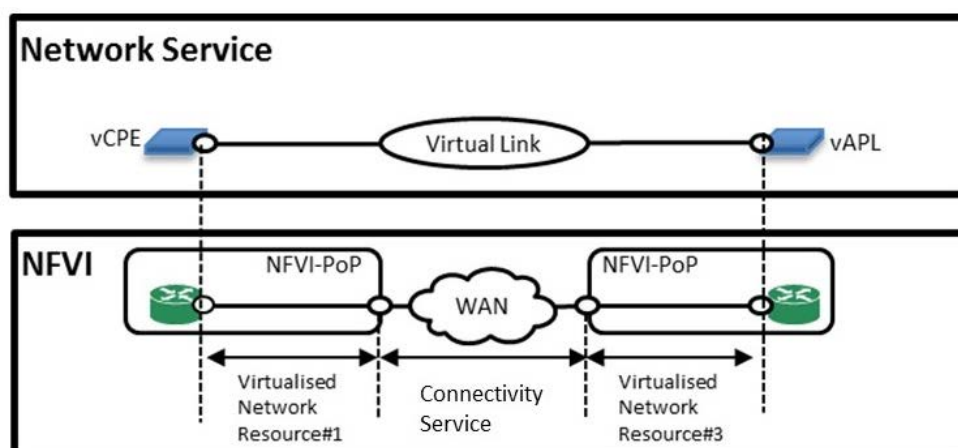


Figure 4.1-1: Connectivity example for enabling Network Service

As mentioned in ETSI GR NFV-IFA 022 [i.3], clause 5.4.3 of ETSI GS NFV-MAN 001 [i.2] introduces the concept of WAN Infrastructure Manager (WIM) which is typically used to establish connectivity between endpoints in different NFVI-PoPs. Clause 5.6 of ETSI GS NFV-MAN 001 [i.2] shows a "hybrid network environment example illustrating the goal of NFV to have fully programmable open interfaces for service and Resource Orchestration within and across NFVI-PoPs". It further describes establishing an end-to-end connectivity across virtualised networks in the NFVI-PoPs and the WAN, under the control of the NFVI-PoP's VIMs and WAN's WIMs.

The WIM offers the following interfaces:

- MSCS Management interface.
- Capacity Management interface.
- Fault Management interface.
- Performance Management interface.

The information elements exchanged via the interfaces above are part of the present document and are described in subsequent clauses.

4.2 Concepts of multi-site connectivity management

The present document specifies interfaces offered by the WIM that enable a consumer (e.g. an NFVO) to request the establishment of network connectivity in between different endpoints at different NFVI-PoPs.

For the establishment of the network connectivity, the WIM may rely on network controllers that handle the fulfilment of the connectivity at a lower level, potentially making use of different network technologies and protocols. The WIM offers to the consumers an abstraction of such network connectivity to ease the provisioning and monitoring of it.

Two types of managed objects are exposed by the WIM concerning network connectivity:

- Multi-Site Connectivity Service (MSCS).
- Multi-Site Network Connection (MSNC).

A MSNC represents the provisioned connectivity enabling the data forwarding between two or more network edge points of the network(s) in between different NFVI-PoPs. MSNCs can be established via diverse network protocols and at different network layers.

A MSCS abstracts the details of network connectivity that is realized by one or more MSNCs. At the same time, the MSCS represents the service agreement in between the consumer and the producer (the WIM) for the required connectivity to be established to connect a set of endpoints.

The following interactions are enabled via the specified interfaces in the present document (not an exhaustive list):

- A consumer can request the creation of a MSCS. The MSCS is fulfilled by the WIM via one or more MSNCs.
- A consumer can retrieve information about a MSCS and the MSNCs that fulfil such a MSCS.
- A consumer can retrieve information about the endpoints among which network connectivity can be provided.
- A consumer can request updating a MSCS, e.g. adding new MSNCs, terminating or updating existing MSNCs.
- A consumer can monitor a MSCS and receive performance and fault monitoring information about the MSNCs that have been provisioned as part of the MSCS.

The MSCS and MSNC are the managed objects by the WIM, which are referred otherwise as "virtualised network resources" in the functional requirements for management of connectivity of Multi-Site services in clauses 6.18 and 11.2 of ETSI GS NFV-IFA 010 [1].

4.3 Multi-site connectivity network framework and resources

The provisioning and lifecycle of MSCSs is supported by the resources of the network(s) interconnecting the different sites. Figure 4.3-1 illustrates an example of a network interconnecting a single domain multi-site environment and the concepts and type of resources supporting the creation of connectivity.

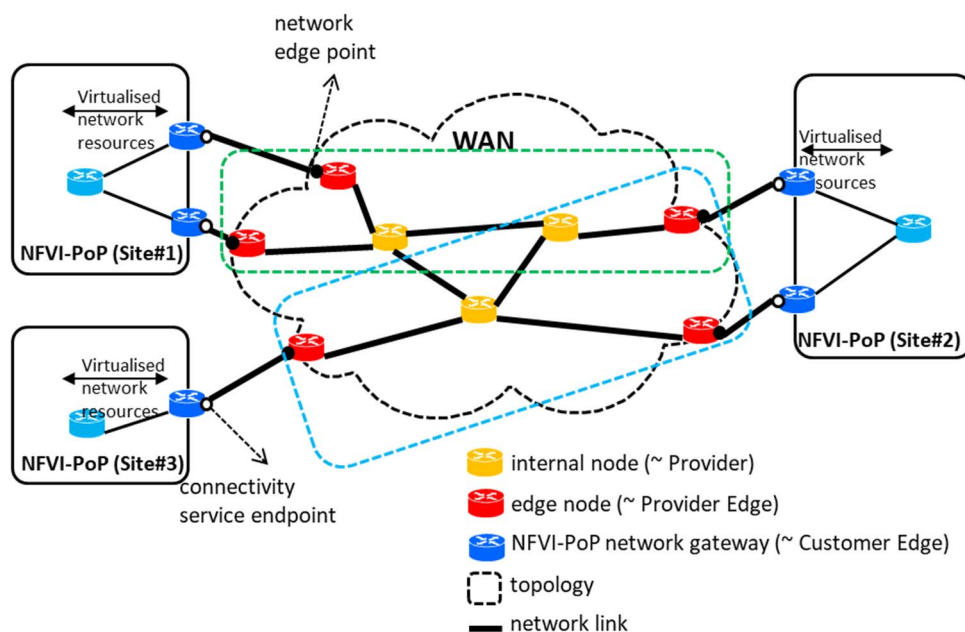


Figure 4.3-1: Multi-site connectivity network framework and concepts

The resources involved in enabling the multi-site connectivity are:

1) Network node

These are the nodes (physical or virtual) enabling the forwarding of data. A node can be internal to the WAN or at the edge of a WAN, exposing network edge points of connectivity for the NFVI-PoPs.

EXAMPLE 1: An example of an internal node is a "Provider" (P) router, and an example of edge node is "Provider Edge" (PE) router.

2) Network link

The network links interconnect and represent the adjacency in between the network nodes of the WAN, and in between the edge network nodes of the WAN and the endpoint nodes in the NFVI-PoP, such as the NFVI-PoP network gateway.

3) Network edge point

The network edge points represent the ingress/egress ports of the (WAN) network(s) in between the NFVI-PoPs (sites). These ports are part of the network edge nodes.

4) Connectivity service endpoint

The connectivity service endpoint is associated to a termination point of the NFVI-PoP (site), which in can be used as an endpoint of the connectivity fulfilled by the MSCS.

The connectivity service endpoint also represents the User Network Interface (UNI) between the NFVI-PoP and the external network that interconnects the multiple sites. In this sense, the connectivity service endpoint represents the shared context information of the network edge link (a.k.a, access link) connecting the NFVI-PoP and the external network (refer also to the VIM's managed object ConnectivityServiceEndpoint defined in clause 8.10.4 of ETSI GS NFV-IFA 005 [i.9]).

EXAMPLE 2: An example of a node providing ports/interfaces as connectivity service endpoint is a "Customer Edge" (CE) router.

5) Network topology

The network topology is a representation of interconnectivity of a particular set of network resources described in terms of network nodes and network links, wherein the forwarding of data among the particular set of network resources is enabled.

A multi-site WAN network has a 1:N relationship with network topology, i.e. one or more network topologies can be represented on top of the network node and link resources. Figure 4.3-1 illustrates an example with two network topologies represented over the WAN.

4.4 Multi-site connectivity network framework and relationship to Network Service

The provisioning and lifecycle of MSCSs is supported by the resources of the WAN interconnecting the different sites. In turn, the MSCS(s) are part of the "resources" forming the NS Virtual Link(s), as also introduced in clause 4.1. Figure 4.4-1 illustrates the relationship between the multi-site connectivity network resources and the multi-site NS.

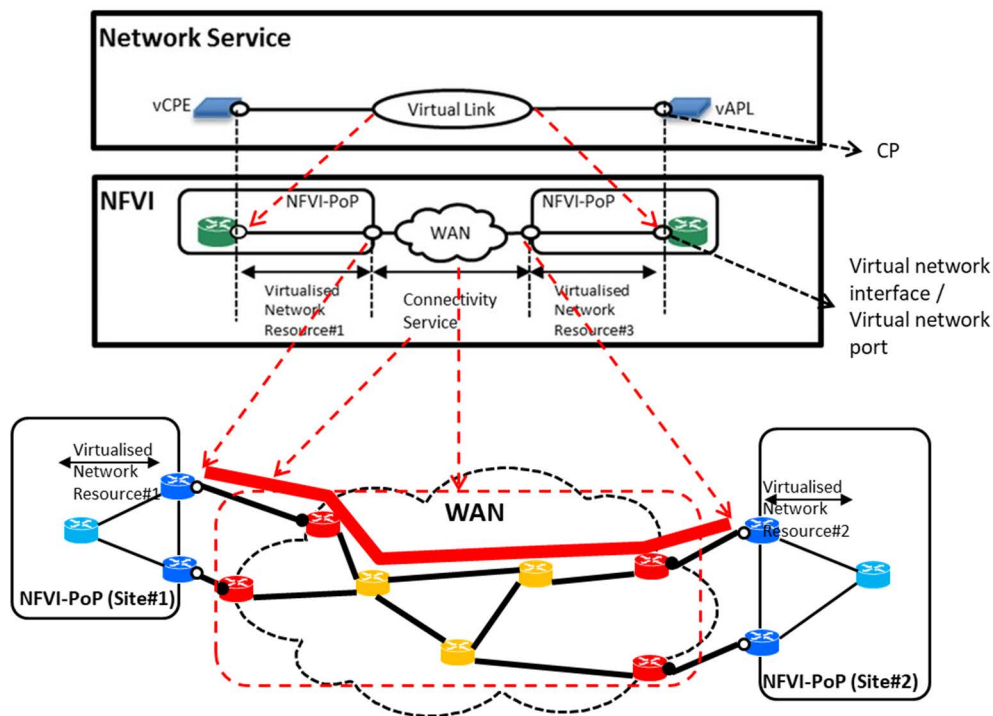


Figure 4.4-1: Multi-site connectivity network framework and relationship to Network Service

In the example of figure 4.4-1, the two VNF instances, vCPE and vAPL, have corresponding CP instances to connect to the NS Virtual Link. The CP instances are realized via network interface resources from the NFVI-PoP and attached to the link ports exposed on virtual network resources also from the NFVI-PoP. The NS Virtual Link is realized with the virtualised network resources from the NFVI-PoPs and the MSCS on the WAN. The MSCS is established in between two connectivity service endpoints, each one associated to ports/interfaces on the corresponding NFVI-PoP network gateways.

4.5 Relation to other NFV Group Specifications

The present document is referencing information from the following NFV Group Specifications and Group Reports:

- Management and Orchestration - Report on Management and Connectivity for Multi-Site Services ETSI GR NFV-IFA 022 [i.3]:
 - ETSI GR NFV-IFA 022 [i.3] provides use cases and recommendations related to multi-site services over WAN.
- Management and Orchestration - Functional requirements specification ETSI GS NFV-IFA 010 [1]:
 - Interfaces exposed and consumed by the WIM are based on the functional requirements specified in ETSI GS NFV-IFA 010 [1] for the WIM FB.

5 Requirements

5.1 Introduction and conventions

5.1.1 Overview

This clause defines or references requirements applicable to interfaces exposed by the WIM.

5.1.2 Conventions

The following notations, defined in ISO/IEC 9646-7 [i.10], are used for the qualifier column of interface information elements:

- M mandatory - the capability is required to be supported.
- O optional - the capability may be supported or not.
- N/A not applicable - in the given context, it is impossible to use the capability.
- CM conditional mandatory - the capability is required to be supported and is conditional on the support of some condition. This condition shall be specified in the Description column.
- CO conditional optional - the capability may be supported or not and is conditional on the support of some condition. This condition shall be specified in the Description column.

The following notation is used for parameters that represent identifiers, and for attributes that represent identifiers in information elements and notifications:

- If parameters are referring to an identifier of an actual object, their type is "Identifier".
- If an object (information element or notification) contains an attribute that identifies the object, the type of that attribute is "Identifier" and the description states that the attribute is the identifier of that particular notification or information element.

EXAMPLE: Identifier "resourceId" of the "NetworkSubnet information element" has type "Identifier" and description "Identifier of this NetworkSubnet information element".

5.2 WIM interface requirements

Table 5.2-1 specifies requirements applicable to the interfaces exposed by the WIM.

Table 5.2-1: WIM interface requirements

Number	Functional requirement description
WimIf.001	The WIM shall provide a MSCS Management interface.
WimIf.002	The WIM shall provide a Capacity Management interface.
WimIf.003	The WIM shall provide a Fault Management interface.
WimIf.004	The WIM shall provide a Performance Management interface.

5.3 Interface requirements

5.3.1 MSCS Management interface requirements

Table 5.3.1-1 specifies requirements applicable to the MSCS Management interface produced by the WIM.

Table 5.3.1-1: MSCS Management interface requirements

Numbering	Functional requirements description
Wimlf.Csm.001	The MSCS Management interface produced by the WIM shall support requesting the creation of a MSCS.
Wimlf.Csm.002	The MSCS Management interface produced by the WIM shall support querying information about MSCSs.
Wimlf.Csm.003	The MSCS Management interface produced by the WIM shall support updating a MSCS.
Wimlf.Csm.004	The MSCS Management interface produced by the WIM shall support deleting a MSCS.
Wimlf.Csm.005	The MSCS Management interface produced by the WIM shall support providing state change notifications about MSCSs.
Wimlf.Csm.006	The MSCS Management interface produced by the WIM shall support creating MSCS reservations.
Wimlf.Csm.007	The MSCS Management interface produced by the WIM shall support querying information about MSCS reservations.
Wimlf.Csm.008	The MSCS Management interface produced by the WIM shall support updating MSCS reservations.
Wimlf.Csm.009	The MSCS Management interface produced by the WIM shall support terminating MSCS reservations.
Wimlf.Csm.010	The MSCS Management interface produced by the WIM shall support notification of changes related to the MSCS reservation.

5.3.2 Capacity Management interface requirements

Table 5.3.2-1 specifies requirements applicable to the Capacity Management interface produced by the WIM.

Table 5.3.2-1: Capacity Management interface requirements

Numbering	Functional requirements description
Wimlf.Cm.001	The Capacity Management interface produced by the WIM shall support querying the capacity, in terms of: <ul style="list-style-type: none"> the amount of available resources (of a certain type and characteristics); and the total amount of resources (of a certain type and characteristics) based on input filter criteria.
Wimlf.Cm.002	The Capacity Management interface produced by the WIM shall support notifications to the consumer of changes in the available and total capacity.
Wimlf.Cm.003	The Capacity Management interface produced by the WIM shall support the query of information about topology within the WAN managed by the WIM.
Wimlf.Cm.004	The Capacity Management interface produced by the WIM shall support querying information about service end points offered by the WAN.

5.3.3 Fault Management interface requirements

Table 5.3.3-1 specifies requirements applicable to the Fault Management interface produced by the WIM.

Table 5.3.3-1: Fault Management interface requirements

Numbering	Functional requirements description
Wimlf.Fm.001	The Fault Management interface produced by the WIM shall enable collecting fault information about MSCSs.
Wimlf.Fm.002	The Fault Management interface produced by the WIM shall support providing alarm notifications related to faults on MSCSs.
Wimlf.Fm.003	The Fault Management interface produced by the WIM shall support providing notification when there is a change in alarm information on MSCSs.
Wimlf.Fm.004	The Fault Management interface produced by the WIM shall support the sending of notification when an alarm has been created.
Wimlf.Fm.005	The Fault Management interface produced by the WIM shall support the sending of notification when an alarm has been cleared.
Wimlf.Fm.006	The Fault Management interface produced by the WIM shall allow unambiguous identification of the alarm.
Wimlf.Fm.007	The Fault Management interface produced by the WIM shall allow unambiguous identification of the MSCS causing the alarm.
Wimlf.Fm.008	The Fault Management interface produced by the WIM point shall allow unambiguous identification of the alarm cause.

5.3.4 Performance Management interface requirements

Table 5.3.4-1 specifies requirements applicable to the Performance Management interface produced by the WIM.

Table 5.3.4-1: Performance Management interface requirements

Numbering	Functional requirements description
Wimlf.Pm.001	The Performance Management interface produced by the WIM shall enable controlling the collection and reporting of performance information for MSCSs.
Wimlf.Pm.002	The Performance Management interface produced by the WIM shall support the capability to notify the availability of performance information.
Wimlf.Pm.003	The Performance Management interface produced by the WIM shall expose the type of network resources for which the WIM collects the performance information in the WAN domain.
Wimlf.Pm.004	The Performance Management interface produced by the WIM shall expose the type of performance information that the WIM can collect for the monitored MSCS(s).
Wimlf.Pm.005	The Performance Management interface produced by the WIM shall enable creating a PM job specifying the type of resource(s) and performance information that are required.
Wimlf.Pm.006	The Performance Management interface produced by the WIM shall enable creating a PM job specifying the granularity for collection and reporting of performance information from specified MSCS(s).
Wimlf.Pm.007	The Performance Management interface produced by the WIM shall enable deleting a PM job.
Wimlf.Pm.008	The Performance Management interface produced by the WIM shall enable issuing notifications of data availability for a PM job.
Wimlf.Pm.009	The Performance Management interface produced by the WIM shall support PM jobs for periodic collection of performance information (bounded or unbounded).
Wimlf.Pm.010	The Performance Management interface produced by the WIM shall support the grouping of measurements (see note).
Wimlf.Pm.011	The Performance Management interface produced by the WIM shall support the setting of threshold conditions on the performance information collected by the WIM for specified MSCS(s).
Wimlf.Pm.012	The Performance Management interface produced by the WIM shall support the deletion of threshold conditions on the performance information collected by the WIM for specified MSCS(s).
Wimlf.Pm.013	The Performance Management interface produced by the WIM shall support the capability to notify about a threshold defined for a specified metric of a MSCS being crossed.
Wimlf.Pm.014	The Performance Management interface produced by the WIM shall enable issuing notifications related to threshold crossing.
Wimlf.Pm.015	The Performance Management interface produced by the WIM shall support querying the list of active PM jobs and defined threshold conditions by the consumer entity that created them.
NOTE:	The measurement group does not imply any modification/aggregation of performance measurements data and may be viewed as an alias for a pre-defined list of measurements.

