



Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Performance Measurements Specification

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Modal verbs terminology

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1 Scope

The present document specifies the performance measurements and use cases for descriptors and interfaces, including Or-Vnfm reference point, Ve-Vnfm reference point, Vi-Vnfm reference point, Or-Vi reference point, Os-Ma-nfvo reference point, and service interfaces produced by Container Infrastructure Service Management (CISM) function and Container Cluster Management (CCM) function, based on the performance metrics collected at NFVI.

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 005](#): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Or-Vi reference point - Interface and Information Model Specification".
- [2] [ETSI GS NFV-IFA 006](#): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Vi-Vnfm reference point - Interface and Information Model Specification".
- [3] [ETSI GS NFV-IFA 008](#): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Ve-Vnfm reference point - Interface and Information Model Specification".
- [4] [ETSI GS NFV-IFA 011](#): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; VNF Descriptor and Packaging Specification".
- [5] Void.
- [6] [ETSI GS NFV-SEC 004](#): "Network Functions Virtualisation (NFV); NFV Security; Privacy and Regulation; Report on Lawful Interception Implications".
- [7] [ETSI GS NFV-SEC 006](#): "Network Functions Virtualisation (NFV); Security Guide; Report on Security Aspects and Regulatory Concerns".
- [8] [ETSI GS NFV-SEC 010](#): "Network Functions Virtualisation (NFV); NFV Security; Report on Retained Data problem statement and requirements".
- [9] [ETSI GS NFV-SEC 012](#): "Network Functions Virtualisation (NFV) Release 3; Security; System architecture specification for execution of sensitive NFV components".
- [10] [ETSI GS NFV-TST 008](#): "Network Functions Virtualisation (NFV) Release 3; Testing; NFVI Compute and Network Metrics Specification".
- [11] [ETSI GS NFV-IFA 040](#): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Requirements for service interfaces and object model for OS container management and orchestration specification".
- [12] [ETSI GS NFV-IFA 036](#): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Requirements for service interfaces and object model for container cluster management and orchestration specification".

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] [Openstack® measurements](#).

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[i.2] ETSI GR NFV 003: "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".

[i.3] [Kubernetes® document](#): "Resource Management for Pods and Containers".

[i.4] [Kubernetes® document](#): "Resource metrics pipeline".

[i.5] [Kubernetes® document](#): "Document stable metrics list".

[i.6] [Kubernetes® document](#): "Tools for Monitoring Resources".

[i.7] [Kubernetes® type definition](#): "Top-level container for holding NodeStats and PodStats".

[i.8] [Linux® Networking Documentation](#): "Interface statistics".

NOTE: Linux® is the registered trademark of Linus Torvalds in the U.S. and other countries.

[i.9] ETSI GS NFV-IFA 045: "Network Functions Virtualisation (NFV) Release 4; Management and Orchestration; Faults and alarms modelling specification".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GR NFV 003 [i.2] apply.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GR NFV 003 [i.2] 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 GR NFV 003 [i.2].

OM	Object Mapping
SC	Status Counter

4 Overview

4.1 Introduction

The present document specifies the performance measurements that are exposed on various NFV MANO reference points (e.g. Or-Vnfm, Ve-Vnfm-em, Vi-Vnfm, Or-Vi and Os-Ma-nfvo) and service interfaces produced by NFV MANO functions (e.g. CISM and CCM). ETSI GS NFV-TST 008 [10] specifies the Network Function Virtualisation Infrastructure (NFVI) performance metrics that will be reported to Virtualised Infrastructure Manager (VIM). VIM processes the performance metrics received from NFVI to generate performance measurements to be sent to NFV Orchestrator (NFVO) and VNF Manager (VNFM). VNFM and NFVO conduct further processing to generate performance measurements. CISM collects and processes the performance metrics about OS container workload received from CIS to generate performance measurements to be sent to NFVO and VNFM. CCM collects and processes the performance metrics about CIS cluster to generate performance measurements to be sent to NFVO.

NOTE: The present document does not specify the path (e.g. from which Kubernetes® function or time series database) by which the CISM can get performance metrics about OS container workload. In general, performance monitoring data flow can take the similar flow of monitoring and generation of alarms concerning container-based VNFC/VNF as described in Figure A.1.2.3-1 in ETSI GS NFV-IFA 045 [i.9].

4.2 Use cases

4.2.1 Use case of virtual compute related measurements

Virtual compute related measurements are used to monitor the loading conditions of virtual compute resources that include memory and CPU. Monitoring parameters associated with the compute related measurements and of interest for a VNF can be declared in the VNFD (see ETSI GS NFV-IFA 011 [4]). The measurements can be used as the triggers to the scale VNF operation (see clause 7.2.4 in ETSI GS NFV-IFA 008 [3]).

When the measurement indicated that the virtualised resources are overloaded, it can trigger the scale out operation. When the measurement indicated that the virtualised resources are underloaded, it can trigger the scale in operation.

4.2.2 Use case of network data volume related measurements

Network data volume related measurements are used to measure the data volume of networking interfaces (see clause 7.1 in ETSI GS NFV-TST 008 [10]) including incoming/outgoing of IP data packets and IP data octets. These measurements provide the traffic condition of the network interfaces. When the traffic condition is too high, then it may request the application to take appropriate action.

4.3 Measurements received at VIM

Table 4.3-1 lists the measurements received at VIM to be used to define the performance measurements in clause 6. The measurements are derived from the performance metrics defined in ETSI GS NFV-TST 008 [10].

Table 4.3-1: Measurements received at VIM

Measurements received at VIM	Description
cpu_utilization	Measure the percentage of CPU utilization in the measurement interval that can be derived from Processor Utilization metric (see clause 6.6 in ETSI GS NFV-TST 008 [10]).
memory_utilization	Measure the percentage of memory utilization in the measurement interval that can be derived from the amount of memory used, which is the sum of Memory Buffered, Memory Cached, Memory Free, Memory Slab (see clause 8.6 in ETSI GS NFV-TST 008 [10]), and the amount of memory allocated.

Measurements received at VIM	Description
disk_utilization	Measure the percentage of disk utilization. See Annex A for an example of the measurement mapping from disk.usage and disk.allocation measurements. No disk metric is defined in ETSI GS NFV-TST 008 [10], since the methods of measurement for storage systems vary widely and depend on the implementation (see clause 8.9 in ETSI GS NFV-TST 008 [10]).
num_of_incoming_packets	Measure the number of incoming packets in the measurement interval that can be derived from received Packet Count metric (see clause 7.6 in ETSI GS NFV-TST 008 [10]).
num_of_outgoing_packets	Measure the number of outgoing packets in the measurement interval that can be derived from transmitted Packet Count metric (see clause 7.6 in ETSI GS NFV-TST 008 [10]).
num_of_incoming_bytes	Measure the number of incoming octets in the measurement interval that can be derived from received Octet Count metric (see clause 7.6 in ETSI GS NFV-TST 008 [10]).
num_of_outgoing_bytes	Measure the number of outgoing octets in the measurement interval that can be derived from transmitted Octet Count metric (see clause 7.6 in ETSI GS NFV-TST 008 [10]).

5 Performance measurement definition template

This clause defines the template to be used to describe the performance measurements.

a) Description

This clause contains the description of the performance measurement.

b) Collection Method

This clause contains the method in which this measurement is obtained:

- **Status Counter (SC):** The entity receives a metric at each predetermined interval. A measurement is generated from processing (e.g. arithmetic mean, peak) all of the samples received in the collection period (see clause 7.7.2.2 in ETSI GS NFV-IFA 006 [2]).
- **Transparent Forwarding (TF):** The entity maintains a measurement count that stores the content of the metric that it received.
- **Object Mapping (OM):** The entity receives a metric for measured object A in the collection period and maps the received metric from measured object A to measured object B. A measurement is generated for measured object B by processing the metric(s), which may be mapped from one or more measured object(s) A to a single measured object B. It is noted that:
 - The source metric for measured object A and the target measurement for measured object B may or may not contain subcounters. How the mapping is done for the case that either of the source metric and target measurement contain subcounters is to be defined case by case in the trigger of the measurement definition.
 - Multiple source metrics for measured object A may be mapped to a single target measurement for measured object B. How the mapping is done for this case is to be defined in the trigger of the measurement definition.

c) Trigger

This clause contains the trigger which causes the counter to be updated.

d) Measurement Unit

This clause contains the unit of the measurement value.

e) Measurement Group

This clause contains the group to which a measurement belongs.

f) Measured Object Type

This clause describes the object of a measurement. See clause 6 for the measured object types defined for the performance measurements specified in the present document.

g) Measurement Name

This clause describes the name of a measurement:

- The measurement name is used to identify a measurement. In case the sub-counter is used, the measurement is identified by <measurement type>.<sub-counter name>.
- The measurement name is used to identify the performanceMetric in the performance report (e.g. see clause 9.7.6 of ETSI GS NFV-IFA 008 [3]).
- In the create PM Job operation, the measurement type is the content of performanceMetric to identify the type of measurement(s) to be collected (e.g. see clause 7.4.2.2 of ETSI GS NFV-IFA 008 [3]). The PM Job is applicable to the sub-counters, if the measurement contains sub-counters.
- Examples of measurement names without sub-counters are:
 - VCpuUsageMean;
 - VCpuUsagePeak.
- Examples of valid measurement names with sub-counters are:
 - VCpuUsageMeanVnf.vCompute1:
 - wherein the "vCompute1" is the value of *computeId* of the *VirtualCompute* Instance (see clause 8.4.3.2.2 of ETSI GS NFV-IFA 006 [2]).
 - VCpuUsageMeanVnf.vCompute2:
 - wherein the "vCompute2" is the value of *computeId* of the *VirtualCompute* Instance (see clause 8.4.3.2.2 of ETSI GS NFV-IFA 006 [2]).

h) Measurement Context

This clause describes the context information of a measurement at the time that the measurement is generated, see ETSI GS NFV-TST 008 [10] for more information. The measurement context provides additional information (than performance name and value) which could facilitate the measurement consumer to do the tasks that rely on more detailed information associated with the performance measurement, such as trouble shooting, VNF/VNFC scaling, etc.

The measurement context is only provided in case the measurement producer has knowledge about the context information.

Each measurement may have its specific context, so the detailed measurement context is defined in each measurement definition.

6 Measured object types

6.1 Introduction

This clause defines the measured object types for the performance measurements specified in the present document. Depending on the measurement type, the related measured object can be structured or unstructured. A measurement either relates to an object identified by a combination of object instance identifier and sub-object instance identifier (in case of a structured measured object), or to an object identified by an object instance identifier (in case of an unstructured measured object).

6.2 Measured object type definitions

6.2.1 Virtual compute

The measured object type "VirtualCompute" is used to collect and report the performance measurements for one or more instances of the Virtualised compute resource.

The *objectType*, when used in PM job or performance report, is equal to "VirtualCompute".

The *objectInstanceId*, when used in PM job or performance report, corresponds to *computeId* (see clause 8.4.3.2.2 of ETSI GS NFV-IFA 006 [2] or clause 8.4.3.2.2 of ETSI GS NFV-IFA 005 [1]) of the measured Virtualised compute resource.

6.2.2 VNF

The measured object type "Vnf" is used to collect and report the performance measurements for one or more VNF instances.

The *objectType*, when used in PM job or performance report, is equal to "Vnf".

The *objectInstanceId*, when used in PM job or performance report, corresponds to *vnfInstanceId* that identifies the measured VNF instance.

6.2.3 VNF component

The measured object type "Vnfc" is used to collect and report the performance measurements for one or more VNFC instances.

The *objectType*, when used in PM job or performance report, is equal to "Vnfc".

The *objectInstanceId*, when used in PM job or performance report, corresponds to the *vnfInstanceId* of the VNF instance that contains the measured VNFC instance. The *subObjectInstanceId*, when used in PM job or performance report, corresponds to the *vnfcInstanceId* that identifies the measured VNFC instance.

6.2.4 Virtual network

The measured object type "VirtualNetwork" is used to collect and report the performance measurements for one or more instances of the virtual network.

The *objectType*, when used in PM job or performance report, is equal to "VirtualNetwork".

The *objectInstanceId*, when used in PM job or performance report, corresponds to *networkResourceId* (see clause 8.4.5.2 of ETSI GS NFV-IFA 006 [2] or clause 8.4.5.2 of ETSI GS NFV-IFA 005 [1]) of the measured virtual network instance.

6.2.5 Virtual storage

The measured object type "VirtualStorage" is used to collect and report the performance measurements for one or more instances of the Virtualised storage resource.

The *objectType*, when used in PM job or performance report, is equal to "VirtualStorage".

The *objectInstanceId*, when used in PM job or performance report, corresponds to *storageId* (see clause 8.4.7.2 of ETSI GS NFV-IFA 006 [2] or clause 8.4.7.2 of ETSI GS NFV-IFA 005 [1]) of the measured Virtualised storage resource.

6.2.6 Internal connection point of a VNF instance

The measured object type "VnfIntCp" is used to collect and report the performance measurements for one or more instances of the VNF internal CP.

The *objectType*, when used in PM job or performance report, is equal to "VnfIntCp".

The *objectInstanceId*, when used in PM job or performance report, corresponds to the *vnfInstanceId* of the VNF instance which the VNF internal CP belongs to. The *subObjectInstanceId*, when used in PM job or performance report, corresponds to the instance identifier of the measured VNF internal CP instance.

6.2.7 External connection point of a VNF instance

The measured object type "VnfExtCp" is used to collect and report the performance measurements for one or more instances of the VNF external CP.