6 Interfaces exposed by WIM

6.1 Introduction

Clause 5.8.2 of ETSI GS NFV-MAN 001 [i.2] introduces the producer-consumer paradigm, *"Interfaces represent a published contract offered by a producer functional block, exposing externally the functions produced. They can be consumed by any other consumer functional block that is authenticated and authorized to access and consume the functions offered"*.

For all the interfaces in this clause, the producer exposing the interfaces is the WIM.

6.2 MSCS Management Interface

6.2.1 Description

This interface allows an authorized consumer to perform operations related to MSCS. The following operations are defined for this interface:

- Create MSCS
- Query MSCS
- Update MSCS
- Terminate MSCS
- Subscribe
- Notify
- Query Subscription Info
- Terminate Subscription
- Create MSCS Reservation
- Query MSCS Reservation
- Update MSCS Reservation
- Terminate MSCS Reservation

6.2.2 Create MSCS operation

6.2.2.1 Description

This operation allows an authorized consumer to request the creation of a MSCS from the WIM.

Table 6.2.2.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.2.1-1: Create MSCS operation

Message	Requirement	Direction
CreateMscsRequest	Mandatory	Consumer → WIM
CreateMscsResponse	Mandatory	WIM → Consumer

6.2.2.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.2.2-1.

Table 6.2.2.2-1: Create MSCS operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
reservationId	M	0..1	Identifier	Identifier of the resource reservation applicable to this MSCS management operation.
mscsData	M	1	MscsData	The MSCS data provides information about the particular MSCS to be created.

6.2.2.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.2.3-1.

Table 6.2.2.3-1: Create MSCS operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
mscs	M	1	Mscs	If MSCS type is created satisfactorily, it shall contain the data relative to the instantiated MSCS. See clause 8.2.2.5.

6.2.2.4 Operation results

As a result of this operation, the producer (WIM) shall indicate to the consumer whether or not the MSCS was successfully created. If the operation was not successful, the WIM shall return to the consumer appropriate error information.

6.2.3 Query MSCS operation

6.2.3.1 Description

This operation allows querying information about instantiated MSCSs from the WIM.

Table 6.2.3.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.3.1-1: Query MSCS operation

Message	Requirement	Direction
QueryMscsRequest	Mandatory	Consumer → WIM
QueryMscsResponse	Mandatory	WIM → Consumer

6.2.3.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.3.2-1.

Table 6.2.3.2-1: Query MSCS operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Query filter based on e.g. name, identifier, meta-data information or status information, expressing the type of information to be retrieved. It can also be used to specify one or more MSCSs to be queried by providing their identifiers.
attributeSelector	M	0..N	String	It provides a list of attribute names of MSCS. If present, only these attributes shall be returned for the MSCS matching the filter. If absent, the information of the complete MSCS shall be returned.

6.2.3.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.3.3-1.

Table 6.2.3.3-1: Query MSCS operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
queryResult	M	0..N	Mscs	Details of the MSCS information available and matching the input filter. If attributeSelector is present, only the attributes listed in attributeSelector shall be returned for the selected entities.

6.2.3.4 Operation results

As a result of this operation, the producer (WIM) shall indicate to the consumer whether or not it was possible to process the query. If the operation was not successful, the WIM shall return to the consumer appropriate error information.

6.2.4 Update MSCS operation

6.2.4.1 Description

This operation allows updating the information of an instantiated MSCS, e.g. name and description, as well as properties of the instantiated MSCS, such as adding/removing MSCS endpoints or changing the MSCS profile.

Table 6.2.4.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.4.1-1: Update MSCS operation

Message	Requirement	Direction
UpdateMscsRequest	Mandatory	Consumer → WIM
UpdateMscsResponse	Mandatory	WIM → Consumer

6.2.4.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.4.2-1.

Table 6.2.4.2-1: Update MSCS operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
connectivityServiceId	M	1	Identifier	Identifier of the MSCS to be updated.
addMscsEndpoint	M	0..N	MscsEndpointData	Information about the MSCS endpoints to add to the MSCS.
removeMscsEndpoint	M	0..N	Identifier (Reference to MscsEndpointInfo)	Identifier of the MSCS Endpoints to remove from the MSCS.
modifyMscsEndpoint	M	0..N	MscsEndpointInfo	Properties of an existing MSCS endpoint of the MSCS to change. The mscsEndpointId of the MscsEndpointInfo to change shall refer to an existing MSCS endpoint in the MSCS.
modifyMscsProfile	M	0..1	MscsProfile	New properties of the MSCS profile to change.
mscsName	M	0..1	String	New human readable name for the MSCS.
mscsDescription	M	0..1	String	New human readable description for the MSCS

NOTE: In the multiple input parameters, cardinality zero supports the case of not requesting to update such an attribute.

6.2.4.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.4.3-1.

Table 6.2.4.3-1: Update MSCS operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
mscs	M	0..1	Mscs	It contains the data relative to the MSCS updated successfully. See clause 8.2.2.5.

6.2.4.4 Operation results

As a result of this operation, the producer (WIM) shall indicate to the consumer whether or not the MSCS was successfully updated. If the operation was not successful, the WIM shall return to the consumer appropriate error information.

As part of the update, changes in the existing set of MSNC supporting the MSCS can be performed. For instance, a new MSNC can be created to address changes in the MSCS connectivity profile, due to the addition/removal/update of MSCS endpoints.

6.2.5 Terminate MSCS operation

6.2.5.1 Description

This operation allows terminating one instantiated MSCS. Table 6.2.5.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.5.1-1: Terminate MSCS operation

Message	Requirement	Direction
TerminateMscsRequest	Mandatory	Consumer → WIM
TerminateMscsResponse	Mandatory	WIM → Consumer

6.2.5.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.5.2-1.

Table 6.2.5.2-1: Terminate MSCS operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
connectivityServiceId	M	1	Identifier	Identifier of the MSCS to be terminated.

6.2.5.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.5.3-1.

Table 6.2.5.3-1: Terminate MSCS operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
connectivityServiceId	M	1	Identifier	Identifier of the MSCS that is terminated successfully.

6.2.5.4 Operation results

As a result of this operation, the producer (WIM) shall indicate to the consumer whether or not the MSCS was successfully terminated. If the operation was not successful, the WIM shall return to the consumer appropriate error information.

6.2.6 Subscribe operation

6.2.6.1 Description

This operation enables an authorized consumer to subscribe with a filter in order to receive notifications sent by the WIM which are related to MSCS changes or MSCS reservation changes. Table 6.2.6.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.6.1-1: Subscribe operation

Message	Requirement	Direction
SubscribeRequest	Mandatory	Consumer → WIM
SubscribeResponse	Mandatory	WIM → Consumer

6.2.6.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.6.2-1.

Table 6.2.6.2-1: Subscribe operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Input filter for selecting notifications to subscribe to changes related to MSCS or MSCS reservation. The filter can be on resource, type of notification or attribute of the notification.

6.2.6.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.6.3-1.

Table 6.2.6.3-1: Subscribe operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Identifier of the subscription realized.

6.2.6.4 Operation results

After successful subscription, the consumer is registered to receive notifications sent by the WIM which are related to MSCS changes or MSCS reservation changes. The result of the operation shall indicate if the subscription has been successful or not with a standard success/error result. For a particular subscription, only notifications matching the filter will be delivered to the consumer.

6.2.7 Notify operation

6.2.7.1 Description

This operation distributes notifications to subscribers. It is a one-way operation issued by the WIM that cannot be invoked as an operation by the consumer. In order to receive notifications, the consumer shall have a subscription. Table 6.2.7.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.7.1-1: Notify operation

Message	Requirement	Direction
Notify	Mandatory	WIM → Consumer

The following notifications can be notified/sent by this operation:

- MscsChangeNotification. See clause 8.2.4.
- MscsReservationChangeNotification. See clause 8.2.5.

6.2.8 Query Subscription Info operation

6.2.8.1 Description

This operation enables the consumer to query information about subscriptions table 6.2.8.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.8.1-1: Query Subscription Info operation

Message	Requirement	Direction
QuerySubscriptionInfoRequest	Mandatory	Consumer → WIM
QuerySubscriptionInfoResponse	Mandatory	WIM → Consumer

6.2.8.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.8.2-1.

Table 6.2.8.2-1: Query Subscription Info operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filtering criteria to select one or a set of subscriptions. See note.
NOTE: Details are left for the protocol design stage.				

6.2.8.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.8.3-1.

Table 6.2.8.3-1: Query Subscription Info operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
queryResult	M	0..N	Not Specified	Information about the subscription(s) matching the query (see note).
NOTE: Details are left for the protocol design stage.				

6.2.8.4 Operation results

After successful operation, the WIM has queried the internal subscription objects. The result of the operation indicates if it has been successful or not with a standard success/error result. For a particular query, information about the subscriptions to notifications that are matching the filter shall be returned.

6.2.9 Terminate Subscription operation

6.2.9.1 Description

This operation enables the consumer to terminate a particular subscription.

Table 6.2.9.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.9.1-1: Terminate Subscription operation

Message	Requirement	Direction
TerminateSubscriptionRequest	Mandatory	Consumer → WIM
TerminateSubscriptionResponse	Mandatory	WIM → Consumer

6.2.9.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.9.2-1.

Table 6.2.9.2-1: Terminate Subscription operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Identifier of the subscription to be terminated.

6.2.9.3 Output Parameters

No output parameter.

6.2.9.4 Operation results

After successful termination of a subscription, the identified subscription does not exist anymore, and the consumer will not receive notifications related to that subscription any longer. The result of the operation shall indicate if the subscription termination has been successful or not with a standard success/error result.

6.2.10 Create MSCS Reservation operation

6.2.10.1 Description

This operation allows an authorized consumer to request the reservation of MSCS from the WIM.

Table 6.2.10.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.10.1-1: Create MSCS Reservation operation

Message	Requirement	Direction
CreateMscsReservationRequest	Mandatory	Consumer → WIM
CreateMscsReservationResponse	Mandatory	WIM → Consumer

6.2.10.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.10.2-1.

Table 6.2.10.2-1: Create MSCS Reservation operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
mscsReservation	M	1	MscsReservationData	The properties that characterize the MSCS that needs to be reserved. See clause 8.2.3.2.
startTime	M	1	DateTime	Indicates the earliest time to start the use of the MSCS. A value of 0 indicates that the MSCS is reserved for immediate use.
endTime	M	0..1	DateTime	Indicates the end time of the MSCS reservation and is used by the WIM to schedule the reservation. If not present, the MSCS is reserved for unlimited time.
expiryTime	M	0..1	DateTime	Indicates the time the WIM can release the reservation in case no allocation request against this reservation was made.

6.2.10.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.10.3-1.

Table 6.2.10.3-1: Create MSCS Reservation operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
reservationData	M	1	ReservedMscs	Element containing information about the reserved MSCS. See clause 8.2.3.3.

6.2.10.4 Operation results

After successful operation, the WIM has created the internal management objects for the MSCS reservation and updated the information about the MSCS capacity according to the newly reservations. In addition, the WIM shall return to the consumer information on the newly created reservation plus any additional information about the create reservation request operation. The WIM may also return intermediate status reports during the reservation process.

If the operation was not successful, the WIM shall return to the consumer appropriate error information.

6.2.11 Query MSCS Reservation operation

6.2.11.1 Description

This operation allows querying information about reserved MSCS that the consumer has access to.

Table 6.2.11.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.11.1-1: Query MSCS Reservation operation

Message	Requirement	Direction
QueryMscsReservationRequest	Mandatory	Consumer → WIM
QueryMscsReservationResponse	Mandatory	WIM → Consumer

6.2.11.2 Input parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.11.2-1.

Table 6.2.11.2-1: Query MSCS Reservation operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
queryReservationFilter	M	1	Filter	Query filter based on e.g. layer protocol or reservation status. It can also be used to specify one or more reservations to be queried by providing their identifiers.
attributeSelector	M	0..N	String	It provides a list of attributes names of ReservedMscs. If present, only these attributes are returned for the reserved MSCS matching the filter. If absent, the complete information of the reserved MSCS is returned.

6.2.11.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.11.3-1.

Table 6.2.11.3-1: Query MSCS Reservation operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
queryResult	M	0..N	ReservedMscs	Element containing information about the reserved MSCS matching the input filter. If attributeSelector is present, only the attributes listed in attributeSelector are returned for the selected entities. The cardinality can be 0 if no matching reservation exists. See clause 8.2.3.3.

6.2.11.4 Operation results

After successful operation, the WIM has queried the internal management objects for the MSCS reservations. The result of the query shall indicate with a standard success/error result if the query has been processed correctly. For a particular query, information about the MSCS reservations that the consumer has access to and that are matching the filter shall be returned.

6.2.12 Update MSCS Reservation operation

6.2.12.1 Description

This operation allows updating MSCS reservations, such as the timing schedule (start, end and expiry time), adding/removing MSCS endpoints to the reserved set or changing the MSCS profile of the reserved MSCS.

Table 6.2.12.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.12.1-1: Update MSCS Reservation operation

Message	Requirement	Direction
UpdateMscsReservationRequest	Mandatory	Consumer → WIM
UpdateMscsReservationResponse	Mandatory	WIM → Consumer

6.2.12.2 Input parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.12.2-1.

Table 6.2.12.2-1: Update MSCS Reservation operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
reservationId	M	1	Identifier	Identifier of the existing reservation to be updated.
addEndpoint	M	0..N	Identifier (Reference to ConnectivityServiceEndpointInfo)	Identifier of the connectivity service endpoints to be added to the reserved MSCS.
removeEndpoint	M	0..N	Identifier (Reference to ConnectivityServiceEndpointInfo)	Identifier of the connectivity service endpoint to remove from the reserved MSCS.
modifyMscsProfile	M	0..1	MscsProfile	New properties of the MSCS profile to change for the reserved MSCS.
startTime	M	0..1	DateTime	Indicates the earliest time to start the use of the MSCS. If not present, the original setting will not be changed. If present and the time value is 0, the MSCS is reserved for immediate use.
endTime	M	0..1	DateTime	Indicates the end time of the reservation (when the issuer of the request expects that the MSCS will no longer be needed) and used by the WIM to schedule the reservation. If not present, the MSCS is reserved for unlimited usage time.
expiryTime	M	0..1	DateTime	Indicates the time the WIM can release the reservation in case no allocation request against this reservation was made.

6.2.12.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.12.3-1.

Table 6.2.12.3-1: Update MSCS Reservation operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
reservationData	M	1	ReservedMscs	Element containing information about the updated reserved MSCS. See clause 8.2.3.3.

6.2.12.4 Operation results

After successful operation, the WIM has updated the internal management objects for the MSCS reservation and updated the information about the MSCS capacity according to the updated reserved capacity. In addition, the WIM shall return to the consumer information on the updated reservation plus any additional information about the update request operation.

If the operation was not successful, the WIM shall return to the consumer appropriate error information.

6.2.13 Terminate MSCS Reservation operation

6.2.13.1 Description

This operation allows an authorized consumer to request the termination of MSCS reservations.

Table 6.2.13.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.2.13.1-1: Terminate MSCS Reservation operation

Message	Requirement	Direction
TerminateMscsReservationRequest	Mandatory	Consumer → WIM
TerminateMscsReservationResponse	Mandatory	WIM → Consumer

6.2.13.2 Input Parameters

The parameters sent when invoking the operation shall follow the indications provided in table 6.2.13.2-1.

Table 6.2.13.2-1: Terminate MSCS Reservation operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
reservationId	M	1..N	Identifier	Identifier(s) of the MSCS reservation(s) to be terminated.

6.2.13.3 Output Parameters

The parameters returned by the operation shall follow the indications provided in table 6.2.13.3-1.

Table 6.2.13.3-1: Terminate MSCS Reservation operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
reservationId	M	1..N	Identifier	Identifier(s) of the MSCS reservation(s) successfully terminated.

6.2.13.4 Operation results

After successful operation, the WIM has terminated the MSCS reservations and removed the internal management objects for those reservations and updated the information about the MSCS capacity according to the terminated reservations. In addition, the WIM shall return to the consumer information on the terminated reservations plus any additional information about the terminate request operation.

If the operation was not successful, the WIM shall return to the consumer appropriate error information.

6.3 Capacity Management interface

6.3.1 Description

This interface allows providing to the Consumer information about the resources capacity (e.g. bandwidth, virtual network identifiers, etc.), topology, and network edge points of the network in between different NFVI-PoPs. As such, the interface offers operations to the Consumer to get information about the network edge points for the MSCS endpoints of the NFVI-PoPs (from the perspective of the WAN). It also provides information about the consumed and available capacity on the underlying network resources supporting the establishment of the MSCSs. The WIM, as producer of the interface, shall support the capacity measurements specified in the clause B.2.

The interface also provides the necessary operations to handle the management of subscriptions to notifications, and the issuing of such notifications carrying information about changes in the capacity and/or topology.

The following operations are defined for this interface which will be consumed by the Consumer:

- Query Capacity operation.
- Create Capacity Threshold operation.
- Query Topology Information operation.
- Query Node Information operation.

- Query Link Information operation.
- Query Network Edge Point Information operation.
- Subscribe operation.
- Notify operation.
- Terminate Subscription operation.
- Query Subscription Information operation.

6.3.2 Query Capacity operation

6.3.2.1 Description

This operation enables a Consumer to retrieve information about the capacity of the network in between the NFVI-PoPs. Such information can then be used for capacity and network connectivity planning.

The operation allows retrieval of information about the available, allocated, reserved and total capacity of the network resources managed by the WIM.

Table 6.3.2.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.2.1-1: Query Capacity operation

Message	Requirement	Direction
QueryCapacityRequest	Mandatory	Consumer → WIM
QueryCapacityResponse	Mandatory	WIM → Consumer

6.3.2.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.2.2-1.

Table 6.3.2.2-1: Query Capacity operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter to select the capacity information. It can be a single identifier, multiple identifiers or a wildcard. The filter shall support queries that filter by different resource criteria: <ul style="list-style-type: none"> • all network; • all network topologies, or a specific subset; • by network node; and • by network links.
attributeSelector	M	0..N	String	Provides a list of attribute names. If present, only these attributes (i.e. available, total, reserved and/or allocated capacity) shall be returned for the capacity information. If absent, the complete information about capacity shall be returned.
timePeriod	M	0..1	TimePeriodInformation	The time interval for which capacity is queried. When omitted, an interval starting "now" shall be used. The time interval can be specified since reservation of MSCSs can be made for a specified time interval.

6.3.2.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.3.2.3-1.

Table 6.3.2.3-1: Query Capacity operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
capacityInfo	M	1..N	CapacityInfo	The capacity information according to the input request. The information items correspond to those specified in the CapacityInfo.