The *objectType*, when used in PM job or performance report, is equal to "VnfExtCp".

The *objectInstanceId*, when used in PM job or performance report, corresponds to the *vnfInstanceId* of the VNF instance that exposes the measured VNF external CP instance. The *subObjectInstanceId*, when used in PM job or performance report, corresponds to the instance identifier of the measured VNF external CP instance.

6.2.8 Service access point

The measured object type "Sap" is used to collect and report the performance measurements for one or more SAP instances of an NS instance.

The *objectType*, when used in PM job or performance report, is equal to "Sap".

The *objectInstanceId*, when used in PM job or performance report, corresponds to the *NsInstanceId* of the NS instance that exposes the measured SAP. The *subObjectInstanceId*, when used in PM job or performance report, corresponds to the instance identifier of the measured SAP instance.

6.2.9 CIS cluster node

The measured object type "CisClusterNode" is used to collect and report the performance measurements for one or more CIS cluster nodes.

The *objectType*, when used in PM job or performance report, is equal to "CisClusterNode".

The *objectInstanceId*, when used in PM job or performance report, corresponds to *cisClusterNodeId* (see clause 4.2.4 of ETSI GS NFV-IFA 036 [12]) that identifies the measured CIS cluster node.

6.2.10 MCIO-C

The measured object type "Mcio-c" is used to collect and report the performance measurements for one or more instances of a Compute MCIO (see clause 5.2 of ETSI GS NFV-IFA 040 [11]) corresponding to a group of one or more OS containers.

NOTE: Pod is an example of Compute MCIO corresponding to a group of one or more OS containers in a Kubernetes® environment.

The *objectType*, when used in PM job or performance report, is equal to "Mcio-c".

The *objectInstanceId*, when used in PM job or performance report, corresponds to "ID of Compute MCIO" mapped to the resource handle's "resourceId" (see clause 9.4.7 of ETSI GS NFV-IFA 008 [3]) of the measured compute MCIO.

7 Performance measurements

7.1 Performance measurements produced by VIM

7.1.1 Introduction

The performance measurements defined in this clause 7.1 are applicable to the following reference points:

- Vi-Vnfm;
- Or-Vi (for indirect mode of resource allocation, in case indirect mode is supported).

7.1.2 Mean virtual CPU usage

- a) **Description:** This measurement provides the mean virtual CPU usage of the Virtualised compute resource.
- b) **Collection Method:** SC.
- c) **Trigger:** VIM receives the `cpu_utilization` measurement for the virtual compute instance from NFVI at the pre-defined interval, and then takes the arithmetic mean of the virtual CPU usage metrics received in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** `VirtualisedComputeResource`.
- f) **Measured Object Type:** `VirtualCompute`.
- g) **Measurement Name:** `VCpuUsageMean`.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last `cpu_utilization` measurement received from NFVI in the collection period.
 - **TickInterval:** Indicates the tick interval (see ETSI GS NFV-TST 008 [10]) of the last `cpu_utilization` measurement received from NFVI in the collection period.
 - **MeasurementInterval:** Equals the "number of `cpu_utilization` measurements" \times "measurement interval" (see ETSI GS NFV-TST 008 [10]) of the `cpu_utilization` measurements" received from NFVI in the collection period.
 - **ExecutionContext:** Indicates the execution context (see ETSI GS NFV-TST 008 [10]) of the `cpu_utilization` measurements received from NFVI in the collection period. When a single "non-Idle" VCPU Utilization is required, the sum of the utilization of all the non-Idle execution contexts should be reported as the "active" execution context.

7.1.3 Peak virtual CPU usage

- a) **Description:** This measurement provides the peak virtual CPU usage of the Virtualised compute resource.
- b) **Collection Method:** SC.
- c) **Trigger:** VIM receives the `cpu_utilization` measurement for the virtual compute instance from NFVI at the pre-defined interval, and then selects the maximum metric among the virtual CPU usage metrics received in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** `VirtualisedComputeResource`.
- f) **Measured Object Type:** `VirtualCompute`.

g) **Measurement Name:** VCpuUsagePeak.

h) **Measurement Context:**

- **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the cpu_utilization measurement with peak value received from NFVI in the collection period.
- **TickInterval:** Indicates the tick interval (see ETSI GS NFV-TST 008 [10]) of the cpu_utilization measurement with peak value received from NFVI in the collection period.
- **MeasurementInterval:** Equals the "number of cpu_utilization measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the cpu_utilization measurements" received from NFVI in the collection period.
- **Execution Context:** Indicates the execution context (see ETSI GS NFV-TST 008 [10]) of the cpu_utilization measurement with peak value received from NFVI in the collection period. When a single "non-Idle" VCPU Utilization is required, the sum of the utilization of all the non-Idle execution contexts should be reported as the "active" execution context.

7.1.4 Mean memory usage

a) **Description:** This measurement provides the mean memory usage of the Virtualised compute resource.

b) **Collection Method:** SC.

c) **Trigger:** VIM receives the memory_utilization measurement for the virtual compute instance from NFVI at the pre-defined interval, and then takes the arithmetic mean of the memory usage metrics received in the collection period.

d) **Measurement Unit:** Each measurement is a real value (Unit: %).

e) **Measurement Group:** VirtualisedComputeResource.

f) **Measured Object Type:** VirtualCompute.

g) **Measurement Name:** VMemoryUsageMean.

h) **Measurement Context:**

- **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last memory_utilization measurement received from NFVI in the collection period.
- **MeasurementInterval:** Equals the "number of memory_utilization measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the memory_utilization measurements" received from NFVI in the collection period.
- **MeasurementSystemRam:** Indicates the system RAM (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.
- **MeasurementSystemSwapSpace:** Indicates the system SWAP space (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.

7.1.5 Peak memory usage

a) **Description:** This measurement provides the peak memory usage of the Virtualised compute resource.

b) **Collection Method:** SC.

c) **Trigger:** VIM receives the memory_utilization measurement for the virtual compute instance from NFVI at the pre-defined interval, and then selects the maximum metric among the memory usage metrics received in the collection period.

d) **Measurement Unit:** Each measurement is a real value (Unit: %).

e) **Measurement Group:** VirtualisedComputeResource.

- f) **Measured Object Type:** VirtualCompute.
- g) **Measurement Name:** VMemoryUsagePeak.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the memory_utilization measurement with peak value received from NFVI in the collection period.
 - **MeasurementInterval:** Equals the "number of memory_utilization measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the memory_utilization measurements" received from NFVI in the collection period.
 - **MeasurementSystemRam:** Indicates the system RAM (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.
 - **MeasurementSystemSwapSpace:** Indicates the system SWAP space (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.

7.1.6 Mean disk usage

- a) **Description:** This measurement provides the mean disk usage of the Virtualised compute resource.
- b) **Collection Method:** SC.
- c) **Trigger:** VIM receives the disk_utilization measurement for the virtual compute instance from NFVI at the pre-defined interval, and then takes the arithmetic mean of the disk usage metrics received in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VirtualCompute.
- g) **Measurement Name:** VDiskUsageMean.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last disk_utilization measurement received from NFVI in the collection period.
 - **MeasurementInterval:** Equals the "number of disk_utilization measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the disk_utilization measurements" received from NFVI in the collection period.

7.1.7 Peak disk usage

- a) **Description:** This measurement provides the peak disk usage of the Virtualised Compute Resource.
- b) **Collection Method:** SC.
- c) **Trigger:** VIM receives the disk_utilization measurement for the virtual compute instance from NFVI at the pre-defined interval, and then selects the maximum metric among the disk usage metrics received in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VirtualCompute.
- g) **Measurement Name:** VDiskUsagePeak.

h) Measurement Context:

- **MeasurementEndTime:** It indicates the end time (see ETSI GS NFV-TST 008 [10]) of the `disk_utilization` measurement with peak value received from NFVI in the collection period.
- **MeasurementInterval:** Equals the "number of `disk_utilization` measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the `disk_utilization` measurements" received from NFVI in the collection period.

7.1.8 Number of incoming bytes on virtual compute

- a) **Description:** This measurement provides the number of bytes received at the virtual compute. This measurement is split into subcounters per virtual network interface, which is the communication endpoint under an instantiated compute resource.
- b) **Collection Method:** OM.
- c) **Trigger:** VIM receives one or more `num_of_incoming_bytes` measurement for a virtual network interface from NFVI in the collection period, and maps the received `num_of_incoming_bytes` measurement(s) from the virtual network interface to the Virtual Compute instance. The VIM generates the measurement for the subject Virtual Compute instance by assigning the value of the received `num_of_incoming_bytes` measurement(s) to the sub-counter(s) per virtual network interface.
- d) **Measurement Unit:** Each measurement is a real value.
- e) **Measurement Group:** `VirtualNetworkInterface`.
- f) **Measured Object Type:** `VirtualCompute`.
- g) **Measurement Name:** `VNetByteIncoming.vNetIfId`, where `vNetIfId` is equal to the `resourceId` of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last `num_of_incoming_bytes` measurement received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterval:** Equals the "number of `num_of_incoming_bytes` measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the `num_of_incoming_bytes` measurements" received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last `num_of_incoming_bytes` measurement received from NFVI for the measured virtual network interface in the collection period is generated.

7.1.9 Number of outgoing bytes on virtual compute

- a) **Description:** This measurement provides the number of bytes transmitted at the virtual compute. This measurement is split into subcounters per virtual network interface, which is the communication endpoint under an instantiated compute resource.
- b) **Collection Method:** OM.
- c) **Trigger:** VIM receives one or more `num_of_outgoing_bytes` measurement for a virtual network interface from NFVI in the collection period, and maps the received `num_of_outgoing_bytes` measurement(s) from the virtual network interface to the Virtual Compute instance. The VIM generates the measurement for the subject Virtual Compute instance by assigning the value of the received `num_of_outgoing_bytes` measurement(s) to the sub-counter(s) per virtual network interface.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** `VirtualNetworkInterface`.

- f) **Measured Object Type:** VirtualCompute.
- g) **Measurement Name:** VNetByteOutgoing.vNetIfId, where vNetIfId is equal to the resourceId of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last num_of_outgoing_bytes measurement received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterval:** Equals the "number of num_of_outgoing_bytes measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the num_of_outgoing_bytes measurements" received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last num_of_outgoing_bytes measurement received from NFVI for the measured virtual network interface in the collection period is generated.

7.1.10 Number of incoming packets on virtual compute

- a) **Description:** This measurement provides the number of packets received at the virtual compute. This measurement is split into subcounters per virtual network interface, which is the communication endpoint under an instantiated compute resource.
- b) **Collection Method:** OM.
- c) **Trigger:** VIM receives one or more num_of_incoming_packets measurement for a virtual network interface from NFVI in the collection period, and maps the received num_of_incoming_packets measurement(s) from the virtual network interface to the Virtual Compute instance. The VIM generates the measurement for the subject Virtual Compute instance by assigning the value of the received num_of_incoming_packets measurement(s) to the sub-counter(s) per virtual network interface.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** VirtualNetworkInterface.
- f) **Measured Object Type:** VirtualCompute.
- g) **Measurement Name:** VNetPacketIncoming.vNetIfId, where vNetIfId is equal to the resourceId of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last num_of_incoming_packets measurement received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterval:** Equals the "number of num_of_incoming_packets measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the num_of_incoming_packets measurements" received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last num_of_incoming_packets measurement received from NFVI for the measured virtual network interface in the collection period is generated.

7.1.11 Number of outgoing packets on virtual compute

- a) **Description:** This measurement provides the number of packets transmitted at the virtual compute. This measurement is split into subcounters per virtual network interface, which is the communication endpoint under an instantiated compute resource.
- b) **Collection Method:** OM.

- c) **Trigger:** VIM receives one or more `num_of_outgoing_packets` measurement for a virtual network interface from NFVI in the collection period, and maps the received `num_of_outgoing_packets` measurement(s) from the virtual network interface to the Virtual Compute instance. The VIM generates the measurement for the subject Virtual Compute instance by assigning the value of the received `num_of_outgoing_packets` measurement(s) to the sub-counter(s) per virtual network interface.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** `VirtualNetworkInterface`.
- f) **Measured Object Type:** `VirtualCompute`.
- g) **Measurement Name:** `VNetPacketOutgoing.vNetIfId`, where `vNetIfId` is equal to the `resourceId` of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last `num_of_outgoing_packets` measurement received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterval:** Equals the "number of `num_of_outgoing_packets` measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of `num_of_outgoing_packets` measurements" received from NFVI for the measured virtual network interface in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last `num_of_outgoing_packets` measurement received from NFVI for the measured virtual network interface in the collection period is generated.

7.1.12 Number of incoming bytes of a virtual network

- a) **Description:** This measurement provides the number of bytes received at a virtual network instance. This measurement is split into subcounters per virtual network port.
- b) **Collection Method:** OM.
- c) **Trigger:** VIM receives one or more measurements indicating the number of incoming bytes for a virtual network port of a virtual network instance from NFVI in the collection period, and maps the received measurement(s) from the virtual network port to the virtual network instance. The VIM generates the measurement for the subject virtual network instance by assigning the value, or summing up multiple values, of the received measurement(s) to the sub-counter(s) per virtual network port.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** `VirtualisedNetworkResource`.
- f) **Measured Object Type:** `VirtualNetwork`.
- g) **Measurement Name:** `ByteIncoming.vNPort`, where `vNPort` is equal to the `resourceId` of the measured virtual network port.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last measurement indicating the number of incoming bytes of the measured virtual network port received from NFVI in the collection period.
 - **MeasurementInterval:** Equals the "number of measurements indicating the number of incoming bytes" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of measurements indicating the number of incoming bytes" received from NFVI for the measured virtual network port in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last measurement indicating the number of incoming bytes of the measured virtual network port received from NFVI in the collection period is generated.