6.3.2.4 Operation results

In case of success, the WIM has queried the capacity information for the various types of resources according to the input filter. If attributeSelector is present, only the sub-counter values of the capacityValue in the CapacityValuesEntry listed in attributeSelector shall be returned for the filtered capacity information. The result of the query shall indicate with a standard success/error result if the query has been processed correctly.

6.3.3 Create Capacity Threshold operation

6.3.3.1 Description

This operation enables a Consumer to create a threshold and specify threshold levels on the capacity of the network resources managed by the WIM. Notifications will be generated when crossed. Table 6.3.3.1-1 lists the information flow exchange between the Consumer and the WIM.

Table 6.3.3.1-1: Create Capacity Threshold operation

Message	Requirement	Direction
CreateCapacityThresholdRequest	Mandatory	Consumer → WIM
CreateCapacityThresholdResponse	Mandatory	WIM → Consumer

6.3.3.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.3.2-1.

Table 6.3.3.2-1: Create Capacity Threshold operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
objectInstanceId	M	1..N	Identifier (Reference to NetworkInfo, TopologyInfo, NodeInfo, LinkInfo)	Identifiers of the measured network resource object instance for which the threshold will be defined.
thresholdType	M	1	Enum	Defines the type of threshold. The list of possible values is left for the protocol design stage and shall minimally include: single/multi valued threshold, static/dynamic threshold, and template-based threshold.
thresholdDetails	M	1	Not specified	Details of the threshold: value to be crossed, direction in which it is crossed, details on the notification to be generated, etc.

6.3.3.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.3.3.3-1.

Table 6.3.3.3-1: Create Threshold operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
thresholdId	M	1	Identifier	Identifier of the created threshold.

6.3.3.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result. The thresholdId shall only be returned when the operation has been successful.

6.3.4 Delete Capacity Thresholds operation

6.3.4.1 Description

This operation enables a Consumer to delete one or more existing threshold(s) managed by the WIM about capacity management.

NOTE: It is up to the protocol design stage to determine whether this operation should be modelled as a "bulk" operation that allows deleting multiple Thresholds in one request, or as a series of requests that delete one Threshold at a time.

Table 6.3.4.1-1 lists the information flow exchange between the NFV-MANO functional entity and the Consumer.

Table 6.3.4.1-1: Delete Capacity Thresholds operation

Message	Requirement	Direction
DeleteCapacityThresholdsRequest	Mandatory	Consumer → WIM
DeleteCapacityThresholdsResponse	Mandatory	WIM → Consumer

6.3.4.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.4.2-1.

Table 6.3.4.2-1: Delete Capacity Thresholds operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
thresholdId	M	1..N	Identifier	Identifiers of the thresholds to be deleted.

6.3.4.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.3.4.3-1.

Table 6.3.4.3-1: Delete Capacity Thresholds operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
deletedThresholdId	M	1..N	Identifier	Identifiers of the thresholds that have been deleted successfully.

6.3.4.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

6.3.5 Query Capacity Threshold operation

6.3.5.1 Description

This operation enables a Consumer to query the details of one or more existing capacity thresholds on the WIM. Table 6.3.5.1-1 lists the information flow exchange between the Consumer and the WIM.

Table 6.3.5.1-1: Query Capacity Threshold operation

Message	Requirement	Direction
QueryCapacityThresholdRequest	Mandatory	Consumer → WIM
QueryCapacityThresholdResponse	Mandatory	WIM → Consumer

6.3.5.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.5.2-1.

Table 6.3.5.2-1: Query Capacity Threshold operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter defining the thresholds on which the query applies. It can be a single identifier, multiple identifiers or a wildcard.

6.3.5.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.3.5.3-1.

Table 6.3.5.3-1: Query Capacity Threshold operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
thresholdDetails	M	0..N	Threshold	Details of thresholds matching the input filter.

6.3.5.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

6.3.6 Query Topology Information operation

6.3.6.1 Description

This operation enables a Consumer to query information about the one or more topologies of the network in between the NFVI-PoPs. Table 6.3.6.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.6.1-1: Query Topology Information operation

Message	Requirement	Direction
QueryTopologyInfoRequest	Mandatory	Consumer → WIM
QueryTopologyInfoResponse	Mandatory	WIM → Consumer

6.3.6.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.6.2-1.

Table 6.3.6.2-1: Query Topology Information operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter to select the topology information. It can be a single identifier, multiple identifiers or a wildcard. The filter shall also support queries that apply to all topologies, or a particular one.
attributeSelector	M	0..N	String	Provides a list of attribute names. If present, only these attributes shall be returned for the topology information. If absent, the complete information of the topology shall be returned.

6.3.6.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.3.6.3-1.

Table 6.3.6.3-1: Query Topology Information operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
topologyInfo	M	1..N	TopologyInfo	The information items about the topology that are returned. The information items correspond to those specified in the TopologyInfo.

6.3.6.4 Operation results

In case of success, the topology information shall be returned. In case of failure, appropriate error information shall be returned. If attributeSelector is present, only the attributes of TopologyInfo listed in attributeSelector shall be returned for the filtered topology information.

6.3.7 Query Node Information operation

6.3.7.1 Description

This operation enables a Consumer to query information about a node participating in a topology of the network in between the NFVI-PoPs. Table 6.3.7.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.7.1-1: Query Node Information operation

Message	Requirement	Direction
QueryNodeInfoRequest	Mandatory	Consumer → WIM
QueryNodeInfoResponse	Mandatory	WIM → Consumer

6.3.7.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.7.2-1.

Table 6.3.7.2-1: Query Node Information operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter to select the node information. It can be a single identifier, multiple identifiers or a wildcard. The filter shall also support queries that apply to all network nodes, or a particular one.
attributeSelector	M	0..N	String	Provides a list of attribute names. If present, only these attributes shall be returned for the node information. If absent, the complete information of the node shall be returned.

6.3.7.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.3.7.3-1.

Table 6.3.7.3-1: Query Node Information operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
nodeInfo	M	1..N	NodeInfo	The information items about the node that are returned. The information items correspond to those specified in the NodeInfo.

6.3.7.4 Operation results

In case of success, the topology information shall be returned. In case of failure, appropriate error information shall be returned. If attributeSelector is present, only the attributes of NodeInfo listed in attributeSelector shall be returned for the filtered node information.

6.3.8 Query Link Information operation

6.3.8.1 Description

This operation enables a Consumer to query information about a link participating in a topology of the network in between the NFVI-PoPs. Table 6.3.8.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.8.1-1: Query Link Information operation

Message	Requirement	Direction
QueryLinkInfoRequest	Mandatory	Consumer → WIM
QueryLinkInfoResponse	Mandatory	WIM → Consumer

6.3.8.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.8.2-1.

Table 6.3.8.2-1: Query Link Information operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter to select the node information. It can be a single identifier, multiple identifiers or a wildcard. The filter shall also support queries that apply to all network links, or a particular one.
attributeSelector	M	0..N	String	Provides a list of attribute names. If present, only these attributes shall be returned for the link information. If absent, the complete information of the link shall be returned.

6.3.8.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.3.8.3-1.

Table 6.3.8.3-1: Query Link Information operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
linkInfo	M	1..N	LinkInfo	The information items about the link that are returned. The information items correspond to those specified in the LinkInfo.

6.3.8.4 Operation results

In case of success, the topology information shall be returned. In case of failure, appropriate error information shall be returned. If attributeSelector is present, only the attributes of LinkInfo listed in attributeSelector shall be returned for the link information.

6.3.9 Query Network Edge Point Information operation

6.3.9.1 Description

This operation enables a Consumer to query information about network edge points of the network between the NFVI-PoPs. Table 6.3.9.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.9.1-1: Query Network Edge Point Information operation

Message	Requirement	Direction
QueryNetworkEdgePointInfoRequest	Mandatory	Consumer → WIM
QueryNetworkEdgePointInfoResponse	Mandatory	WIM → Consumer

6.3.9.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.9.2-1.

Table 6.3.9.2-1: Query Network Edge Point Information operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter to select the node information. It can be a single identifier, multiple identifiers or a wildcard. The filter shall also support queries that apply to all node edge points, or a particular one.
attributeSelector	M	0..N	String	Provides a list of attribute names. If present, only these attributes shall be returned for the link information. If absent, the complete information of the link shall be returned.

6.3.9.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.3.9.3-1.

Table 6.3.9.3-1: Query Edge Point Information operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
edgePointInfo	M	1..N	NetworkEdgePointInfo	The information items about the edge point that are returned. The information items correspond to those specified in the NetworkEdgePointInfo.

6.3.9.4 Operation results

In case of success, the topology information shall be returned. In case of failure, appropriate error information shall be returned. If attributeSelector is present, only the attributes of NetworkEdgePointInfo listed in attributeSelector shall be returned for the filtered edge point information.

6.3.10 Subscribe operation

6.3.10.1 Description

This operation enables the Consumer to subscribe with a filter for the notifications related to capacity and topology changes sent by the WIM.

NOTE: Specification of the filtering mechanism is left for the protocol design stage.

Table 6.3.10.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.10.1-1: Subscribe operation

Message	Requirement	Direction
SubscribeRequest	Mandatory	Consumer → WIM
SubscribeResponse	Mandatory	WIM → Consumer

6.3.10.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.10.2-1.

Table 6.3.10.2-1: Subscribe operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Input filter for selecting capacity and topology information for which notifications are requested.

6.3.10.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.3.10.3-1.

Table 6.3.10.3-1: Subscribe operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Identifier of the subscription realized.

6.3.10.4 Operation results

As a result of this operation, the WIM shall indicate to the Consumer in the SubscribeResponse message whether the subscription was successful or not. For a particular subscription, only notifications matching the filter shall be delivered to the Consumer.

6.3.11 Notify operation

6.3.11.1 Description

This operation distributes notifications to subscribers. It is a one-way operation issued by the WIM and cannot be invoked as an operation by the Consumer.

In order to receive notifications, the Consumer shall have a subscription.

Table 6.3.11.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.11.1-1: Notify operation

Message	Requirement	Direction
Notify	Mandatory	WIM → Consumer

The following notifications can be notified/sent by this operation:

- CapacityChangeNotification. See clause 8.3.5.
- TopologyChangeNotification. See clause 8.3.11.

6.3.12 Terminate Subscription operation

6.3.12.1 Description

This operation enables the Consumer to terminate a particular subscription. Table 6.3.12.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.12.1-1: Terminate Subscription operation

Message	Requirement	Direction
TerminateSubscriptionRequest	Mandatory	Consumer → WIM
TerminateSubscriptionResponse	Mandatory	WIM → Consumer

6.3.12.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.12.2-1.

Table 6.3.12.2-1: Terminate Subscription operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Identifier of the subscription to be terminated.

6.3.12.3 Output parameters

No output parameter.

6.3.12.4 Operation results

After successful termination of a subscription, the identified subscription does not exist anymore, and the Consumer will not receive notifications related that subscription any longer. The result of the operation shall indicate if the subscription termination has been successful or not with a standard success/error result.

6.3.13 Query Subscription Info operation

6.3.13.1 Description

This operation enables the Consumer to query information about subscriptions. Table 6.3.13.1-1 lists the information flow exchanged between the Consumer and the WIM.

Table 6.3.13.1-1: Query Subscription operation

Message	Requirement	Direction
QuerySubscriptionInfoRequest	Mandatory	Consumer → WIM
QuerySubscriptionInfoResponse	Mandatory	WIM → Consumer

6.3.13.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.3.13.2-1.

Table 6.3.13.2-1: Query Subscription Info operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filtering criteria to select one or a set of subscriptions. See note.
NOTE: Details are left for the protocol design stage.				

6.3.13.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.3.13.3-1.

Table 6.3.13.3-1: Query Subscription Info operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
queryResult	M	0..N	Not specified	Information about the subscription(s) matching the query. See note.
NOTE: Details are left for the protocol design stage.				

6.3.13.4 Operation results

After successful operation, the WIM has queried the internal subscription objects. The result of the operation indicates if it has been successful or not with a standard success/error result. For a particular query, information about the subscriptions to notifications related to capacity and topology that the Consumer has access to and that are matching the filter shall be returned.

6.4 Fault Management interface

6.4.1 Description

This interface shall allow the WIM to provide alarms related to the MSCSs visible to the consumer.

The fault management interface shall support the following operations:

- Subscribe operation: Subscription of consumers with the WIM for the notifications related to the alarms.
- Notify operation: Notifications of alarms or alarm state change from to consumer.
- Terminate Subscription operation: Terminating a particular subscription in the WIM.
- Query Subscription Info operation: Querying subscription information from the WIM.
- Get alarm list operation: Accessing active alarms from the WIM.
- Acknowledge Alarms operation: Acknowledging alarms by the consumer.

6.4.2 Subscribe operation

6.4.2.1 Description

This operation enables the consumer to subscribe with a filter for the notifications related to MSCS alarms sent by the WIM.

NOTE: Specification of the filtering mechanism is left for the protocol design stage.

Table 6.4.2.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.4.2.1-1: Subscribe operation

Message	Requirement	Direction
SubscribeRequest	Mandatory	Consumer → WIM
SubscribeResponse	Mandatory	WIM → Consumer

6.4.2.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.4.2.2-1.

Table 6.4.2.2-1: Subscribe operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Input filter for selecting MSCSs and related alarms. This can contain the MSCS information, severity and cause of the alarm.

6.4.2.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.4.2.3-1.

Table 6.4.2.3-1: Subscribe operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Id of the realized subscription.

6.4.2.4 Operation results

As a result of this operation, the WIM shall indicate to the consumer in the SubscribeResponse message whether the subscription was successful or not. For a particular subscription, only notifications matching the filter shall be delivered to the consumer.

6.4.3 Notify operation

6.4.3.1 Description

This operation distributes notifications to subscribers. It is a one-way operation issued by the WIM and cannot be invoked as an operation by the consumer.

In order to receive notifications, the consumer shall have a subscription.

Table 6.4.3.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.4.3.1-1: Notify operation

Message	Requirement	Direction
Notify	Mandatory	WIM → Consumer

The following notifications can be notified/sent by this operation:

- AlarmNotification. See clause 8.4.3.
- AlarmClearedNotification. See clause 8.4.4.
- AlarmListRebuiltNotification. See clause 8.4.5.

6.4.4 Terminate Subscription operation

6.4.4.1 Description

This operation enables the consumer to terminate a particular subscription. Table 6.4.4.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.4.4.1-1: Terminate Subscription operation

Message	Requirement	Direction
TerminateSubscriptionRequest	Mandatory	Consumer → WIM
TerminateSubscriptionResponse	Mandatory	WIM → Consumer

6.4.4.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.4.4.2-1.

Table 6.4.4.2-1: Terminate Subscription operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Identifier of the subscription to be terminated.

6.4.4.3 Output parameters

No output parameter.

6.4.4.4 Operation results

After successful termination of a subscription, the identified subscription does not exist anymore, and the consumer will not receive notifications related that subscription any longer. The result of the operation shall indicate if the subscription termination has been successful or not with a standard success/error result.

6.4.5 Query Subscription Info operation

6.4.5.1 Description

This operation enables the consumer to query information about subscriptions.

Table 6.4.5.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.4.5.1-1: Query Subscription operation

Message	Requirement	Direction
QuerySubscriptionInfoRequest	Mandatory	Consumer → WIM
QuerySubscriptionInfoResponse	Mandatory	WIM → Consumer

6.4.5.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.4.5.2-1.

Table 6.4.5.2-1: Query Subscription Info operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filtering criteria to select one or a set of subscriptions. See note.

NOTE: Details are left for the protocol design stage.

6.4.5.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.4.5.3-1.

Table 6.4.5.3-1: Query Subscription Info operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
queryResult	M	0..N	Not specified	Information about the subscription(s) matching the query. See note.
NOTE: Details are left for the protocol design stage.				

6.4.5.4 Operation results

After successful operation, the WIM has queried the internal subscription objects. The result of the operation indicates if it has been successful or not with a standard success/error result. For a particular query, information about the subscriptions to notifications related to MSCS fault management that the consumer has access to and that are matching the filter shall be returned.

6.4.6 Get Alarm List operation

6.4.6.1 Description

This operation enables the consumers to query the active alarms from the WIM. Table 6.4.6.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.4.6.1-1: Get Alarm List operation

Message	Requirement	Direction
GetAlarmListRequest	Mandatory	Consumer → WIM
GetAlarmListResponse	Mandatory	WIM → Consumer

6.4.6.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.4.6.2-1.

Table 6.4.6.2-1: Get Alarm List operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Input filter for selecting alarms. This can contain the list of the MSCS identifiers, severity and cause.

6.4.6.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.4.6.3-1.

Table 6.4.6.3-1: Get Alarm List operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
alarm	M	0..N	Alarm	Information about an alarm including AlarmId, affected MSCS Id, and FaultDetails. The cardinality can be "0" to indicate that no Alarm could be retrieved based on the input filter information (e.g. no matching alarm).

6.4.6.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result. For a particular request, only alarms matching the filter shall be delivered to the consumer.

6.4.7 Acknowledge Alarms operation

6.4.7.1 Description

This operation enables the consumer to acknowledge alarms at WIM. Table 6.4.7.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.4.7.1-1: Acknowledge alarms operation

Message	Requirement	Direction
AcknowledgeAlarmsRequest	Mandatory	Consumer → WIM
AcknowledgeAlarmsResponse	Mandatory	WIM → Consumer

6.4.7.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.4.7.2-1.

Table 6.4.7.2-1: Acknowledge alarms operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
alarmId	M	1..N	Identifier (Reference to Alarm)	Identifier of an individual alarm to be acknowledged, or multiple identifiers of the alarms to be acknowledged. See note.
NOTE: It is up to the protocol design stage to determine whether this operation will be modelled as a "bulk" operation that allows acknowledge multiple alarms in one request, or as a series of requests that acknowledge one alarm at a time.				

6.4.7.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.4.7.3-1.

Table 6.4.7.3-1: Acknowledge alarms operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
acknowledgedAlarmId	M	1..N	Identifier (Reference to Alarm)	Identifier of an individual alarm that is acknowledged, or multiple identifiers of the alarms that are acknowledged. See note.
NOTE: It is up to the protocol design stage to determine whether this operation will be modelled as a "bulk" operation that allows acknowledge multiple alarms in one request, or as a series of requests that acknowledge one alarm at a time.				

6.4.7.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

6.5 Performance Management interface

6.5.1 Description

This interface allows providing of performance information (measurement results collection and notifications) related to MSCSs. Collection and reporting of performance information is controlled by a PM job that groups details of performance collection and reporting information. The WIM, as producer of the interface, shall support the performance measurements specified in the clause B.1.

When new performance information is available, the consumer is notified using the notification PerformanceInformationAvailableNotification (see clause 8.5.8). The details of the performance measurements are provided using the PerformanceReport information element (see clause 8.5.5). Delivery mechanism for the performance reports is left for later specification.