7.1.13 Number of outgoing bytes of a virtual network

- a) **Description:** This measurement provides the number of bytes transmitted at a virtual network instance. This measurement is split into subcounters per virtual network port.
- b) **Collection Method:** OM.
- c) **Trigger:** VIM receives one or more measurements indicating the number of outgoing bytes for a virtual network port of a virtual network instance from NFVI in the collection period, and maps the received measurement(s) from the virtual network port to the virtual network instance. The VIM generates the measurement for the subject virtual network instance by assigning the value, or summing up multiple values, of the received measurement(s) to the sub-counter(s) per virtual network port.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** VirtualisedNetworkResource.
- f) **Measured Object Type:** VirtualNetwork.
- g) **Measurement Name:** ByteOutgoing.vNPort, where vNPort is equal to the *resourceId* of the measured virtual network port.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last measurement indicating the number of outgoing bytes of the measured virtual network port received from NFVI in the collection period.
 - **MeasurementInterval:** Equals the "number of measurements indicating the number of outgoing bytes" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of measurements indicating the number of outgoing bytes" received from NFVI for the measured virtual network port in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last measurement indicating the number of outgoing bytes of the measured virtual network port received from NFVI in the collection period is generated.

7.1.14 Number of incoming packets of a virtual network

- a) **Description:** This measurement provides the number of packets received at a virtual network instance. This measurement is split into subcounters per virtual network port.
- b) **Collection Method:** OM.
- c) **Trigger:** VIM receives one or more measurements indicating the number of incoming packets for a virtual network port of a virtual network instance from NFVI in the collection period, and maps the received measurement(s) from the virtual network port to the virtual network instance. The VIM generates the measurement for the subject virtual network instance by assigning the value, or summing up multiple values, of the received measurement(s) to the sub-counter(s) per virtual network port.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** VirtualisedNetworkResource.
- f) **Measured Object Type:** VirtualNetwork.
- g) **Measurement Name:** PacketIncoming.vNPort, where vNPort is equal to the *resourceId* of the measured virtual network port.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last measurement indicating the number of incoming packets of the measured virtual network port received from NFVI in the collection period.

- **MeasurementInterval:** Equals the "number of measurements indicating the number of incoming packets" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of measurements indicating the number of incoming packets" received from NFVI for the measured virtual network port in the collection period.
- **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last measurement indicating the number of incoming packets of the measured virtual network port received from NFVI in the collection period is generated.

7.1.15 Number of outgoing packets of a virtual network

- a) **Description:** This measurement provides the number of packets transmitted at a virtual network instance. This measurement is split into subcounters per virtual network port.
- b) **Collection Method:** OM.
- c) **Trigger:** VIM receives one or more measurements indicating the number of outgoing packets for a virtual network port of a virtual network instance from NFVI in the collection period, and maps the received measurement(s) from the virtual network port to the virtual network instance. The VIM generates the measurement for the subject virtual network instance by assigning the value, or summing up multiple values, of the received measurement(s) to the sub-counter(s) per virtual network port.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** VirtualisedNetworkResource.
- f) **Measured Object Type:** VirtualNetwork.
- g) **Measurement Name:** PacketOutgoing.vNPort, where vNPort is equal to the *resourceId* of the measured virtual network port.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last measurement indicating the number of outgoing packets of the measured virtual network port received from NFVI in the collection period.
 - **MeasurementInterval:** Equals the "number of measurements indicating the number of outgoing packets" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of measurements indicating the number of outgoing packets" received from NFVI for the measured virtual network port in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last measurement indicating the number of outgoing packets of the measured virtual network port received from NFVI in the collection period is generated.

7.1.16 Mean usage of Virtualised storage resource

- a) **Description:** This measurement provides the mean usage of a Virtualised storage resource.
- b) **Collection Method:** TF.
- c) **Trigger:** VIM receives one or more measurements indicating the usage of a Virtualised storage resource from NFVI in the collection period, and generates the measurement by averaging multiple values of the received measurement(s).
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedStorageResource.
- f) **Measured Object Type:** VirtualStorage.
- g) **Measurement Name:** UsageMeanVStorage.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last measurement indicating the usage of the virtualised storage resource received from NFVI in the collection period.
- **MeasurementInterval:** Equals the "number of measurements indicating the usage of the Virtualised storage resource" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of measurements indicating the usage of the Virtualised storage resource" received from NFVI for the measured Virtualised storage resource in the collection period.

7.1.17 Peak usage of Virtualised storage resource

a) Description: This measurement provides the peak usage of a Virtualised storage resource.

b) Collection Method: TF.

c) Trigger: VIM receives one or more measurements indicating the usage of a Virtualised storage resource from NFVI in the collection period, and generates the measurement by taking the maximum of multiple values of the received measurement(s).

d) Measurement Unit: Each measurement is a real value (Unit: %).

e) Measurement Group: VirtualisedStorageResource.

f) Measured Object Type: VirtualStorage.

g) Measurement Name: UsagePeakVStorage.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the measurement indicating the usage of the virtualised storage resource received from NFVI in the collection period.
- **MeasurementInterval:** Equals the "number of measurements indicating the usage of the Virtualised storage resource" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of measurements indicating the usage of the Virtualised storage resource" received from NFVI for the measured Virtualised storage resource in the collection period.

7.1.18 Energy consumption of a virtual compute

a) Description: This measurement provides the total energy consumption of the virtualised compute resource over the collection period.

b) Collection Method: SC.

c) Trigger: VIM receives the energy measurements for the virtual compute instance from NFVI at the pre-defined interval, and then sums the energy measurement values received in the collection period.

d) Measurement Unit: Each measurement is an integer value (Unit: J).

e) Measurement Group: VirtualisedComputeResource.

f) Measured Object Type: VirtualCompute.

g) Measurement Name: EnergyConsumptionVirtualCompute.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time of the last energy consumption measurement received from NFVI in the collection period.
- **MeasurementInterval:** Equals the measurement interval utilized by the NFVI (e.g. 1 second) for providing energy consumption measurements in the collection period.

7.1.19 Mean energy consumption of a virtual compute

- a) **Description:** This measurement provides the mean energy consumption of the virtualised compute resource over the collection period.
- b) **Collection Method:** SC.
- c) **Trigger:** VIM receives the energy measurements for the virtual compute instance from NFVI at the pre-defined interval, and then takes the arithmetic mean of the energy measurement values received in the collection period.
- d) **Measurement Unit:** Each measurement is an integer value (Unit: J).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VirtualCompute.
- g) **Measurement Name:** EnergyConsumptionMeanVirtualCompute.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time of the last energy consumption measurement received from NFVI in the collection period.
 - **MeasurementInterval:** Equals the measurement interval utilized by the NFVI (e.g. 1 second) for providing energy consumption measurements in the collection period.

7.2 Performance measurements produced by VNFM

7.2.1 Introduction

The performance measurements defined in this clause 7.2 are applicable to the following reference points:

- Ve-Vnfm-em.
- Or-Vnfm, with the exceptions that measurements do not apply which are related to aspects internal to the VNF instance, as follows:
 - the measured object type "VNFC" does not apply to this reference point;
 - the measured object type "VnfIntCp" do not apply to this reference point, unless the measured connection point is related to an externally-managed internal virtual link.

Measurements related to VNF/VNFC managed objects consider the two forms of deployment of VNF/VNFC supported by the NFV-MANO, i.e. VM-based and container-based deployments.

7.2.2 Mean virtual CPU usage of VNF/VNFC instance

- a) **Description:** This measurement provides the mean virtual CPU usage of the underlying Virtual Compute instance(s) or groups of one or more OS containers, related to a VNF instance, or to a VNFC instance in a VNF instance. This measurement is split into sub-counters per Virtual Compute instance or group of one or more OS containers.
- b) **Collection Method:** OM.
- c) **Trigger:**
 - For a VM-based VNFC, VNFM receives one or more VCpuUsageMean measurement(s) (see clause 7.1.2) for the VirtualCompute instance(s) from the VIM in the collection period, and maps the received VCpuUsageMean measurement(s) from the VirtualCompute instance to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by assigning the value or averaging multiple values of the received VCpuUsageMean measurement(s) to the sub-counter(s) per VirtualCompute instance.

- For a container-based VNFC, VNFM receives one or more CpuUsageMeanMCIO.container measurements(s) see clause 7.4.2) for the group of one or more OS containers from the CISM in the collection period, and maps the received CpuUsageMeanMCIO.container measurement(s) from the group of one or more OS containers to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by, firstly averaging multiple values of received CpuUsageMeanMCIO.container of the same group of one or more OS containers, and secondly assigning the value or averaging multiple values of the computed averaged values(s) to the sub-counter(s) per group of one or more OS containers.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VNF, VNFC.
- g) **Measurement Name:** VCpuUsageMeanVnf.vComputeId, where *vComputeId* is equal to the *objectInstanceId* of the measured object of the mapped measurement, i.e. VirtualCompute in the case VM-based VNFC and Mcio-c in the case of container-based VNFC.
- h) **Measurement Context:**
- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VCpuUsageMean measurement received from NFVI for the measured Virtualised compute resource in the collection period.
 - **TickInterval:** Indicates the tick interval (see ETSI GS NFV-TST 008 [10]) of the last VCpuUsageMean measurement received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementInterval:** Equals the "number of VCpuUsageMean measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VCpuUsageMean measurements" received from NFVI for the measured Virtualised compute resource in the collection period.
 - **ExecutionContext:** Indicates the execution context (see ETSI GS NFV-TST 008 [10]) of the VCpuUsageMean measurements received from NFVI for the measured Virtualised compute resource in the collection period. When a single "non-Idle" VCPU Utilization is required, the sum of the utilization of all the non-Idle execution contexts should be reported as the "active" execution context.
 - For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last cpu usage measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the cpu usage measurements received from the CIS in the collection period.
 - **ResourcesCpuLimit:** Equals to the value of CPU resources limit.
 - **ResourcesCpuRequest:** Equals to the value of CPU resources request.

7.2.3 Peak virtual CPU usage of VNF/VNFC instance

- a) **Description:** This measurement provides the peak virtual CPU usage of the underlying Virtual Compute instance(s) or groups of one or more OS containers, related to a VNF instance or to a VNFC instance in a VNF instance. This measurement is split into sub-counters per Virtual Compute instance or group of one or more OS containers.
- b) **Collection Method:** OM.

c) **Trigger:**

- For a VM-based VNFC, VNFM receives one or more VCpuUsagePeak measurement(s) (see clause 7.1.3) for the *VirtualCompute* instance(s) from the VIM in the collection period, and maps the received VCpuUsagePeak measurement(s) from the *VirtualCompute* instance to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by assigning the value, or taking the maximum of multiple values of the received VCpuUsagePeak measurement(s) to the sub-counter(s) per *VirtualCompute* instance.
- For a container-based VNFC, VNFM receives one or more CpuUsagePeakMCIO.container measurements(s) (see clause 7.4.3) for the group of one or more OS containers from the CISM in the collection period, and maps the received CpuUsagePeakMCIO.container measurement(s) from the group of one or more OS containers to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by, firstly selecting the maximum of multiple values of received CpuUsagePeakMCIO.container of the same group of one or more OS containers, and secondly assigning the value or taking the maximum of multiple values of the selected value(s) to the sub-counter(s) per group of one or more OS containers.

d) **Measurement Unit:** Each measurement is a real value (Unit: %).

e) **Measurement Group:** VirtualisedComputeResource.

f) **Measured Object Type:** VNF, VNFC.

g) **Measurement Name:** VCpuUsagePeakVnf.vComputeId, where vComputeId is equal to the *objectInstanceId* of the measured object of the mapped measurement, i.e. VirtualCompute in the case VM-based VNFC and Mcio-c in the case of container-based VNFC.

h) **Measurement Context:**

- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VCpuUsageMean measurement received from NFVI for the measured Virtualised compute resource in the collection period.
 - **TickInterval:** Indicates the tick interval (see ETSI GS NFV-TST 008 [10]) of the VCpuUsageMean measurement with peak value received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementInterval:** Equals the "number of VCpuUsageMean measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VCpuUsageMean measurements" received from NFVI for the measured Virtualised compute resource in the collection period.
 - **ExecutionContext:** Indicates the execution context (see ETSI GS NFV-TST 008 [10]) of the VCpuUsageMean measurements received from NFVI for the measured Virtualised compute resource in the collection period. When a single "non-Idle" VCPU Utilization is required, the sum of the utilization of all the non-Idle execution contexts should be reported as the "active" execution context.
- For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last cpu usage measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the cpu usage measurements received from the CIS in the collection period.
 - **ResourcesCpuLimit:** Equals to the value of CPU resources limit.
 - **ResourcesCpuRequest:** Equals to the value of CPU resources request.