The following operations are defined for this interface which will be consumed by the consumer:

- Create PM Job operation.
- Delete PM Jobs operation.
- Query PM Job operation.
- Create Threshold operation.
- Delete Thresholds operation.
- Query Threshold operation.
- Subscribe operation.
- Notify operation.
- Terminate Subscription operation.
- Query Subscription operation.

6.5.2 Create PM Job operation

6.5.2.1 Description

This operation creates a PM job, enabling a consumer to specify a MSCS or set of MSCSs, that the WIM is managing, for which it wants to receive performance information. This allows the requesting consumer to specify its performance information requirements with the WIM.

The consumer shall issue a Subscribe request for PerformanceInformationAvailable notifications in order to know when new collected performance information is available.

Table 6.5.2.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.2.1-1: Create PM Job operation

Message	Requirement	Direction
CreatePmJobRequest	Mandatory	Consumer → WIM
CreatePmJobResponse	Mandatory	WIM → Consumer

6.5.2.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.2.2-1.

Table 6.5.2.2-1: Create PM Job operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
selector	M	1	ObjectSelection	Defines the MSCs for which performance information is to be collected.
performanceMetric	M	0..N	String	This defines the type of performance metric(s) for the specified MSCs. At least one of the two attributes (performance metric or metricGroup) shall be present.
performanceMetricGroup	M	0..N	String	Group of performance metrics. A metric group is a pre-defined list of metrics, known to the producer that it can decompose to individual metrics. At least one of the two attributes (performance metric or metricGroup) shall be present.
collectionPeriod	M	1	Enum	Specifies the periodicity at which the WIM will collect performance information. See note.
reportingPeriod	M	1	Enum	Specifies the periodicity at which the WIM will report to the consumer about performance information. See note.
reportingBoundary	O	0..1	Not specified.	Identifies a boundary after which the reporting will stop. The boundary shall allow a single reporting as well as periodic reporting up to the boundary.
NOTE:	At the end of each reportingPeriod, the WIM shall inform the consumer about availability of the performance data collected for each completed collection period during this reportingPeriod. While the exact definition of the types for collectionPeriod and reportingPeriod is left for further specification, it is recommended that the reportingPeriod be equal to or a multiple of the collectionPeriod. In the latter case, the performance data for the collection periods within one reporting period would be reported together.			

6.5.2.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.5.2.3-1.

Table 6.5.2.3-1: Create PM Job operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
pmJobId	M	1	Identifier	Identifier of the created PM job.

6.5.2.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

The pmJobId shall only be returned when the operation has been successful.

6.5.3 Delete PM Jobs operation

6.5.3.1 Description

This operation deletes one or more PM job(s). Table 6.5.3.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.3.1-1: Delete PM Jobs operation

Message	Requirement	Direction
DeletePmJobsRequest	Mandatory	Consumer → WIM
DeletePmJobsResponse	Mandatory	WIM → Consumer

6.5.3.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.3.2-1.

Table 6.5.3.2-1: Delete PM Jobs operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
pmJobId	M	1..N	Identifier	Identifiers of the PM jobs to be deleted.

6.5.3.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.5.3.3-1.

Table 6.5.3.3-1: Delete PM Jobs operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
deletedPmJobId	M	1..N	Identifier	Identifiers of the PM Jobs that have been deleted successfully.

6.5.3.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

6.5.4 Query PM Job operation

6.5.4.1 Description

This operation enables the consumer to solicit from the WIM the details of one or more PM job(s). This operation does not return performance reports. Table 6.5.4.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.4.1-1: Query PM Job operation

Message	Requirement	Direction
QueryPmJobRequest	Mandatory	Consumer → WIM
QueryPmJobResponse	Mandatory	WIM → Consumer

6.5.4.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.4.2-1.

Table 6.5.4.2-1: Query PM Job operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter defining the PM Jobs on which the query applies. It can be a single identifier, multiple identifiers or a wildcard.

6.5.4.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.5.4.3-1.

Table 6.5.4.3-1: Query PM Job operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
pmJobDetails	M	1..N	PmJob	Details of PM jobs matching the input filter.

6.5.4.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

6.5.5 Create Threshold operation

6.5.5.1 Description

This operation allows the consumer to create a threshold and specify threshold levels on specified performance metric (for MSCS(s)) for which notifications will be generated when crossed. Creating a threshold does not trigger collection of metrics. In order for the threshold to be active, there needs to be a PM job collecting the needed metric for the selected entities.

Table 6.5.5.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.5.1-1: Create Threshold operation

Message	Requirement	Direction
CreateThresholdRequest	Mandatory	Consumer → WIM
CreateThresholdResponse	Mandatory	WIM → Consumer

6.5.5.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.5.2-1.

Table 6.5.5.2-1: Create Threshold operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
selector	M	1	ObjectSelection	Defines the MSCS instances for which the threshold will be defined.
performanceMetric	M	1	String	Defines the performance metric on which the threshold will be defined.
thresholdType	M	1	Enum	Defines the type of threshold. The list of possible values is left for the protocol design stage and might include: single/multi valued threshold, static/dynamic threshold, template-based threshold, etc.
thresholdDetails	M	1	Not specified.	Details of the threshold: value to be crossed, direction in which it is crossed, details on the notification to be generated, etc.

6.5.5.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.5.5.3-1.

Table 6.5.5.3-1: Create Threshold operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
thresholdId	M	1	Identifier	Identifier of created threshold.

6.5.5.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result. The thresholdId shall only be returned when the operation has been successful.

6.5.6 Delete Thresholds operation

6.5.6.1 Description

This operation allows the consumer to delete one or more existing threshold(s). Table 6.5.6.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.6.1-1: Delete Thresholds operation

Message	Requirement	Direction
DeleteThresholdsRequest	Mandatory	Consumer → WIM
DeleteThresholdsResponse	Mandatory	WIM → Consumer

6.5.6.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.6.2-1.

Table 6.5.6.2-1: Delete Thresholds operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
thresholdId	M	1..N	Identifier	Identifiers of the thresholds to be deleted.

6.5.6.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.5.6.3-1.

Table 6.5.6.3-1: Delete Thresholds operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
deletedThresholdId	M	1..N	Identifier	Identifiers of the thresholds that have been deleted successfully.

6.5.6.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

6.5.7 Query Threshold operation

6.5.7.1 Description

This operation allows the consumer to query the details of an existing threshold. Table 6.5.7.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.7.1-1: QueryThreshold operation

Message	Requirement	Direction
QueryThresholdRequest	Mandatory	Consumer → WIM
QueryThresholdResponse	Mandatory	WIM → Consumer

6.5.7.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.7.2-1.

Table 6.5.7.2-1: QueryThreshold operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filter defining the thresholds on which the query applies. It can be a single identifier, multiple identifiers or a wildcard.

6.5.7.3 Output parameters

The parameters returned by the operation shall follow the indications provided in table 6.5.7.3-1.

Table 6.5.7.3-1: QueryThreshold operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
thresholdDetails	M	1..N	Threshold	List of threshold details matching the input filter.

6.5.7.4 Operation results

The result of the operation indicates if it has been successful or not with a standard success/error result.

6.5.8 Subscribe operation

6.5.8.1 Description

This operation enables the consumers to subscribe with a filter for the notifications related to performance information with the WIM.

NOTE: Specification of the filtering mechanism is left for the protocol design stage.

Table 6.5.8.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.8.1-1: Subscribe operation

Message	Requirement	Direction
SubscribeRequest	Mandatory	Consumer → WIM
SubscribeResponse	Mandatory	WIM → Consumer

6.5.8.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.8.2-1.

Table 6.5.8.2-1: Subscribe operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Input filter for selecting notifications. The filter can be on MSCS, type of notification or attribute of the notification.

6.5.8.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.5.8.3-1.

Table 6.5.8.3-1: Subscribe operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Identifier of the realized subscription.

6.5.8.4 Operation results

As a result of this operation, the WIM shall indicate to the consumer in the SubscribeResponse message whether the subscription was successful or not. For a particular subscription, only notifications matching the filter shall be delivered to the consumer.

6.5.9 Notify operation

6.5.9.1 Description

This operation distributes notifications to subscribers. It is a one-way operation issued by the WIM that cannot be invoked as an operation by the consumer. In order to receive notifications, the consumer shall have a subscription. Table 6.5.9.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.9.1-1: Notify operation

Message	Requirement	Direction
Notify	Mandatory	WIM → Consumer

The following notifications can be notified/sent by this operation:

- PerformanceInformationAvailableNotification. See clause 8.5.8.
- ThresholdCrossedNotification. See clause 8.5.9.

6.5.10 Terminate Subscription operation

6.5.10.1 Description

This operation enables the consumer to terminate a particular subscription. Table 6.5.10.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.10.1-1: Terminate Subscription operation

Message	Requirement	Direction
TerminateSubscriptionRequest	Mandatory	Consumer → WIM
TerminateSubscriptionResponse	Mandatory	WIM → Consumer

6.5.10.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.10.2-1.

Table 6.5.10.2-1: Terminate Subscription operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
subscriptionId	M	1	Identifier	Identifier of the subscription to be terminated.

6.5.10.3 Output parameters

No output parameter.

6.5.10.4 Operation results

After successful termination of a subscription, the identified subscription does not exist anymore, and the consumer will not receive notifications related that subscription any longer. The result of the operation shall indicate if the subscription termination has been successful or not with a standard success/error result.

6.5.11 Query Subscription Info operation

6.5.11.1 Description

This operation enables the consumer to query information about subscriptions. Table 6.5.11.1-1 lists the information flow exchanged between the consumer and the WIM.

Table 6.5.11.1-1: Query Subscription operation

Message	Requirement	Direction
QuerySubscriptionInfoRequest	Mandatory	Consumer → WIM
QuerySubscriptionInfoResponse	Mandatory	WIM → Consumer

6.5.11.2 Input parameters

The input parameters sent when invoking the operation shall follow the indications provided in table 6.5.11.2-1.

Table 6.5.11.2-1: Query Subscription Info operation input parameters

Parameter	Qualifier	Cardinality	Content	Description
filter	M	1	Filter	Filtering criteria to select one or a set of subscriptions. Details are left for the protocol design stage.

6.5.11.3 Output parameters

The output parameters returned by the operation shall follow the indications provided in table 6.5.11.3-1.

Table 6.5.11.3-1: Query Subscription Info operation output parameters

Parameter	Qualifier	Cardinality	Content	Description
queryResult	M	0..N	Not specified	Information about the subscription(s) matching the query. Details are left for the protocol design stage.

7 Interfaces consumed by WIM

There are no interfaces identified from the consumer side that are consumed by the WIM.

8 Information elements exchanged

8.1 Introduction

This clause defines, or references, definitions of information elements used in the interfaces defined in the present document.

8.2 Information elements and notifications related to MSCS Management

8.2.1 Introduction

The clauses below define information elements and notifications related to MSCS management.

8.2.2 Information elements related to MSCS

8.2.2.1 Introduction

The information elements in this group encapsulate information related to MSCS.

8.2.2.2 MscsData Information element

8.2.2.2.1 Description

The MscsData information element encapsulates information needed for creating or updating a MSCS.

8.2.2.2.2 Attributes

The MscsData information element shall follow the indications provided in table 8.2.2.2.2-1.

Table 8.2.2.2.2-1: Attributes of the MscsData information element

Attribute	Qualifier	Cardinality	Content	Description
mscsName	M	0..1	String	Human readable name for the MSCS.
mscsDescription	M	0..1	String	Human readable description for the MSCS.
mscsEndpoint	M	2..N	MscsEndpointData	MSCS endpoints for establishing the MSCS.
mscsProfile	M	1	MscsProfile	Profile of the MSCS determining connectivity constraints and requirements.
mscsLayerProtocol	M	1	Not specified	Protocol aspects for particular layer determining the type of MSNCs to be established realizing the MSCS, e.g. I2vpn, I3vpn with specific protocol technologies such as EVPN, VPLS, VPWS, BGP/MPLS IP VPN. The attribute allows the specification of identifiers of the virtual private network segments, associated to the particular layer protocol.

8.2.2.3 MscsEndpointData information element

8.2.2.3.1 Description

The MscsEndpointData information element encapsulates information about the MSCS endpoint and the network configuration necessary to setup the connectivity to/from MSCS endpoint to the multi-site (WAN) network edge point.

8.2.2.3.2 Attributes

The MscsEndpointData information element shall follow the indications provided in table 8.2.2.3.2-1.

Table 8.2.2.3.2-1: Attributes of the MscsEndpointData information element

Attribute	Qualifier	Cardinality	Content	Description
connectivityServiceEndpointId	M	1	Identifier (Reference to ConnectivityServiceEndpointInfo)	References a connectivity service endpoint that acts as MSCS endpoint of the MSCS.
directionality	M	1	Enum	Directionality of the data traffic in the context of the terminating MSCS endpoint. Allowed values: <ul style="list-style-type: none"> • INBOUND (into the endpoint); • OUTBOUND (from the endpoint); • BOTH.
networkAddressing	M	1	Not specified	Information about the network addressing configuration applicable in between the MSCS endpoint and the network edge point.
lag	M	0..1	Not specified	Link aggregation configuration for the link in between the MSCS endpoint and the WAN network edge point.

8.2.2.4 MscsProfile information element

8.2.2.4.1 Description

The MscsProfile information element encapsulates information determining the connectivity constraints and requirements for the MSCS.

8.2.2.4.2 Attributes

The MscsProfile information element shall follow the indications provided in table 8.2.2.4.2-1.

Table 8.2.2.4.2-1: Attributes of the MscsProfile information element

Attribute	Qualifier	Cardinality	Content	Description
bandwidthIn	M	1	Number	Incoming bandwidth (in Mbps).
bandwidthOut	M	0..1	Number	Outgoing bandwidth (in Mbps). If value is not provided, symmetric traffic bandwidth, i.e. same value as bandwidthIn shall be assumed.
qosMetric	M	0..N	Not specified	Set of QoS related metrics such as cost, delay, delay variation and latency. Time-based values shall be expressed in milliseconds.
directionality	M	1	Enum	Directionality of the data traffic. Allowed values: UNIDIRECTIONAL, BIDIRECTIONAL.
mtu	M	1	Number	Maximum transmission unit value determining the largest PDU size that can be transmitted.
protectionScheme	M	0..1	Enum	Describes the resiliency requirements. The value is used to determine the capabilities and number of MSNCs needed to fulfil certain availability. Allowed values: UNPROTECTED, <0:1>, <1:1>, <1+1>, <1:N>, <M:N>
connectivityMode	M	1	Enum	The type of connectivity to be enabled. Allowed values: P2P (point-to-point), MP (multipoint).
numSegment	M	1	Number	Number of virtual private network segments (to be) enabled.
segmentId	M	0..N	Identifier	Identifiers of the virtual private network segments, e.g. the virtual network identifier (VNI), routing distinguishers (RD), etc.

8.2.2.5 Mscs Information element

8.2.2.5.1 Description

The Mscs information element encapsulates information about an established MSCS.

8.2.2.5.2 Attributes

The Mscs information element shall follow the indications provided in table 8.2.2.5.2-1.

Table 8.2.2.5.2-1: Attributes of the Mscs information element

Attribute	Qualifier	Cardinality	Content	Description
mcsId	M	1	Identifier	Identifier of the MSCS.
mcsName	M	0..1	String	Human readable name of the MSCS.
mcsDescription	M	0..1	String	Human readable description of the MSCS.
mcsEndpoint	M	2..N	MscsEndpointInfo	MSCS endpoints on the established MSCS.
mcsProfile	M	1	MscsProfile	Profile of the MSCS determining connectivity constraints and requirements.
msnc	M	0..N	Msnc	The attribute represents the data related to the instantiated MSNC realizing the MSCS. Cardinality can be zero if a MSNC has not been established yet.

8.2.2.6 Msnc information element

8.2.2.6.1 Description

The Msnc information element encapsulates information about an established MSNC on the multi-site network, partly or fully, realizing the MSCS.

8.2.2.6.2 Attributes

The MSNC information element shall follow the indications provided in table 8.2.2.6.2-1.

Table 8.2.2.6.2-1: Attributes of the Msnc information element

Attribute	Qualifier	Cardinality	Content	Description
msncId	M	1	Identifier	Identifier of the MSNC.
msncEndpointId	M	2..N	Identifier (Reference to NetworkEdgePointInfo)	The multi-site network edge points across which the MSNC is established.
path	M	1..N	Identifier (Reference to NodeInfo)	The path of the MSNC through the network nodes in the underlying network topology.
msncProfile	M	1	MsncProfile	Information of the MSNC with connectivity constrains and requirements applicable to the individual MSNC realizing a MSCS.
msncLayerProtocol	M	1	Not specified	A structure describing: <ul style="list-style-type: none"> • Protocol aspects for particular layer of the established MSNC realizing the MSCS, e.g. I2vpn, I3vpn with specific protocol technologies such as EVPN, VPLS, VPWS, BGP/MPLS IP VPN. • Identifiers of the virtual private network segments, e.g. the virtual network identifier (VNI), routing distinguishers (RD), etc. associated to the particular layer protocol.

8.2.2.7 MsncProfile information element

8.2.2.7.1 Description

The MsncProfile information element encapsulates information about the connectivity constraints and requirements of a particular MSNC realizing the MSCS.

8.2.2.7.2 Attributes

The MsnProfile information element shall follow the indications provided in table 8.2.2.7.2-1.

Table 8.2.2.7.2-1: Attributes of the MsnProfile information element

Attribute	Qualifier	Cardinality	Content	Description
bandwidthIn	M	1	Number	Incoming bandwidth (in Mbps).
bandwidthOut	M	1	Number	Outgoing bandwidth (in Mbps).
qosMetric	M	0..N	Not specified	Set of QoS related metrics such as cost, delay, delay variation and latency. Time-based values shall be expressed in milliseconds.
directionality	M	1	Enum	Directionality of the data traffic on the enabled MSNC. Allowed values: UNIDIRECTIONAL, BIDIRECTIONAL.
mtu	M	1	Number	Maximum transmission unit value determining the largest PDU size that can be transmitted.
protectionScheme	M	0..1	Enum	Describes the resiliency requirements of the particular MSNC. Allowed values: UNPROTECTED, <0:1>, <1:1>, <1+1>, <1:N>, <M:N>
connectionMode	M	1	Enum	The type of enabled connection. Allowed values: P2P (point-to-point), MP (multipoint).

8.2.2.8 MscsEndpointInfo information element

8.2.2.8.1 Description

The MscsEndpointInfo information element encapsulates information about network configuration of the MSCS endpoint of an MSCS. The MSCS Endpoint relates a connectivity service endpoint with the MSCS.

8.2.2.8.2 Attributes

The MscsEndpointInfo information element shall follow the indications provided in table 8.2.2.8.2-1.