7.2.4 Mean memory usage of VNF/VNFC instance

- a) **Description:** This measurement provides the mean memory usage of the underlying Virtual Compute instance(s) or groups of one or more OS containers related to a VNF instance or to a VNFC instance in a VNF instance. This measurement is split into sub-counters per Virtual Compute instance or group of one or more OS containers.
- b) **Collection Method:** OM.
- c) **Trigger:**
- For a VM-based VNFC, VNFM receives one or more VMemoryUsageMean measurement(s) (see clause 7.1.4) for the *VirtualCompute* instance(s) from the VIM in the collection period, and maps the received VMemoryUsageMean measurement(s) from the *VirtualCompute* instance to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by assigning the value or averaging the multiple values of the received VMemoryUsageMean measurement(s) to the sub-counter(s) per *VirtualCompute* instance.
 - For a container-based VNFC, VNFM receives one or more MemoryUsageMeanMCIO.container measurement(s) (see clause 7.4.4) for the group of one or more OS containers from the CISM in the collection period, and maps the received MemoryUsageMeanMCIO.container measurement(s) from the group of one or more OS containers to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by, firstly averaging multiple values of received MemoryUsageMeanMCIO.container of the same group of one or more OS containers, and secondly assigning the value or averaging the multiple values of the computed averaged values(s) to the sub-counters(s) per group of one or more OS containers.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VNF, VNFC.
- g) **Measurement Name:** VMemoryUsageMeanVnf.vComputeId, where vComputeId is equal to the *objectInstanceId* of the measured object of the mapped measurement, i.e. VirtualCompute in the case VM-based VNFC and Mcio-c in the case of container-based VNFC.
- h) **Measurement Context:**
- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VMemoryUsageMean measurement received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementInterval:** Equals the "number of VMemoryUsageMean measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VMemoryUsageMean measurements" received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementSystemRam:** Indicates the system RAM (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.
 - **MeasurementSystemSwapSpace:** Indicates the system SWAP space (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.
 - For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last memory usage measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the memory usage measurements received from the CIS in the collection period.
 - **ResourcesMemoryLimit:** Equals to the value of memory resources limit.

- **ResourcesMemoryRequest:** Equals to the value of memory resources request.

7.2.5 Peak memory usage of VNF/VNFC instance

- a) **Description:** This measurement provides the peak memory usage of the underlying Virtual Compute instance(s) or groups of one or more OS containers related to a VNF instance or to a VNFC instance in a VNF instance. This measurement is split into sub-counters per Virtual Compute instance or group of one or more OS containers.
- b) **Collection Method:** OM.
- c) **Trigger:**
 - For a VM-based VNFC, VNFM receives one or more VMemoryUsagePeak measurement(s) (see clause 7.1.5) for the *VirtualCompute* instance(s) from the VIM in the collection period, and maps the received VMemoryUsagePeak measurement(s) from the *VirtualCompute* instance to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by assigning the value or taking the maximum of multiple values of the received VMemoryUsagePeak measurement(s) to the sub-counter(s) per *VirtualCompute* instance.
 - For a container-based VNFC, VNFM receives one or more MemoryUsagePeakMCIO.container measurement(s) (see clause 7.4.5) for the group of one or more OS containers from the CISM in the collection period, and maps the received MemoryUsagePeakMCIO.container measurement(s) from the group of one or more OS containers to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by, firstly selecting the maximum of multiple values of received MemoryUsagePeakMCIO.container of the same group of one or more OS containers, and secondly assigning the value or taking the maximum of multiple values of the selected value(s) to the sub-counters(s) per group of one or more OS containers.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VNF, VNFC.
- g) **Measurement Name:** VMemoryUsagePeakVnf.vComputeId, where vComputeId is equal to the *objectInstanceId* of the measured object of the mapped measurement, i.e. VirtualCompute in the case VM-based VNFC and Mcio-c in the case of container-based VNFC.
- h) **Measurement Context:**
 - For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the VMemoryUsageMean measurement with peak value received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementInterval:** Equals the "number of VMemoryUsageMean measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VMemoryUsageMean measurements" received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementSystemRam:** Indicates the system RAM (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.
 - **MeasurementSystemSwapSpace:** Indicates the system SWAP space (see ETSI GS NFV-TST 008 [10]) of the measured Virtualised compute resource.
 - For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last memory usage measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the memory usage measurements received from the CIS in the collection period.

- **ResourcesMemoryLimit:** Equals to the value of memory resources limit.
- **ResourcesMemoryRequest:** Equals to the value of memory resources request.

7.2.6 Mean disk usage of VNF/VNFC instance

- a) **Description:** This measurement provides the mean disk usage of the underlying Virtual Compute instance or group of one or more OS containers related to a VNF instance or to a VNFC instance in a VNF instance. This measurement is split into sub-counters per Virtual Compute instance or group of one or more OS containers.
- b) **Collection Method:** OM.
- c) **Trigger:**
- For a VM-based VNFC, VNFM receives one or more VDiskUsageMean measurement(s) (see clause 7.1.6) for the *VirtualCompute* instance(s) from the VIM in the collection period, and maps the received VDiskUsageMean measurement(s) from the *VirtualCompute* instance to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by assigning the value, or averaging the multiple values of the received VDiskUsageMean measurement(s) to the sub-counter(s) per *VirtualCompute* instance.
 - For a container-based VNFC, VNFM receives one or more StorageUsageMeanMCIO.container measurement(s) (see clause 7.4.10) for the group of one or more OS containers from the CISM in the collection period, and maps the received StorageUsageMeanMCIO.container measurement(s) from the group of one or more OS containers to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by, firstly averaging multiple values of received StorageUsageMeanMCIO.container of the same group of one or more OS containers, and secondly assigning the value or averaging multiple values of the computed averaged value(s) to the sub-counter(s) per group of one or more OS containers.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VNF, VNFC.
- g) **Measurement Name:** VDiskUsageMeanVnf.vComputeId, where vComputeId is equal to the *objectInstanceId* of the measured object of the mapped measurement, i.e. VirtualCompute in the case VM-based VNFC and Mcio-c in the case of container-based VNFC.
- h) **Measurement Context:**
- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VDiskUsageMean measurement received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementInterval:** Equals the "number of VDiskUsageMean measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VDiskUsageMean measurements" received from NFVI for the measured Virtualised compute resource in the collection period.
 - For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last storage resource usage measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the storage resource usage measurements received from the CIS in the collection period.