Table 8.2.2.8.2-1: Attributes of the MscsEndpointInfo information element

Attribute	Qualifier	Cardinality	Content	Description
mscsEndpointId	M	1	Identifier	Identifier of the MSCS Endpoint.
connectivityServiceEndpointId	M	1	Identifier (Reference to ConnectivityServiceEndpointInfo)	References the connectivity service endpoint that acts as MSCS endpoint for the MSCS.
directionality	M	1	Enum	Directionality of the data traffic in the context of the terminating MSCS endpoint. Allowed values: INBOUND (into the endpoint), OUTBOUND (from the endpoint), BOTH.
networkAddressing	M	1	Not specified	Information about the network addressing configuration applicable in between the MSCS endpoint and the network edge point.
lag	M	0..1	Not specified	Link aggregation configuration for the link in between the MSCS endpoint and the WAN network edge point.

8.2.3 Information elements related to MSCS Reservation

8.2.3.1 Introduction

The information elements in this group encapsulate information related to MSCS reservation.

8.2.3.2 MscsReservationData information element

8.2.3.2.1 Description

The MscsReservationData information element encapsulates information needed for creating a MSCS reservation.

8.2.3.2.2 Attributes

The attributes of the MscsReservationData information element shall follow the indications provided in table 8.2.3.2.2-1.

Table 8.2.3.2.2-1: Attributes of the MscsReservationData information element

Attribute	Qualifier	Cardinality	Content	Description
mscsLayerProtocol	M	0..1	Not specified	Protocol aspects for particular layer determining the type of MSNCs to be reserved realizing the MSCS, e.g. I2vpn, I3vpn with specific protocol technologies such as EVPN, VPLS, VPWS, BGP/MPLS IP VPN.
connectivityServiceEndpointId	M	0..N	Identifier (Reference to Connectivity ServiceEndpointInfo)	Identifiers of the connectivity service endpoints of the MSCS to be reserved.
mscsProfile	M	0..1	MscsProfile	The profile determining the connectivity information, constraints and requirements for the MSCS to be reserved.

8.2.3.3 ReservedMscs information element

8.2.3.3.1 Description

This clause describes the attributes for the ReservedMscs information element. A ReservedMscs provides information about the properties of a reserved MSCS including references to the MSCS endpoints, profile, protocol layer information, etc.

8.2.3.3.2 Attributes

The ReservedMscs information element shall follow the indications provided in table 8.2.3.3.2-1.

Table 8.2.3.3.2-1: Attributes of the ReservedMscs information element

Attribute	Qualifier	Cardinality	Content	Description
reservationId	M	1	Identifier	Identifier of the MSCS reservation.
mscsLayerProtocol	M	1	Not specified	Protocol aspects for particular layer determining the type of MSNCs that has been reserved, e.g. l2vpn, l3vpn with specific protocol technologies such as EVPN, VPLS, VPWS, BGP/MPLS IP VPN.
connectivityServiceEndpointId	M	0..N	Identifier (Reference to ConnectivityServiceEndpointInfo)	Identifiers of the service connectivity endpoints of the MSCS that has been reserved. See clause 8.3.12.
mscsProfile	M	0..1	MscsProfile	Information specifying additional attributes of the MSCS that has been reserved. See clause 8.2.2.4.
reservationStatus	M	1	Not specified	Status of the MSCS reservation, e.g. to indicate if a reservation is being used, if a reservation has been created but not in use yet.
startTime	M	0..1	DateTime	Indicates the time to start the consumption of the MSCS. If the time value is 0, the MSCS is reserved for immediate use.
endTime	M	0..1	DateTime	Indicates the end time of the reservation (when it is expected that the MSCS will no longer be needed) and used by the WIM to schedule the reservation. If not present, the MSCS is reserved for unlimited usage time.
expiryTime	M	0..1	DateTime	Indicates the time the WIM can release the reservation in case no allocation request against this reservation was made.

8.2.4 MscsChangeNotification

8.2.4.1 Description

This notification informs the receiver of changes related to the MSCSs managed by the WIM. The support of the notification is mandatory.

8.2.4.2 Trigger conditions

This notification is produced when the MSCS is changed due to updating the MSCS, or due to changes in the MSNC realizing the MSCS, or due to changes in the underlying supporting resources performed due to maintenance and operation, such as:

- Change of network path, e.g. to avoid network congestion or achieve load balance, etc.
- Change of network QoS, e.g. to adjust bandwidth, etc.
- Operation and management of WAN resources, e.g. to share WAN connectivity resource, etc.
- Update the MSCS, e.g. adding new MSNCs, terminating or updating existing MSNCs, etc.

8.2.4.3 Attributes

The MscsChangeNotification shall follow the indications provided in table 8.2.4.3-1.

Table 8.2.4.3-1: Attributes of MscsChangeNotification

Attribute	Qualifier	Cardinality	Content	Description
mcsId	M	1	Identifier	Identifier of the MSCS for which the change notification is issued.
changedMscsProfile	M	0..1	Not specified	Details of the changes regarding the profile of the MSCS. It shall be present when the notification refers to changes on the profile, and it shall include the data that has been changed.
affectedComponent	M	0..N	Not specified	Identification and information about components or sub-objects of the MSCS that were affected in the change. The applicable components of the MSCS shall be MSCS Endpoints and MSNCs. The attribute shall enable providing information about: <ul style="list-style-type: none"> the type of change, such as addition, removal, modification; the identification of the resource concerning the change with a reference to the corresponding sub-components of the MSCS, and any additional data about the change if the change concerns to a modification. See example in the present clause.
NOTE:	It is up to protocol stage design to determine whether additional attributes are needed in the notification to categorize the types of changes that concern to the MSCS according to the information provided by the notification and trigger conditions.			

EXAMPLE: An example when adding new MSCS Endpoint to an existing MSCS follows:

```
networkId: "wan-eu-de-zone1-nfvi-pops_1_2",
changedMscsProfile: "",
affectedComponent: [
  {"addition", "mscs-endpoint-99", ""},
]
```

8.2.5 MscsReservationChangeNotification

8.2.5.1 Description

This notification informs the receiver of changes related to the MSCS reservations managed by the WIM. The support of the notification is mandatory.

8.2.5.2 Trigger conditions

This notification shall be produced when:

- A MSCS reservation has been updated, e.g. the profile, or schedule.
- A MSCS reservation changed due to changes in the underlying supporting resources that are part of this reservation (e.g. this can include pre-reserved connections, network links, etc.).
- The status of the MSCS reservation changes.

8.2.5.3 Attributes

The MscsReservationChangeNotification shall follow the indications provided in table 8.2.5.3-1.

Table 8.2.5.3-1: Attributes of MscsReservationChangeNotification

Attribute	Qualifier	Cardinality	Content	Description
reservationId	M	1	Identifier	Identifier of the MSCS reservation for which the change notification is issued.
changedMscsProfile	M	0..1	Not specified	Details of the changes regarding the profile of the MSCS reservation. It shall be present when the notification refers to changes on the profile, and it shall include the data that has been changed.
affectedComponent	M	0..N	Not specified	Identification and information about reserved components or sub-objects of the reserved MSCS that were affected in the change. It shall be present when the notification refers to changes in components. The applicable components of the MSCS shall be connectivity service endpoints that had been associated to the reservation. The attribute shall enable providing information about: <ul style="list-style-type: none"> the type of change, such as addition, removal, modification; the identification of the resource concerning the change with a reference to the corresponding sub-components of the reserved MSCS, and any additional data about the change.
changedTime	M	0..N	KeyValuePair	The time (startTime, endTime or expiryTime) that has changed and new value.
reservationStatus	M	0..1	Not specified	New status of the MSCS reservation, e.g. to indicate when a reservation has started to be used.
NOTE: It is up to protocol stage design to determine whether additional attributes are needed in the notification to categorize the types of changes that concern to the MSCS reservation according to the information provided by the notification and trigger conditions.				

8.3 Information elements and notifications related to capacity and topology management

8.3.1 Introduction

The clauses below define information elements and notifications related to capacity and topology management.

8.3.2 CapacityInfo information element

8.3.2.1 Description

The CapacityInfo information element encapsulates information about capacity of the network in between the NFVI-PoPs (sites). Capacity information can be held on a variety of key performance indicators (KPI) such as bandwidth, logical network identifiers (e.g. VNI), etc.

8.3.2.2 Attributes

The attributes of the CapacityInfo information element shall follow the indications provided in table 8.3.2.2-1.

Table 8.3.2.2-1: Attributes of the CapacityInfo information element

Attribute	Qualifier	Cardinality	Content	Description
objectType	M	1	Enum	Type of measured object (i.e. resource) in the network to which the capacity information is related. Allowed values: <ul style="list-style-type: none"> • NODE; • LINK; • TOPOLOGY; • NETWORK.
objectInstanceId	M	1	Identifier (Reference to NodeInfo, LinkInfo, TopologyInfo, or NetworkInfo)	Identifies the measured object (i.e. resource) of the network.
capacityValue	M	1..N	CapacityValueEntry	Value of the capacity associated to the resource.

8.3.3 CapacityValueEntry information element

8.3.3.1 Description

The CapacityValueEntry information element encapsulates values about a capacity metric. Capacity values include total, allocated, reserved and available capacity, which can be expressed via sub-counters.

8.3.3.2 Attributes

The attributes of the CapacityValueEntry information element shall follow the indications provided in table 8.3.3.2-1.

Table 8.3.3.2-1: Attributes of the CapacityValueEntry information element

Attribute	Qualifier	Cardinality	Content	Description
capacityMetricName	M	1	String	Name of the capacity metric. This attribute shall contain the "Measurement Name" value of the related capacity measurement as defined in clause B.2.
capacityValue	M	1	Value	Value of the capacity metric. The type of this attribute shall correspond to the "Measurement Unit" of the related capacity measurement as defined in clause B.2.

8.3.4 TimePeriodInformation information element

8.3.4.1 Description

The TimePeriodInformation information element specifies a time period for which capacity is queried.

8.3.4.2 Attributes

The attributes of the TimePeriodInformation information element shall follow the indications provided in table 8.3.4.2-1.

Table 8.3.4.2-1: Attributes of the TimePeriodInformation information element

Attribute	Qualifier	Cardinality	Content	Description
startTime	M	1	DateTime	Indication when the capacity query period starts.
endTime	M	1	DateTime	Indication when the capacity query period ends.

8.3.5 CapacityThreshold information element

8.3.5.1 Description

The CapacityThreshold information element defines threshold for triggering capacity change notifications.

8.3.5.2 Attributes

The attributes of the CapacityThreshold information element shall follow the indications provided in table 8.3.5.2-1.

Table 8.3.5.2-1: Attributes of the CapacityThreshold information element

Attribute	Qualifier	Cardinality	Content	Description
thresholdId	M	1	Identifier	Indication when the capacity query period starts.
objectInstanceId	M	1	Identifier (Reference to NetworkInfo, TopologyInfo, NodeInfo, or LinkInfo)	Identifier of the measured network resource object instance for which the threshold is defined.
thresholdType	M	1	Enum	Type of threshold. The list of possible values is left for the protocol design stage, but it shall minimally include: single/multi valued threshold, static/dynamic threshold, template-based threshold.
thresholdDetails	M	1	Not specified	Details of the threshold: value to be crossed and direction in which it is crossed and capacity information to which it applies (available, total, reserved, allocated).

8.3.6 CapacityChangeNotification

8.3.6.1 Description

This notification informs the receiver of changes in the capacity of the network in between the NFVI-PoPs managed by the WIM. The object instances for this information element shall be networks, topologies, nodes and links.

The support of this notification is mandatory.

8.3.6.2 Trigger Conditions

The notification shall be produced when:

- Allocation/termination/updating of Connections and Multi-site Connectivity Services affecting the available, reserved, and/or allocated capacity.
- Addition/removal/upgrading of network nodes and links affecting the available and total capacity.
- Faults and repair of network infrastructure affecting the available and total capacity.

8.3.6.3 Attributes

The attributes of the CapacityChangeNotification shall follow the indications provided in table 8.3.6.3-1.

Table 8.3.6.3-1: Attributes of the CapacityChangeNotification

Attribute	Qualifier	Cardinality	Content	Description
thresholdId	M	1	Identifier (Reference to CapacityThreshold)	Threshold which has been crossed.
crossingDirection	M	1	Enum	An indication of whether the threshold was crossed in upward or downward direction. Allowed values: <ul style="list-style-type: none"> • UP; • DOWN.
objectInstanceId	M	1	Identifier (Reference to NetworkInfo, TopologyInfo, NodeInfo, or LinkInfo)	Object (network resource) instance for which the threshold has been defined and the threshold has been crossed.
capacityValueEntry	M	1..N	CapacityValuesEntry	Capacity information related to the capacity change. See note.
NOTE: The CapacityChangeNotification uses the CapacityValuesEntry information element. In the present notification, only the values of CapacityValuesEntry that have been requested as part of the creation of the capacity threshold shall be returned.				

8.3.7 NetworkInfo information element

8.3.7.1 Description

The NetworkInfo information element encapsulates information about a network in between the NFVI-PoPs (sites).

The relationship in between the information elements specified in the present clause is depicted in figure 8.3.7.1-1, which illustrates the information model of network resources and topology for multi-site connectivity.

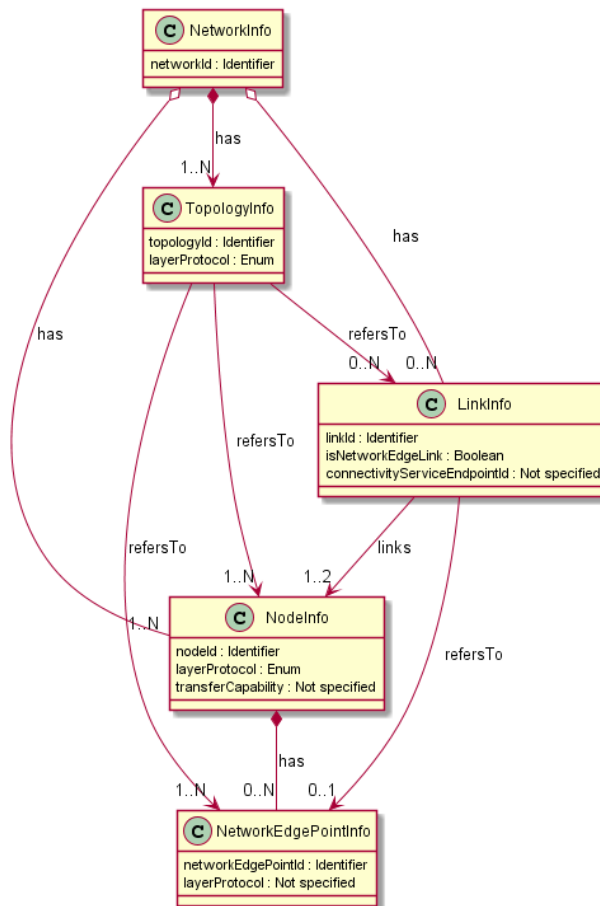


Figure 8.3.7.1-1: Network resources and topology modelling for multi-site connectivity

8.3.7.2 Attributes

The attributes of the NetworkInfo information element shall follow the indications provided in table 8.3.7.2-1.

Table 8.3.7.2-1: Attributes of the NetworkInfo information element

Attribute	Qualifier	Cardinality	Content	Description
networkId	M	1	Identifier	Identifies the network node.
topology	M	1..N	TopologyInfo	Describes a network topology built with the nodes/links of the network.
node	M	1..N	NodeInfo	Describes a node which is part of the network.
link	M	0..N	LinkInfo	Describes a link which is part of the network.
NOTE: Cardinality can be zero to support the use case that a single node can interconnect the multiple sites. It also supports the use case of having higher level network abstractions represented by single nodes.				

8.3.8 TopologyInfo information element

8.3.8.1 Description

The TopologyInfo information element encapsulates information about a topology of the network in between the NFVI-PoPs (sites).

8.3.8.2 Attributes

The attributes of the TopologyInfo information element shall follow the indications provided in table 8.3.8.2-1.

Table 8.3.8.2-1: Attributes of the TopologyInfo information element

Attribute	Qualifier	Cardinality	Content	Description
topologyId	M	1	Identifier	Identifies the topology information element.
layerProtocol	M	1	Enum	The protocol for particular layer used for creating the topology. Examples are: <ul style="list-style-type: none"> • MPLS-TE; • Optical Data Unit (ODU); • Ethernet (ETH); and • Optical Channel (OCh).
nodeId	M	1..N	Identifier (Reference to NodeInfo)	References to a node which is part of this network topology.
linkId	M	0..N	Identifier (Reference to LinkInfo)	References to a link which is part of this network topology. See note.
networkEdgePointId	M	1..N	Identifier (Reference to NetworkEdgePointInfo)	References to the network edge points of the topology.
NOTE: Cardinality can be zero to support the use case that a single physical node can interconnect the multiple sites. It also supports the use case of having higher level network abstractions represented by single nodes.				

8.3.9 NodeInfo information element

8.3.9.1 Description

The NodeInfo information element encapsulates information about a node of the network in between the NFVI-PoPs (sites).

8.3.9.2 Attributes

The attributes of the NodeInfo information element shall follow the indications provided in table 8.3.9.2-1.

Table 8.3.9.2-1: Attributes of the NodeInfo information element

Attribute	Qualifier	Cardinality	Content	Description
nodeId	M	1	Identifier	Identifies the network node.
layerProtocol	M	1..N	Enum	Supported protocols for particular layers.
transferCapability	M	1..N	Not specified	Information about the data transfer capabilities of the network node, e.g. switching, routing capabilities.
networkEdgePointId	M	0..N	NetworkEdgePointInfo	Describes a network edge point of the network which is mapped to a node point (an actual port (or interface)) of this network node.
NOTE: Cardinality can be zero to support the case of the network node participating in the network as a "core or internal network node" (e.g. a -P- network node).				

8.3.10 LinkInfo information element

8.3.10.1 Description

The LinkInfo information element encapsulates information about a point to point link in between two nodes of the network in between the NFVI-PoPs (sites), or a point to point link at the edge of the network enabling the connectivity between the connectivity service endpoint of the NFVI-PoP and the WAN.

NOTE: The links in the network are assumed to be bidirectional, and therefore the set of network nodes and links create an undirected graph.

8.3.10.2 Attributes

The attributes of the LinkInfo information element shall follow the indications provided in table 8.3.10.2-1.

Table 8.3.10.2-1: Attributes of the LinkInfo information element

Attribute	Qualifier	Cardinality	Content	Description
linkId	M	1	Identifier	Identifies the network link.
nodeId	M	1..2	Identifier (Reference to NodeInfo)	Reference to the nodes terminating the link. See note.
isNetworkEdgeLink	M	1	Boolean	Defines whether this is a link at the edge of the network, and thus enabling the connectivity to a connectivity service endpoint of the NFVI-PoP. It shall be set to True if this is a network edge link, false otherwise.
networkEdgePointId	M	0..1	Identifier (Reference to NetworkEdgePointInfo)	References a network edge point corresponding to a node edge point (port or interface) of one of the nodes terminating the link. A reference shall be provided if "isNetworkEdgeLink" equals true.
connectivityServiceEndpointId	M	0..1	Identifier (Reference to ConnectivityServiceEndpointInfo)	References a connectivity service endpoint of the NFVI-PoP which is reachable via this link.
NOTE: Cardinality can be one to support the case of the network link participating in the network as a network edge link, hence being one of the terminating points not identifiable as a node of the network in between the NFVI-PoPs.				

8.3.11 NetworkEdgePointInfo information element

8.3.11.1 Description

The NetworkEdgePointInfo information element encapsulates information about a network edge point of the network in between the NFVI-PoPs (sites). The network edge points represent the ingress/egress ports of the network in between the NFVI-PoPs.

8.3.11.2 Attributes

The attributes of the NetworkEdgePointInfo information element shall follow the indications provided in table 8.3.11.2-1.

Table 8.3.11.2-1: Attributes of the NetworkEdgePointInfo information element

Attribute	Qualifier	Cardinality	Content	Description
networkEdgePointId	M	1	Identifier	Identifies the network edge point.
layerProtocol	M	1..N	Not specified	Provides information about the supported protocols supported for particular layers.

8.3.12 ConnectivityServiceEndpointInfo information element

8.3.12.1 Description

The ConnectivityServiceEndpointInfo information element encapsulates information about a connectivity service endpoint of an NFVI-PoP on which a MSCS can be terminated. The WIM's managed object ConnectivityServiceEndpointInfo relates one to one with the VIM's managed object ConnectivityServiceEndpoint (refer to clause 8.10.4 of ETSI GS NFV-IFA 005 [i.9]).

NOTE: The setup of a concrete instance of ConnectivityServiceEndpointInfo (e.g. its creation and maintenance) is not specified in the present document.

8.3.12.2 Attributes

The attributes of the ConnectivityServiceEndpointInfo information element shall follow the indications provided in table 8.3.12.2-1.

Table 8.3.12.2-1: Attributes of the ConnectivityServiceEndpointInfo information element

Attribute	Qualifier	Cardinality	Content	Description
connectivityServiceEndpointId	M	1	Identifier	Identifies the connectivity service endpoint.
layerProtocol	M	1..N	Not specified	Provides information about the protocols supported on the connectivity service endpoint.
linkId	M	1	Identifier (Reference to LinkInfo)	References the network link over which the connectivity service endpoint is reachable.

8.3.13 TopologyChangeNotification

8.3.13.1 Description

This notification informs the receiver of changes in the network in between the NFVI-PoPs managed by the WIM in terms of topology, nodes, and/or links. The object instances for this information element shall be networks, topologies, nodes and links.

The support of this notification is mandatory.

8.3.13.2 Trigger Conditions

The notification shall be produced when:

- Adding and removing a network node from a network topology.
- Modifying the characteristics of a network node.
- Adding and removing a network link from a network topology
- Modifying the characteristics of a network link.
- Making a new topology available, modifying an existing topology (e.g. addition or removing of referred network nodes and network links), or removing a topology from the network.
- Adding and removing a network edge point from a network topology.
- Modifying the characteristics of a network edge point.

8.3.13.3 Attributes

The attributes of the TopologyChangeNotification shall follow the indications provided in table 8.3.13.3-1.

Table 8.3.13.3-1: Attributes of the TopologyChangeNotification

Attribute	Qualifier	Cardinality	Content	Description
networkId	M	0..1	Identifier (Reference to NetworkInfo)	Identifies the network that has changed. It shall be present when changes occur on an existing network. See note 1.
changedInfo	M	0..N	Not specified	Information about the characteristics that have changed (added, removed, updated). The attribute shall enable providing information about: <ul style="list-style-type: none"> the type of change, such as addition, removal, modification; the identification of the resource concerning the change with a reference to the corresponding TopologyInfo, NodeInfo or LinkInfo, and any additional data about the change if the change concerns to a modification. See example in the present clause.

NOTE 1: If the notification concerns to the addition or removal of a network, the information about the change shall be provided as part of the changedInfo.

NOTE 2: It is up to protocol stage design to determine whether additional attributes are needed in the notification to categorize the types of changes that concern to the network topology according to the information provided by the notification and trigger conditions.

EXAMPLE 1: An example when adding new network nodes to an existing network follows:

```
networkId: "wan-eu-de-zone1",
changedInfo: [
  {"addition", "node2-zone1", ""},
  {"addition", "node3-zone1", ""},
  {"removal", "node1-zone1", ""},
  {"modification", "node0-zone1", [{"sub-change1"}, {"sub-change2}]}
]
```

EXAMPLE 2: An example when adding a new network follows:

```
networkId: ""
changedInfo: [
  {"addition"; "wan-eu-de-zone2"; ""}
]
```

8.4 Information elements and notifications related to Fault management

8.4.1 Introduction

The clauses below define information elements and notifications related to fault management.

8.4.2 Alarm information element

8.4.2.1 Description

The Alarm information element encapsulates information about an alarm.

8.4.2.2 Attributes

The attributes of the Alarm information element shall follow the indications provided in table 8.4.2.2-1.

Table 8.4.2.2-1: Attributes of the Alarm information element

Attribute	Qualifier	Cardinality	Content	Description
alarmId	M	1	Identifier	Identifier of this Alarm information element.
managedObjectId	M	1	Identifier	Identifier of the affected managed object. The Managed Objects shall be MSCSs.
rootCauseFaultyObject	M	0..1	Identifier	References the root cause faulty element or sub-object associated to the MSCS, when the fault is directly linked to such element. The managed sub-object shall be MSNCs.
alarmRaisedTime	M	1	DateTime	Timestamp indicating when the alarm was raised by the MSCS.
alarmChangedTime	M	0..1	DateTime	Timestamp indicating when the alarm was last changed.
alarmClearedTime	M	0..1	DateTime	Timestamp indicating when the alarm was cleared.
ackState	M	1	Enum	State of the alarm, permitted values include: <ul style="list-style-type: none"> • Acknowledged. • Unacknowledged.
perceivedSeverity	M	1	Enum	Perceived severity of the managed object failure, legal values: <ul style="list-style-type: none"> • Critical. • Major. • Minor. • Warning. • Indeterminate. • Cleared.
eventTime	M	1	DateTime	Timestamp indicating when the fault was observed.
eventType	M	1	Enum	Type of the event. The allowed values for the eventType attribute use the event type defined in Recommendation ITU-T X.733 [3]: <ul style="list-style-type: none"> • Communication Alarm. • Processing Alarm. • Environment Alarm. • QoS Alarm. • Equipment Alarm.
faultType	M	1	String	Additional information related to the type of the fault.
probableCause	M	1	String	Information about the probable cause of the fault.
isRootCause	M	1	Boolean	Parameter indicating if this fault is the root for other correlated alarms. If TRUE, then the alarms listed in the parameter correlatedAlarmId are caused by this fault.
correlatedAlarmId	M	0..N	Identifier (Reference to Alarm)	List of identifiers of other alarms correlated to this fault.
faultDetails	M	0..N	Not specified.	Provides additional information about the fault. When a fault in the MSCS is produced due to a faulty network resource, this attribute shall provide information identifying such a network resource (e.g. network node, link) and additional information to typify the fault.

8.4.3 AlarmNotification

8.4.3.1 Description

This notification informs the receiver of alarms related to the MSCSs managed by the WIM.

The notification is mandatory.

8.4.3.2 Trigger conditions

The notification shall be produced when:

- An alarm has been created.
- An alarm has been updated, e.g. if the severity of the alarm has changed.

8.4.3.3 Attributes

The attributes of the AlarmNotification shall follow the indications provided in table 8.4.3.3-1.

Table 8.4.3.3-1: Attributes of the AlarmNotification

Attribute	Qualifier	Cardinality	Content	Description
alarm	M	1	Alarm	Information about an alarm including AlarmId, affected MSCS ID, and FaultDetails.

8.4.4 AlarmClearedNotification

8.4.4.1 Description

This notification informs the receiver of the clearing of an alarm related to the MSCSs managed by the WIM. The alarm's perceived severity shall be set to "cleared" since the corresponding fault has been solved.

The notification is mandatory.

8.4.4.2 Trigger conditions

The notification shall be produced when:

- An alarm has been cleared.

8.4.4.3 Attributes

The attributes of the AlarmClearedNotification shall follow the indications provided in table 8.4.4.3-1.

Table 8.4.4.3-1: Attributes of the AlarmClearedNotification

Attribute	Qualifier	Cardinality	Content	Description
alarmId	M	1	Identifier (Reference to Alarm)	Alarm identifier.
alarmClearedTime	M	1	DateTime	Timestamp indicating when the alarm was cleared.

8.4.5 AlarmListRebuiltNotification

8.4.5.1 Description

This notification informs the receiver that the active alarm list has been rebuilt by the WIM. Upon receipt of this notification, the receiver needs to use the "Get Alarm List" operation to synchronize its view on current active alarms with that of the WIM.

The notification is mandatory.

8.4.5.2 Trigger conditions

The notification shall be produced when:

- Active alarm list has been rebuilt by the WIM, e.g. if the WIM detects its storage holding the alarm list is corrupted.

8.4.5.3 Attributes

The AlarmListRebuiltNotification does not contain any attributes.

8.5 Information elements and notifications related to Performance Management

8.5.1 Introduction

The clauses below define information elements and notifications related to performance management.

8.5.2 ObjectSelection information element

8.5.2.1 Description

This information element allows specifying the MSCS or MSNC instances on which performance information will be provided. The ObjectSelection is a pattern to select object instances. The pattern is used in multiple interfaces. In the present interface, the ObjectSelection pattern is used to select MSCS or MSNC instances.

The pattern proposes 2 exclusive options:

- 1) Provide a list of object types and a filter to specify object properties.
- 2) Provide a list of object instances.

8.5.2.2 Attributes

The attributes of the ObjectSelection information element shall follow the indications provided in table 8.5.2.2-1.

Table 8.5.2.2-1: Attributes of the ObjectSelection information element

Attribute	Qualifier	Cardinality	Content	Description
objectType	M	0..N	String	Defines the type of measured object: MSCS or MSNC. One of the two (objectType+ objectFilter or objectInstancelId) shall be present.
objectFilter	M	0..1	Filter	The filter applies on the object types to specify on which object instances the performance information is requested to be collected. One of the two (objectType+ objectFilter or objectInstancelId) shall be present.
objectInstancelId	M	0..N	Identifier	Identifies the object instances for which performance information is requested to be collected. The object instances for this information element shall be MSCS or MSNC instances. One of the two (objectType+ objectFilter or objectInstancelId) shall be present.

8.5.3 PmJob information element

8.5.3.1 Description

This information element provides the details of the PM Job. The object instances for this information element shall be MSCS or MSNC instances.

8.5.3.2 Attributes

The attributes of the PmJob information element shall follow the indications provided in table 8.5.3.2-1.

Table 8.5.3.2-1: Attributes of the PmJob information element

Attribute	Qualifier	Cardinality	Content	Description
pmJobId	M	1	Identifier	Identifier of this PmJob information element.
objectSelector	M	1	ObjectSelection	Defines the object instances for which performance information is requested to be collected. The object instances for this information element shall be MSCS or MSNC instances.
performanceMetric	M	0..N	String	This defines the type of performance metric(s) for the object instances. Valid values are specified as "Measurement Name" values in the performance measurements of clause B.1. At least one of the two (performance metric or metricGroup) shall be present.
performanceMetricGroup	M	0..N	String	Group of performance metrics. A metric group is a pre-defined list of metrics, known to the producer that it can decompose to individual metrics. Valid values are specified as "Measurement Group" values in the performance measurements of clause B.1. At least one of the two (performance metric or metricGroup) shall be present.
collectionPeriod	M	1	Enum	Specifies the periodicity at which the producer will collect performance information. See note.
reportingPeriod	M	1	Enum	Specifies the periodicity at which the producer will report to the consumer about performance information. See note.
reportingBoundary	O	0..1	Not specified.	Identifies a boundary after which the reporting will stop. The boundary shall allow a single reporting as well as periodic reporting up to the boundary.
NOTE: At the end of each reportingPeriod, the producer shall inform the consumer about availability of the performance data collected for each completed collection period during this reportingPeriod. While the exact definition of the types for collectionPeriod and reporting period is left for further specification, it is recommended that the reportingPeriod be equal or a multiple of the collectionPeriod. In the latter case, the performance data for the collection periods within one reporting period would be reported together.				

8.5.4 Threshold information element

8.5.4.1 Description

This information element provides the details of a threshold. The object instances for this information element shall be MSCS or MSNC instances.

8.5.4.2 Attributes

The attributes of the Threshold information element shall follow the indications provided in table 8.5.4.2-1.

Table 8.5.4.2-1: Attributes of the Threshold information element

Attribute	Qualifier	Cardinality	Content	Description
thresholdId	M	1	Identifier	Identifier of this Threshold information element.
objectSelector	M	1	ObjectSelection	Defines the object instances associated with the threshold. The object instances for this information element shall be MSCS or MSNC instances.
performanceMetric	M	1	String	Defines the performance metric associated with the threshold. Valid values are specified as "Measurement Name" value in the performance measurements of clause B.1.
thresholdType	M	1	Enum	Type of threshold. The list of possible values is left for the protocol design stage and might include: single/multi valued threshold, static/dynamic threshold, template-based threshold, etc.
thresholdDetails	M	1	Not specified.	Details of the threshold: value to be crossed, details on the notification to be generated.

8.5.5 PerformanceReport information element

8.5.5.1 Description

This information element defines the format of a performance report provided by the producer to the consumer on a specified object instance or a set of them. The object instances for this information element shall be MSCS or MSNC instances.

8.5.5.2 Attributes

The attributes of the PerformanceReport information element shall follow the indications provided in table 8.5.5.2-1.

Table 8.5.5.2-1: Attributes of the PerformanceReport information element

Attribute	Qualifier	Cardinality	Content	Description
performanceReport	M	1..N	PerformanceReportEntry	List of performance information entries.

8.5.6 PerformanceReportEntry information element

8.5.6.1 Description

This information element defines a single performance report entry. The object instances for this information element shall be MSCS or MSNC instances.

8.5.6.2 Attributes

The attributes of the PerformanceReportEntry information element shall follow the indications provided in table 8.5.6.2-1.

Table 8.5.6.2-1: Attributes of the PerformanceReportEntry information element

Attribute	Qualifier	Cardinality	Content	Description
objectType	M	1	String	Defines the object type. The object types for this information element shall be the MSCS or MSNC.
objectInstanceId	M	1	Identifier	The object instance for which the performance metric is reported. The object instances for this information element shall be MSCS or MSNC instances.
performanceMetric	M	1	String	Name of the metric collected. This attribute shall contain the "Measurement Name" value of the related performance measurement as defined in clause B.1.
performanceValue	M	1..N	PerformanceValueEntry	List of performance values with associated timestamp and measurement context.

8.5.7 PerformanceValueEntry information element

8.5.7.1 Description

This information element defines a single performance value with its associated time stamp and measurement context (see clause B.1).

8.5.7.2 Attributes

The attributes of the PerformanceValueEntry information element shall follow the indications provided in table 8.5.7.2-1.

Table 8.5.7.2-1: Attributes of the PerformanceValueEntry information element

Attribute	Qualifier	Cardinality	Content	Description
timeStamp	M	1	DateTime	Timestamp indicating when the data was collected.
performanceValue	M	1	Value	Value of the metric collected. The type of this attribute shall correspond to the "Measurement Unit" of the related performance measurement as defined in clause B.1.
measurementContext	M	0..1	Not specified	Measurement context of the metric collected. This attribute shall contain the "Measurement Context" value of the related performance measurement as defined in Clause B.1.

8.5.8 PerformanceInformationAvailableNotification

8.5.8.1 Description

This notification informs the receiver that performance information is available. Delivery mechanism for the performance reports is not specified in the present document. The object instances for this information element shall be MSCS or MSNC instances.

8.5.8.2 Trigger Conditions

The notification shall be produced when:

- New performance information is available.

8.5.8.3 Attributes

The attributes of the PerformanceInformationAvailableNotification shall follow the indications provided in table 8.5.8.3-1.

Table 8.5.8.3-1: Attributes of the PerformanceInformationAvailableNotification

Attribute	Qualifier	Cardinality	Content	Description
objectInstanceId	M	1..N	Identifier	Object instances for which performance information is available. The object instances for this information element shall be MSCS or MSNC instances.

8.5.9 ThresholdCrossedNotification

8.5.9.1 Description

This notification informs the receiver that a threshold value has been crossed. The object instances for this information element shall be MSCS or MSNC instances.

8.5.9.2 Trigger Conditions

The notification shall be produced when:

- A Threshold has been crossed. Depending on threshold type, there might be a single or multiple crossing values.

8.5.9.3 Attributes

The attributes of the ThresholdCrossedNotification shall follow the indications provided in table 8.5.9.3-1.

Table 8.5.9.3-1: Attributes of the ThresholdCrossedNotification

Attribute	Qualifier	Cardinality	Content	Description
thresholdId	M	1	Identifier (Reference to Threshold)	Threshold which has been crossed.
crossingDirection	M	1	Enum	An indication of whether the threshold was crossed in upward or downward direction. Values: UP, DOWN.
objectInstanceId	M	1	Identifier	Object instance for which the threshold has been crossed. The object instances for this information element shall be MSCS or MSNC instances.
performanceMetric	M	1	String	Performance metric associated with the threshold. This attribute shall contain the "Measurement Name" value of the related performance measurements as defined in clause B.1.
performanceValue	M	1	Value	Value of the metric that resulted in threshold crossing. The type of this attribute shall correspond to the "Measurement Unit" of the related performance measurement as defined in clause B.1.

Annex A (informative): Terminology mapping

A.1 Introduction

The present annex provides a translation of the concepts of the present document to an industry understandable terminology used in multi-site connectivity as defined in external organizations.

A.2 ACTN terminology

A.2.1 Introduction

The present clause provides a translation of the concepts of the present document to terminology used in IETF (Internet Engineering Task Force). IETF RFC 8453 [i.4] outlines the Framework for ACTN; the IETF RFC 8454 [i.5] outlines the information model for ACTN. When IETF ACTN (Abstraction and Control of TE Networks) is used, the following terminology is applicable.

A.2.2 Mapping between IFA 032 and ACTN terminology

A.2.2.1 Mapping of concepts

Table A.2.2.1-1 illustrates the mapping between the present document specification and IETF ACTN for easy understanding across the concepts.

Table A.2.2.1-1: Terminology mapping between the present document specification and IETF ACTN

ETSI GS NFV-IFA 032 (the present document)	IETF ACTN
Network edge link (LinkInfo with isNetworkEdgeLink=true)	Access link
NFVI-PoP network gateway (see note 1)	Customer Node
Network link	Link
Network node	Node
Network node (where NodeInfo has one or more networkEdgePointId)	Operator Node
Network Edge Point	Operator Node port
Network Topology	TE Topology
MSNC	TE Tunnel
Connectivity Service Endpoint (see note 2)	Access Point or VN Endpoint (from IETF RFC 8454 [i.5])
MSCS	Virtual Network (VN)
MSCS Endpoint	VN Access Point (VNAP)
NOTE 1: Not specified explicitly in the present document, but it maps to the NFVI-PoP network gateway or CE router (see clause 4.3).	
NOTE 2: The ACTN's Access Point is a logical identifier that identifies an access link in between the customer and operator nodes and it is used for the setup of the VN. Similarly, the Connectivity Service Endpoint fulfils the same role, but in addition, the Connectivity Service Endpoint also identifies the endpoint from the customer node's perspective.	

A.2.2.2 Description of IETF ACTN concepts

Access Link:

A link between a customer node and an operator node.

Access Point (AP):

An AP is a logical identifier shared between the customer and the operator used to identify an access link. The AP is used by the customer when requesting a Virtual Network Service (VNS). Note that the term "TE Link Termination Point" describes the endpoints of links, while an AP is a common identifier for the link itself.

The usage of the AP provides also a degree of confidentiality between the customer and the operator, which do not share information about the CE and PE nodes but just identifiers of the points where it is possible to access the network.

The customer and the provider will have different views of how their resources can be connected to the APs. It is also possible to define parameters against the AP such as reservable bandwidth and physical bandwidth.

Customer Node:

Node on the Customer network (e.g. nodes serving fixed residential users, mobile users, and small enterprises).

Domain:

A domain is "any collection of network elements within a common sphere of address management or path computation responsibility". Domain is part of an operator's network that is under common management (i.e. under shared operational management using the same instances of a tool and the same policies). Network elements are often grouped into domains based on technology types, vendor profiles, and geographic proximity.

Inter-domain link:

A link between domains under distinct management administration.

Link:

A link is an edge on the graph representation of a TE topology. Two nodes connected by a link are said to be "adjacent" in the TE topology. In a physical network topology, a link corresponds to a physical connection. In an abstract network topology, a link (sometimes called an "abstract link") is a representation of the potential to connect a pair of points with certain TE parameters. Network abstraction may be applied recursively, so a link in one topology may be created by applying abstraction to the links in the underlying topology.

Node:

A node is a vertex on the graph representation of a TE topology. In a physical network topology, a node corresponds to a physical network element (NE) such as a router. In an abstract network topology, a node (sometimes called an "abstract node") is a representation as a single vertex of one or more physical NEs and their connecting physical connections. The concept of a node represents the ability to connect from any access to the node (a link end) to any other access to that node, although "limited cross-connect capabilities" may also be defined to restrict this functionality. Network abstraction may be applied recursively, so a node in one topology may be created by applying abstraction to the nodes in the underlying topology.

Operator Node:

Node in Operator network (e.g. transport network nodes and edge points connecting Customer nodes).

TE:

Traffic Engineering (TE) encompasses application of technology and scientific principles to achieve performance objectives of operational networks.

Virtual Network (VN):

A VN is a network provided by a service provider to a customer for the customer to use in any way it wants as though it was a physical network. Virtual Networks are built from abstractions of the underlying TE networks. There are two views of a VN as follows:

The VN can be abstracted as a set of edge-to-edge links (a Type 1 VN). Each link is referred as a "VN member" and is formed as an end-to-end tunnel across the underlying networks. Such tunnels may be constructed by recursive slicing or abstraction of paths in the underlying networks and can encompass edge points of the customer's network, access links, intra-domain paths, and inter-domain links.

The VN can also be abstracted as a topology of virtual nodes and virtual links (a Type 2 VN). The operator needs to map the VN to actual resource assignment, which is known as "virtual network embedding". The nodes in this case include physical endpoints, border nodes, and internal nodes as well as abstracted nodes. Similarly, the links include physical access links, inter-domain links, and intra-domain links as well as abstract links.

Type 1 VN is a special case of a Type 2 VN.

The key advantage of VN concept is, the operator does not have to deal with issues related to the management and control of multiple domains.

An underlay connectivity between two remote nodes (i.e. belonging to different autonomous systems (AS)) is composed by a number of intra-domain tunnels, plus inter domain links, plus configuration mechanisms to handover the traffic from one AS to another AS (e.g. Inter AS option A, B or C). This complexity is hidden by the VN, which represent the result of the stitching of all these items into an end to end connection.

A VN can be P2P (point-to-point) or MP2MP (multipoint-to-multipoint) and each branch of the VN is called VN member.

VN Access Point (VNAP):

A Virtual Network Access Point (VNAP) is the binding between an AP and a VN. It is used to allow different VNs to start from the same AP. It also allows for traffic engineering on the access and/or inter-domain links (e.g. keeping track of bandwidth allocation). A different VNAP is created on an AP for each VN.

VNS:

A Virtual Network Service (VNS) is the service agreement between a customer and operator to provide a VN.

Annex B (normative): Performance and capacity metrics and measurements

B.1 Metrics and performance measurements

B.1.1 Introduction

The performance monitoring of MSCS and MSNC is supported by the Performance Management interface. The interface supports the handling of PM jobs, performance Thresholds, and the issue of notifications about the availability of the performance information. There are two types of information relevant to the performance management:

- the type of measured objects; and
- the performance measurement on a specific measured object type.

Clause B.1.2 defines the measured object types for the performance measurements specified in the present document. Clause B.1.3 specifies the performance measurements.

The WIM shall generate the measurement value(s) according to the "Collection Method" and "Trigger" defined in each respective performance measurement.

B.1.2 Measured object type definitions

B.1.2.1 Mscs object type

The measured object type "Mscs" shall be used to collect and report the performance measurements for one MSCS.

The `objectType`, when used in PM job or performance report, shall be equal to "Mscs".

The `objectInstanceId`, when used in PM job or performance report, shall be equal to the `mscsId` of the measured MSCS instance (see clause 8.2.2.5).

B.1.2.2 Msnc object type

The measured object type "Msnc" shall be used to collect and report the performance measurements for one MSNC.

The `objectType`, when used in PM job or performance report, shall be equal to "Msnc".

The `objectInstanceId`, when used in PM job or performance report, shall be equal to the `msncId` of the measured MSNC instance (see clause 8.2.2.6).

B.1.3 Performance measurements

B.1.3.1 MSCS measurements

B.1.3.1.1 Number of incoming packets

- a) **Description:** This measurement provides the number of packets received/incoming at the MSCS (i.e. incoming into the WAN, from the network perspective). This measurement is split into sub-counters per MSCS endpoint.
- b) **Collection Method:** SC.

- c) **Trigger:** The WIM counts the number of incoming packets for each one of the MSCS endpoints. The WIM generates the measurement for the subject Mscs by assigning the value of the collected number of incoming packets measurement(s) to the sub-counters per MSCS endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MscsEndpoints.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** NetPacketIncoming.MscsEndpointId, where MscsEndpointId is equal to mscsEndpointId, the identifier of the measured MSCS endpoint (see clause 8.2.2.8).
- h) **Measurement Context:**
 - *MeasurementInterval:* the duration of the observation by the measurement system to assess the metric.

B.1.3.1.2 Number of outgoing packets

- a) **Description:** This measurement provides the number of packets transmitted/outgoing at the MSCS (i.e. outgoing from the WAN, from the network perspective). This measurement is split into sub-counters per MSCS endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of outgoing packets for each one of the MSCS endpoints. The WIM generates the measurement for the subject Mscs by assigning the value of the collected number of outgoing packets measurement(s) to the sub-counters per MSCS endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MscsEndpoints.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** NetPacketOutgoing.MscsEndpointId, where MscsEndpointId is equal to mscsEndpointId, the identifier of the measured MSCS endpoint (see clause 8.2.2.8).
- h) **Measurement Context:**
 - *MeasurementInterval:* the duration of the observation by the measurement system to assess the metric.

B.1.3.1.3 Number of incoming bytes

- a) **Description:** This measurement provides the number of bytes received/incoming at the MSCS (i.e. incoming into the WAN, from the network perspective). This measurement is split into sub-counters per MSCS endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of incoming bytes for each one of the MSCS endpoints. The WIM generates the measurement for the subject Mscs by assigning the value of the collected number of incoming bytes measurement(s) to the sub-counters per MSCS endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MscsEndpoints.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** NetBytesIncoming.MscsEndpointId, where MscsEndpointId is equal to mscsEndpointId, the identifier of the measured MSCS endpoint (see clause 8.2.2.8).
- h) **Measurement Context:**
 - *MeasurementInterval:* the duration of the observation by the measurement system to assess the metric.

B.1.3.1.4 Number of outgoing bytes

- a) **Description:** This measurement provides the number of bytes transmitted/outgoing at the MSCS (i.e. outgoing from the WAN, from the network perspective). This measurement is split into sub-counters per MSCS endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of outgoing bytes for each one of the MSCS endpoints. The WIM generates the measurement for the subject Mscs by assigning the value of the collected number of outgoing bytes measurement(s) to the sub-counters per MSCS endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MscsEndpoints.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** NetBytesOutgoing.MscsEndpointId, where *MscsEndpointId* is equal to `mscsEndpointId`, the identifier of the measured MSCS endpoint (see clause 8.2.2.8).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.1.5 Maximum one-way delay

- a) **Description:** This measurement provides the maximum one-way delay among all pairs of MSCS endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM selects the maximum value of the one-way delay measured among all the pairs of MSCS endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MscsDelay.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** OneWayDelayMax.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.
 - *EndpointPair*: the information about the MSCS endpoints in between the maximum one-way delay has been observed. Format: Source:*SourceMscsEndpointId*.Dest:*DestMscsEndpointId*, where *MscsEndpointId* is equal to `mscsEndpointId`, the identifier of the source MSCS endpoint, and *DestMscsEndpointId* is equal to `mscsEndpointId`, the identifier of the destination MSCS endpoint (see clause 8.2.2.8).

B.1.3.1.6 Minimum one-way delay

- a) **Description:** This measurement provides the minimum one-way delay among all pairs of MSCS endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM selects the minimum value of the one-way delay measured among all the pairs of MSCS endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MscsDelay.
- f) **Measured Object Type:** Mscs.

- g) **Measurement Name:** OneWayDelayMin.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.
 - *EndpointPair*: the information about the MSCS endpoints in between the minimum one-way delay has been observed. Format: Source:SourceMscsEndpointId.Dest:DestMscsEndpointId, where *MscsEndpointId* is equal to `mscsEndpointId`, the identifier of the source MSCS endpoint, and *DestMscsEndpointId* is equal to `mscsEndpointId`, the identifier of the destination MSCS endpoint (see clause 8.2.2.8).

B.1.3.1.7 Mean one-way delay

- a) **Description:** This measurement provides the mean one-way delay among all pairs of MSCS endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM takes the arithmetic mean of all the collected one-way delay measurements among all the pairs of MSCS endpoints in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MscsDelay.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** OneWayDelayMean.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.1.8 Maximum one-way delay variation

- a) **Description:** This measurement provides the maximum one-way delay variation among all pairs of MSCS endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM selects the maximum value of the one-way delay variation measured among all the pairs of MSCS endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MscsDelay.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** OneWayDelayVarMax.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.
 - *EndpointPair*: the information about the MSCS endpoints in between the maximum one-way delay variation has been observed. Format: Source:SourceMscsEndpointId.Dest:DestMscsEndpointId, where *MscsEndpointId* is equal to `mscsEndpointId`, the identifier of the source MSCS endpoint, and *DestMscsEndpointId* is equal to `mscsEndpointId`, the identifier of the destination MSCS endpoint (see clause 8.2.2.8).

B.1.3.1.9 Minimum one-way delay variation

- a) **Description:** This measurement provides the minimum one-way delay variation among all pairs of MSCS endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM selects the minimum value of the one-way delay variation measured among all the pairs of MSCS endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MscsDelay.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** OneWayDelayVarMin.
- h) **Measurement Context:**
 - *MeasurementInterval:* the duration of the observation by the measurement system to assess the metric.
 - *EndpointPair:* the information about the MSCS endpoints in between the minimum one-way delay variation has been observed. Format: Source:*SourceMscsEndpointId*.Dest:*DestMscsEndpointId*, where *MscsEndpointId* is equal to `mscsEndpointId`, the identifier of the source MSCS endpoint, and *DestMscsEndpointId* is equal to `mscsEndpointId`, the identifier of the destination MSCS endpoint (see clause 8.2.2.8).

B.1.3.1.10 Mean one-way delay variation

- a) **Description:** This measurement provides the mean one-way delay variation among all pairs of MSCS endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM takes the arithmetic mean of all the measured one-way delay variation measurements among all the pairs of MSCS endpoints in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MscsDelay.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** OneWayDelayVarMean.
- h) **Measurement Context:**
 - *MeasurementInterval:* the duration of the observation by the measurement system to assess the metric.

B.1.3.1.11 Packet loss rate

- a) **Description:** This measurement provides the percentage of packets lost among all expected packets to be forwarded in the MSCS.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM computes the percentage as $((num_packets_lost / num_total_packets) \times 100)$, where the *num_total_packets* represents the number of packets that should have been forwarded by the MSCS.
- d) **Measurement Unit:** Each measurement is a real value (unit: %).
- e) **Measurement Group:** MscsPacket.
- f) **Measured Object Type:** Mscs.

- g) **Measurement Name:** PacketLossRate.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.1.12 Packet collision rate

- a) **Description:** This measurement provides the rate of packet collisions among all expected packets to be forwarded in the MSCS.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM computes the percentage as $((num_collision_packets / num_total_packets) \times 100)$, where the *num_total_packets* represents the number of packets that should have been forwarded by the MSCS.
- d) **Measurement Unit:** Each measurement is a real value (unit: %).
- e) **Measurement Group:** MscsPacket.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** PacketCollisionRate.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.1.13 Number of incoming broadcast packets

- a) **Description:** This measurement provides the number of broadcast packets received/incoming at the MSCS (i.e. incoming into the WAN, from the network perspective). This measurement is split into sub-counters per MSCS endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of incoming broadcast packets for each one of the MSCS endpoints. The WIM generates the measurement for the subject Mscs by assigning the value of the collected number of incoming broadcast packets measurement(s) to the sub-counters per MSCS endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MscsEndpoints.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** NetBroadcastPacketIncoming.*MscsEndpointId*, where *MscsEndpointId* is equal to *mscsEndpointId*, the identifier of the measured MSCS endpoint (see clause 8.2.2.8).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.1.14 Number of outgoing broadcast packets

- a) **Description:** This measurement provides the number of broadcast packets transmitted/outgoing at the MSCS (i.e. outgoing from the WAN, from the network perspective). This measurement is split into sub-counters per MSCS endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of outgoing broadcast packets for each one of the MSCS endpoints. The WIM generates the measurement for the subject Mscs by assigning the value of the collected number of outgoing broadcast packets measurement(s) to the sub-counters per MSCS endpoint.

- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MscsEndpoints.
- f) **Measured Object Type:** Mscs.
- g) **Measurement Name:** NetBroadcastPacketOutgoing.MscsEndpointId, where *MscsEndpointId* is equal to `mscsEndpointId`, the identifier of the measured MSCS endpoint (see clause 8.2.2.8).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2 MSNC measurements

B.1.3.2.1 Number of incoming packets

- a) **Description:** This measurement provides the number of packets received/incoming at the MSNC (i.e. incoming into the WAN, from the network's perspective). This measurement is split into sub-counters per MSNC endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of incoming packets for each one of the MSNC endpoints. The WIM generates the measurement for the subject MsnC by assigning the value of the collected number of incoming packets measurement(s) to the sub-counters per MSNC endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MsnCEndpoints.
- f) **Measured Object Type:** MsnC.
- g) **Measurement Name:** NetPacketIncoming.MsnCEndpointId, where *MsnCEndpointId* is equal to `msnCEndpointId`, the identifier of the measured MSNC endpoint (see clause 8.2.2.6).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.2 Number of outgoing packets

- a) **Description:** This measurement provides the number of packets transmitted/outgoing at the MSNC (i.e. outgoing from the WAN, from the network's perspective). This measurement is split into sub-counters per MSNC endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of outgoing packets for each one of the MSNC endpoints. The WIM generates the measurement for the subject MsnC by assigning the value of the collected number of outgoing packets measurement(s) to the sub-counters per MSNC endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MsnCEndpoints.
- f) **Measured Object Type:** MsnC.
- g) **Measurement Name:** NetPacketOutgoing.MsnCEndpointId, where *MsnCEndpointId* is equal to `msnCEndpointId`, the identifier of the measured MSNC endpoint (see clause 8.2.2.6).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.3 Number of incoming bytes

- a) **Description:** This measurement provides the number of bytes received/incoming at the MSNC (i.e. incoming into the WAN, from the network's perspective). This measurement is split into sub-counters per MSNC endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of incoming bytes for each one of the MSNC endpoints. The WIM generates the measurement for the subject Msnc by assigning the value of the collected number of incoming bytes measurement(s) to the sub-counters per MSNC endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MsncEndpoints.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** NetBytesIncoming.*MsncEndpointId*, where *MsncEndpointId* is equal to `msncEndpointId`, the identifier of the measured MSNC endpoint (see clause 8.2.2.6).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.4 Number of outgoing bytes

- a) **Description:** This measurement provides the number of bytes transmitted/outgoing at the MSNC (i.e. outgoing from the WAN, from the network perspective). This measurement is split into sub-counters per MSNC endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of outgoing bytes for each one of the MSNC endpoints. The WIM generates the measurement for the subject Msnc by assigning the value of the collected number of outgoing bytes measurement(s) to the sub-counters per MSNC endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MsncEndpoints.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** NetBytesOutgoing.*MsncEndpointId*, where *MsncEndpointId* is equal to `msncEndpointId`, the identifier of the measured MSNC endpoint (see clause 8.2.2.6).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.5 Maximum one-way delay

- a) **Description:** This measurement provides the maximum one-way delay among all pairs of MSNC endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM selects the maximum value of the one-way delay measured among all the pairs of MSNC endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MsncDelay.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** OneWayDelayMax.

h) **Measurement Context:**

- *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.
- *EndpointPair*: the information about the MSNC endpoints in between the maximum one-way delay has been observed. Format: *Source:SourceMsnEndpointId.Dest:DestMsnEndpointId*, where *MsnEndpointId* is equal to `msncEndpointId`, the identifier of the source MSNC endpoint, and *DestMsnEndpointId* is equal to `msncEndpointId`, the identifier of the destination MSNC endpoint (see clause 8.2.2.6).

B.1.3.2.6 Minimum one-way delay

- a) **Description:** This measurement provides the minimum one-way delay among all pairs of MSNC endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM selects the minimum value of the one-way delay measured among all the pairs of MSNC endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MsnDelay.
- f) **Measured Object Type:** Msn.
- g) **Measurement Name:** OneWayDelayMin.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.
 - *EndpointPair*: the information about the MSNC endpoints in between the minimum one-way delay has been observed. Format: *Source:SourceMsnEndpointId.Dest:DestMsnEndpointId*, where *MsnEndpointId* is equal to `msncEndpointId`, the identifier of the source MSNC endpoint, and *DestMsnEndpointId* is equal to `msncEndpointId`, the identifier of the destination MSNC endpoint (see clause 8.2.2.6).

B.1.3.2.7 Mean one-way delay

- a) **Description:** This measurement provides the mean one-way delay among all pairs of MSNC endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM takes the arithmetic mean of all the collected one-way delay measurements among all the pairs of MSNC endpoints in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MsnDelay.
- f) **Measured Object Type:** Msn.
- g) **Measurement Name:** OneWayDelayMean.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.8 Maximum one-way delay variation

- a) **Description:** This measurement provides the maximum one-way delay variation among all pairs of MSNC endpoints.
- b) **Collection Method:** SC.

- c) **Trigger:** The WIM selects the maximum value of the one-way delay variation measured among all the pairs of MSNC endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MsncDelay.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** OneWayDelayVarMax.
- h) **Measurement Context:**
 - *MeasurementInterval:* the duration of the observation by the measurement system to assess the metric.
 - *EndpointPair:* the information about the MSNC endpoints in between the maximum one-way delay variation has been observed. Format: Source:*SourceMsncEndpointId*.Dest:*DestMsncEndpointId*, where *MsncEndpointId* is equal to `msncEndpointId`, the identifier of the source MSNC endpoint, and *DestMsncEndpointId* is equal to `msncEndpointId`, the identifier of the destination MSNC endpoint (see clause 8.2.2.6).

B.1.3.2.9 Minimum one-way delay variation

- a) **Description:** This measurement provides the minimum one-way delay variation among all pairs of MSNC endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM selects the minimum value of the one-way delay variation measured among all the pairs of MSNC endpoints.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MsncDelay.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** OneWayDelayVarMin.
- h) **Measurement Context:**
 - *MeasurementInterval:* the duration of the observation by the measurement system to assess the metric.
 - *EndpointPair:* the information about the MSNC endpoints in between the minimum one-way delay variation has been observed. Format: Source:*SourceMsncEndpointId*.Dest:*DestMsncEndpointId*, where *MsncEndpointId* is equal to `msncEndpointId`, the identifier of the source MSNC endpoint, and *DestMsncEndpointId* is equal to `msncEndpointId`, the identifier of the destination MSNC endpoint (see clause 8.2.2.6).

B.1.3.2.10 Mean one-way delay variation

- a) **Description:** This measurement provides the mean one-way delay variation among all pairs of MSNC endpoints.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM takes the arithmetic mean of all the measured one-way delay variation measurements among all the pairs of MSNC endpoints in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (unit: ms).
- e) **Measurement Group:** MsncDelay.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** OneWayDelayVarMean.

h) **Measurement Context:**

- *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.11 Packet loss rate

- a) **Description:** This measurement provides the percentage of packets lost among all expected packets to be forwarded in the MSNC.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM computes the percentage as $((num_packets_lost / num_total_packets) \times 100)$, where the *num_total_packets* represents the number of packets that should have been forwarded by the MSNC.
- d) **Measurement Unit:** Each measurement is a real value (unit: %).
- e) **Measurement Group:** MsncPacket.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** PacketLossRate.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.12 Packet collision rate

- a) **Description:** This measurement provides the rate of packet collisions among all expected packets to be forwarded in the MSNC.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM computes the percentage as $((num_collision_packets / num_total_packets) \times 100)$, where the *num_total_packets* represents the number of packets that should have been forwarded by the MSNC.
- d) **Measurement Unit:** Each measurement is a real value (unit: %).
- e) **Measurement Group:** MsncPacket.
- f) **Measured Object Type:** Msnc.
- g) **Measurement Name:** PacketCollisionRate.
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.13 Number of incoming broadcast packets

- a) **Description:** This measurement provides the number of broadcast packets received/incoming at the MSNC (i.e. incoming into the WAN, from the network's perspective). This measurement is split into sub-counters per MSNC endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of incoming broadcast packets for each one of the MSNC endpoints. The WIM generates the measurement for the subject Msnc by assigning the value of the collected number of incoming broadcast packets measurement(s) to the sub-counters per MSNC endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** MsncEndpoints.
- f) **Measured Object Type:** Msnc.

- g) **Measurement Name:** NetBroadcastPacketIncoming.*MsncEndpointId*, where *MsncEndpointId* is equal to `msncEndpointId`, the identifier of the measured MSNC endpoint (see clause 8.2.2.6).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.1.3.2.14 Number of outgoing broadcast packets

- a) **Description:** This measurement provides the number of broadcast packets transmitted/outgoing at the MSNC (i.e. outgoing from the WAN, from the network's perspective). This measurement is split into sub-counters per MSNC endpoint.
- b) **Collection Method:** SC.
- c) **Trigger:** The WIM counts the number of outgoing broadcast packets for each one of the MSNC endpoints. The WIM generates the measurement for the subject *Msn* by assigning the value of the collected number of outgoing broadcast packets measurement(s) to the sub-counters per MSNC endpoint.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** *Msn*Endpoints.
- f) **Measured Object Type:** *Msn*.
- g) **Measurement Name:** NetBroadcastPacketOutgoing.*MsncEndpointId*, where *MsncEndpointId* is equal to `msncEndpointId`, the identifier of the measured MSNC endpoint (see clause 8.2.2.6).
- h) **Measurement Context:**
 - *MeasurementInterval*: the duration of the observation by the measurement system to assess the metric.

B.2 Metrics and capacity measurements

B.2.1 Introduction

The capacity monitoring of multi-site network connectivity is supported by the Capacity Management interface. The interface supports querying capacity data, as well as handling capacity Thresholds, and the issue of notifications about capacity changes. There are two types of information relevant to the capacity management:

- the type of measured objects, according to the capacity and topology information objects; and
- the capacity values on a specific measured object type.

Clause B.2.2 defines the measured object types for the capacity measurements specified in the present document. Clause B.2.3 specifies the capacity measurements.

The WIM shall generate the measurement value(s) according to the "Trigger" defined in each respective capacity measurement.

B.2.2 Measured object type definitions

B.2.2.1 Network object type

The measured object type "Network" shall be used to collect and report the capacity information of a network in between the NFVI-PoPs (sites).

The `objectType`, when used in querying capacity information, shall be equal to "NETWORK".

The `objectInstanceId`, when used in querying capacity information or notifying about capacity changes, shall be equal to the `networkId` of the measured network (see clause 8.3.7).

B.2.2.2 Topology object type

The measured object type "Topology" shall be used to collect and report the capacity information of a topology instance of the network in between the NFVI-PoPs (sites).

The `objectType`, when used in querying capacity information, shall be equal to "TOPOLOGY".

The `objectInstanceId`, when used in querying capacity information or notifying about capacity changes, shall be equal to the `topologyId` of the measured topology (see clause 8.3.8).

B.2.2.3 Node object type

The measured object type "Node" shall be used to collect and report the capacity information of a network node of the network in between the NFVI-PoPs (sites).

The `objectType`, when used in querying capacity information, shall be equal to "NODE".

The `objectInstanceId`, when used in querying capacity information or notifying about capacity changes, shall be equal to the `nodeId` of the measured network node (see clause 8.3.9).

B.2.2.4 Link object type

The measured object type "Link" shall be used to collect and report the capacity information of a network link of the network in between the NFVI-PoPs (sites).

The `objectType`, when used in querying capacity information, shall be equal to "LINK".

The `objectInstanceId`, when used in querying capacity information or notifying about capacity changes, shall be equal to the `linkId` of the measured network link (see clause 8.3.10).

B.2.3 Capacity measurements

B.2.3.1 Network measurements

B.2.3.1.1 Bandwidth

- a) **Description:** This measurement provides capacity values related to bandwidth over the total set of links in the network. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** For the allocated, reserved and available capacity values, the WIM computes the average bandwidth considering the total n set of links i in the network as the "sum of bandwidth per link divided by the number of links in the network ($(\sum_i bw_i)/n$)", wherein bw_i is the corresponding percentage of bandwidth on link i , whether allocated, available or reserved over the total link throughput. For the total capacity value, the WIM computes the average total bandwidth capacity considering the total n set of links I in the network as the "sum of bandwidth throughput per link divided by the number of links in the network".
- c) **Measurement Unit:** Each measurement of allocated, reserved and available capacity is a real value (unit: %). The sub-counter value of total capacity is an integer (unit: Mbps).
- d) **Measured Object Type:** NETWORK.
- e) **Measurement Name:** NetBw.[total | allocated | reserved | available], where *total*, *allocated*, *reserved* and *available* are sub-counters of the respective capacity.

B.2.3.1.2 Number of logical networks

- a) **Description:** This measurement provides capacity values related to the number of logical networks, such as virtual network identifiers (VNI). This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the available number of logical networks in the network. The total capacity value equals to the maximum number of supported logical network.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** NETWORK.
- e) **Measurement Name:** NetNumLogical.[*total* | *allocated* | *reserved* | *available*], where *total*, *allocated*, *reserved* and *available* are sub-counters of the respective capacity.

B.2.3.2 Topology measurements

B.2.3.2.1 Number of circuits (tunnels)

- a) **Description:** This measurement provides capacity values related to the number of circuits supported by the particular layer protocol to which the topology is associated. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the number of circuits in the topology. The total capacity value equals to the maximum number of supported circuits.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** TOPOLOGY.
- e) **Measurement Name:** TopoNumCircuits.[*total* | *allocated* | *reserved* | *available*], where *total*, *allocated*, *reserved* and *available* are sub-counters of the respective capacity.

B.2.3.2.2 Number of routing areas

- a) **Description:** This measurement provides capacity values related to the number of routing areas supported by the particular layer protocol to which the topology is associated. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts number of routing areas in the topology. The total capacity value equals to the maximum number of supported routing areas.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** TOPOLOGY.
- e) **Measurement Name:** TopoNumRoutingAreas.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.2.3 Number of routing peers

- a) **Description:** This measurement provides capacity values related to the number of routing peers supported by the particular layer protocol to which the topology is associated. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the number of routing peers in the topology. The total capacity value equals to the maximum number of supported routing peers.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** TOPOLOGY.
- e) **Measurement Name:** TopoNumRoutingPeers.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.2.4 Number of edge nodes per routing area

- a) **Description:** This measurement provides capacity values related to the number of edge nodes per routing area, as supported by the particular layer protocol to which the topology is associated. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the number of edge nodes per routing area in the topology. The total capacity value equals to the maximum number of supported edge nodes.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** TOPOLOGY.
- e) **Measurement Name:** TopoNumEdgeNodesRoutingArea.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.3 Node measurements

B.2.3.3.1 Number of logical forwarding entries

- a) **Description:** This measurement provides capacity values related to the number of logical network entries, such as virtual routing/forwarding tables, split per supported layer protocol and transfer capabilities of the network node. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the number of logical forwarding entries in the network node. The total capacity value equals to the maximum number of supported logical forwarding entries.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** NODE.
- e) **Measurement Name:** NodeNumLogicalForwardingEntries.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.3.2 Number of routing peers of a node

- a) **Description:** This measurement provides capacity values related to the number of routing peers associated to the measured network node, split per supported layer protocol by the network node. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the total number of routing peers associated to the network node. The total capacity value equals to the maximum number of supported routing peers of a node.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** NODE.
- e) **Measurement Name:** NodeNumRoutingPeers.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.3.3 Number of bidirectional forwarding detection sessions

- a) **Description:** This measurement provides capacity values related to the number of bidirectional forwarding detection sessions of the network node. This measurement is applicable for network edge node (i.e. PE-type network node). This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the number of bidirectional forwarding detection sessions of the network node. The total capacity value equals to the maximum number of supported bidirectional forwarding detection sessions.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** NODE.

- e) **Measurement Name:** NodeNumBfdSessions.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.3.4 Number of link aggregation group members

- a) **Description:** This measurement provides capacity values related to the number of link aggregation group members of the network node. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the number of link aggregation group members of the network node. The total capacity value equals to the maximum number of supported link aggregation group members.
- c) **Measurement Unit:** Each measurement is an integer.
- d) **Measured Object Type:** NODE.
- e) **Measurement Name:** NodeNumLagMembers.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.3.5 Forwarding load

- a) **Description:** This measurement provides capacity values related to the forwarding load of the network node, split per supported layer protocol and transfer capabilities of the network node. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM computes the forwarding load of the network node. The total capacity value equals to the maximum supported forwarding load.
- c) **Measurement Unit:** Each measurement of allocated and available capacity is a real value (unit: %). The measurement of total capacity is an integer (unit: frames/packets per second).
- d) **Measured Object Type:** NODE.
- e) **Measurement Name:** NodeForwardingLoad.[*total* | *allocated* | *available*], where *total*, *allocated*, and *available* are sub-counters of the respective capacity.

B.2.3.3.6 CPU load

- a) **Description:** This measurement provides capacity values related to the CPU load of the network node. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the total (maximum supported) and allocated (in use) CPU load of the network node. The total capacity value equals to the maximum supported CPU capacity.
- c) **Measurement Unit:** Each measurement of allocated is a real value (unit: %). The measurement of total capacity is an integer (unit: Mhz).
- d) **Measured Object Type:** NODE.
- e) **Measurement Name:** NodeCpuLoad.[*total* | *allocated*], where *total*, and *allocated* are sub-counters of the respective capacity.

B.2.3.3.7 Memory load

- a) **Description:** This measurement provides capacity values related to the memory load of the network node. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the total (maximum supported) and allocated (in use) memory load of the network node. The total capacity value equals to the maximum supported memory capacity.
- c) **Measurement Unit:** Each measurement of allocated is a real value (unit: %). The measurement of total capacity is an integer (unit: Mbyte).
- d) **Measured Object Type:** NODE.

- e) **Measurement Name:** NodeMemLoad.[*total* | *allocated*], where *total* and *allocated* are sub-counters of the respective capacity.

B.2.3.4 Link measurements

B.2.3.4.1 Bandwidth

- a) **Description:** This measurement provides capacity values related to bandwidth on a network link. This measurement is split into sub-counters per capacity value type.
- b) **Trigger:** The WIM counts the total (maximum supported), allocated, and available throughput load of the network link. For the total capacity value, the WIM retrieves the nominal link throughput.
- c) **Measurement Unit:** Each measurement of allocated, reserved and available capacity is a real value (unit: %). The measurement of total capacity is an integer (unit: Mbps).
- d) **Measured Object Type:** LINK.
- e) **Measurement Name:** LinkBw.[*total* | *allocated* | *reserved* | *available*], where *total*, *allocated*, *reserved* and *available* are sub-counters of the respective capacity.

Annex C (normative): Security and Regulatory Concerns

C.1 Risk analysis and assessment

Table C.1-1 is the output of the Threat, Risk, Vulnerability Analysis according to ETSI GS NFV-SEC 006 [i.6].

Table C.1-1: Threat, Risk, Vulnerability Analysis

A Security Environment		
a.1 Assumptions		
a.1.1	A set of management networks providing connectivity for management purposes among the existing NFV-MANO functional entities (NFVO, VNFM and VIM) and the WIM, whose produced interfaces are specified in the present document.	
a.1.2	Internal attackers have access to the management network.	See a.1.1 in Table 1 of ETSI GS NFV-SEC 014 [i.7].
a.1.3	Internal attackers are attached to the management network.	See a.1.7 in Table 1 of ETSI GS NFV-SEC 014 [i.7].
a.1.4	Internal attackers have access to the NFV-MANO functional entities.	Specialized from a.1.3, and a.1.5 in Table 1 of ETSI GS NFV-SEC 014 [i.7].
a.2 Assets		
a.2.1	Existing NFV-MANO functional entities: these are the NFVO, VNFM and VIM. These assets offer interfaces for consuming NFV-MANO services as well as are responsible for storing relevant NFV-MANO information and artefacts (e.g. VNF Packages, NSD, VNFD, images, etc.). The NFVO can act as a consumer of the interfaces produced by the WIM.	See clause 4.1 of ETSI GS NFV-IFA 031 [i.8].
a.2.2	WIM: it is responsible for assisting in the management of connectivity over the WAN infrastructure.	
a.2.3	NFVI-PoP: N-PoP where a Network Function is or could be deployed as Virtual Network Function (VNF).	
a.2.4	Interfaces produced by the WIM for the management of WAN resources and connectivity across multiple NFVI-PoPs.	See clause 5.2
a.2.5	Fault alarm: fault information reported to a consumer including information to identify the object on which the fault occurred, the type of fault that was identified, the cause of the fault, the timestamp information about when the event causing the fault was observed, as well as timing information about the alarm that is raised.	See clause 8.4.2
a.2.6	Performance and capacity metrics: performance and capacity information that need to be reported/acquired.	See annex B.
a.2.7	The credentials of authorized administrators with legitimate access to the NFV-MANO functional entities and the WIM.	Specialized from a.2.2 in Table 1 of ETSI GS NFV-SEC 014 [i.7].
a.2.8	WAN resources, such as network nodes and links, which are used for the establishment of multi-site connectivity services (MSCS) by using one or more multi-site network connections (MSNC).	See clauses 4.3, 8.3.7, 8.3.8, 8.3.9 and 8.3.10.
a.3 Threat agents		
a.3.1	Unauthorized user of assets.	
a.3.1.1	Agent can be human, e.g. an administrator with access to the assets.	
a.3.1.2	Agent can be a piece of software, e.g. a malicious computer program installed during an earlier access and programmed to run later.	
a.3.2	(Industrial) espionage agent.	
a.3.3	Sabotage agent.	
a.3.4	Internal threat agent, e.g. corrupt employee.	
a.4 Threats		
a.4.1	Unauthorized read (viewing/copying/consuming of data and interfaces).	Refer to threat agents a.3.1, a.3.2 and a.3.4. Refer to all assets in a.2.
a.4.2	Unauthorized write action (masquerade ("spoofing"), forgery, loss or corruption of information).	Refer to threat agents a.3.3 and a.3.4. Refer to all assets in a.2.

a.4.3	Unauthorized access.	Refer to threat agents a.3.1, a.3.2, a.3.3. Refer to all assets in a.2.
a.4.4	Repudiation (endpoint and threat agents).	Refer to threat agent a.3.4. Refer to assets a.2.4, a.2.5, a.2.6 and a.2.7.
a.4.5	Denial of service.	Refer to threat agents a.3.3 and a.3.4. Refer to assets in a.2.1, a.2.2, a.2.3, a.2.4, and a.2.8.
B Security Objectives		
b.1 Requirements for the assets relevant to the present document's scope		
b.1.1	The WIM shall ensure that only authorized and authenticated entities can access (read or write) the provided interfaces and that data is exchanged in a confidential manner following the requirements for access controls and communications security (see clauses 8.5 and 8.6 in ETSI GS NFV-SEC 012 [2]).	
b.1.2	The WIM shall ensure the authenticity and integrity of all data exchanged on the interfaces following the requirements for authentication control (see clause 8.4 in ETSI GS NFV-SEC 012 [2]).	
b.1.3	The WIM shall ensure that data provenance is logged.	
b.1.4	The WIM shall ensure that collected data is authentic.	Collected data includes fault, connectivity information, timestamps, etc.
b.1.5	The WIM shall provide means to detect and mitigate denial of service attacks.	
b.1.6	The WIM shall ensure the authenticity of the WAN resources.	
b.1.7	The WIM shall prevent replay of any data following requirements for authentications control (see clause 8.4 in ETSI GS NFV-SEC 012 [2]).	

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