7.2.7 Peak disk usage of VNF/VNFC instance

- a) **Description:** This measurement provides the peak disk usage of the underlying Virtual Compute instances or groups of one or more OS containers related to a VNF instance or to a VNFC instance in a VNF instance. This measurement is split into sub-counters per Virtual Compute instance or group of one or more OS containers.
- b) **Collection Method:** OM.
- c) **Trigger:**
- For a VM-based VNFC, VNFM receives one or more VDiskUsagePeak measurement(s) (see clause 7.1.7) for the *VirtualCompute* instance(s) from the VIM in the collection period, and maps the received VDiskUsagePeak measurement(s) from the *VirtualCompute* instance to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by assigning the value or taking the maximum of multiple values of the received VDiskUsagePeak measurement(s) to the sub-counter(s) per *VirtualCompute* instance.
 - For a container-based VNFC, VNFM receives one or more StorageUsagePeakMCIO.container measurement(s) (see clause 7.4.11) for the group of one or more OS containers from the CISM in the collection period, and maps the received StorageUsagePeakMCIO.container measurement(s) from the group of one or more OS containers to the VNF instance, or the combination of VNF instance and VNFC instance. The VNFM generates the measurement for the subject VNF/VNFC instance by, firstly selecting the maximum of multiple values of received StorageUsagePeakMCIO.container of the same group of one or more OS containers, and secondly assigning the value or taking the maximum of multiple values of the selected value(s) to the sub-counters(s) per group of one or more OS containers.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** VirtualisedComputeResource.
- f) **Measured Object Type:** VNF, VNFC.
- g) **Measurement Name:** VDiskUsagePeakVnf.vComputeId, where vComputeId is equal to the *objectInstanceId* of the measured object of the mapped measurement, i.e. VirtualCompute in the case VM-based VNFC and Mcio-c in the case of container-based VNFC.
- h) **Measurement Context:**
- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the VDiskUsageMean measurement with peak value received from NFVI for the measured Virtualised compute resource in the collection period.
 - **MeasurementInterval:** Equals the "number of VDiskUsageMean measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VDiskUsageMean measurements" received from NFVI for the measured Virtualised compute resource in the collection period.
 - For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last storage resource usage measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the storage resource usage measurements received from the CIS in the collection period.

7.2.8 Number of incoming bytes of VNF internal CP

- a) **Description:** This measurement provides the number of bytes received by a VNF internal Connection Point (CP).
- b) **Collection Method:** OM.

c) **Trigger:**

- For a VM-based VNFC, VNFM receives one or more VNetByteIncoming.vNetIfIId measurement(s) (see clause 7.1.8) for the Virtual Compute instance(s) from the VIM in the collection period, and maps the received VNetByteIncoming.vNetIfIId measurement(s) from the Virtual Compute instance to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by assigning the value, or summing up multiple values, of the mapped VNetByteIncoming.vNetIfIId subcounter(s).
- For a container-based VNFC, VNFM receives one or more NetByteIncomingMCIO.vNetIfIId measurement(s) (see clause 7.4.6) for the group of one or more OS containers from the CISM in the collection period, and maps the received NetByteIncomingMCIO.vNetIfIId measurement(s) from the group of one or more OS containers to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by assigning the value, or summing up multiple values, of the mapped NetByteIncoming.vNetIfIId subcounter(s).

d) **Measurement Unit:** Each measurement is an integer value.

e) **Measurement Group:** VnfInternalCP.

f) **Measured Object Type:** VnfIntCP.

g) **Measurement Name:** ByteIncomingVnfIntCp.

h) **Measurement Context:**

- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VNetByteIncoming.vNetIfIId measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of VNetByteIncoming.vNetIfIId measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VNetByteIncoming.vNetIfIId measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last VNetByteIncoming.vNetIfIId measurement received from NFVI for the measured CP in the collection period is generated.
- For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Rxbytes measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Rxbytes measurements received from the CIS in the collection period.

7.2.9 Number of outgoing bytes of VNF internal CP

a) **Description:** This measurement provides the number of bytes transmitted by a VNF internal CP.

b) **Collection Method:** OM.

c) **Trigger:**

- For a VM-based VNFC, VNFM receives one or more VNetByteOutgoing.vNetIfIId measurement(s) (see clause 7.1.9) for the Virtual Compute instances from the VIM in the collection period, and maps the received VNetByteOutgoing.vNetIfIId measurement(s) from the Virtual Compute instance to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by mapping the value of vNetIfIId to the CP of the VNFC instance, and assigning the value, or summing up multiple values, of the mapped VNetByteOutgoing.vNetIfIId subcounter(s).

- For a container-based VNFC, VNFM receives one or more *NetByteOutgoingMCIO.vNetIfId* measurement(s) (see clause 7.4.7) for the group of one or more OS containers from the CISM in the collection period, and maps the received *NetByteOutgoing.vNetIfId* measurement(s) from the group of one or more OS containers to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by mapping the value of *vNetIfId* to the CP of the VNFC instance, and assigning the value, or summing up multiple values, of the mapped *NetByteOutgoingMCIO.vNetIfId* subcounter(s).
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** *VnfInternalCP*.
- f) **Measured Object Type:** *VnfIntCP*.
- g) **Measurement Name:** *ByteOutgoingVnfIntCp*.
- h) **Measurement Context:**
- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last *VNetByteOutgoing.vNetIfId* measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of *VNetByteOutgoing.vNetIfId* measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the *VNetByteOutgoing.vNetIfId* measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last *VNetByteOutgoing.vNetIfId* measurement received from NFVI for the measured CP in the collection period is generated.
 - For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last *TxBytes* measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the *TxBytes* measurements received from the CIS in the collection period.

7.2.10 Number of incoming packets of VNF internal CP

- a) **Description:** This measurement provides the number of packets received by a VNF internal CP.
- b) **Collection Method:** OM.
- c) **Trigger:**
- For a VM-based VNFC, VNFM receives one or more *VNetPacketIncoming.vNetIfId* measurement(s) (see clause 7.1.10) for the Virtual Compute instances from the VIM in the collection period, and maps the received *VNetPacketIncoming.vNetIfId* measurement(s) from the Virtual Compute instance to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by mapping the value of *vNetIfId* to the CP of the VNFC instance, and assigning the value, or summing up multiple values, of the mapped *VNetPacketIncoming.vNetIfId* subcounter(s).
 - For a container-based VNFC, VNFM receives one or more *NetPacketIncomingMCIO.vNetIfId* measurement(s) (see clause 7.4.8) for the groups of one more OS containers from the CISM in the collection period, and maps the received *NetPacketIncomingMCIO.vNetIfId* measurement(s) from the group of one or more OS containers to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by mapping the value of *vNetIfId* to the CP of the VNFC instance, and assigning the value, or summing up multiple values, of the mapped *NetPacketIncomingMCIO.vNetIfId* subcounter(s).
- d) **Measurement Unit:** Each measurement is an integer value.

- e) **Measurement Group:** VnfInternalCP.
- f) **Measured Object Type:** VnfIntCP.
- g) **Measurement Name:** PacketIncomingVnfIntCp.
- h) **Measurement Context:**
 - For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VNetPacketIncoming.vNetIfId measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of VNetPacketIncoming.vNetIfId measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VNetPacketIncoming.vNetIfId measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last VNetPacketIncoming.vNetIfId measurement received from NFVI for the measured CP in the collection period is generated.
 - For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time of the last Rx_Packets measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Rx_Packets measurements received from the CIS in the collection period.

7.2.11 Number of outgoing packets of VNF internal CP

- a) **Description:** This measurement provides the number of packets transmitted by a VNF internal CP.
- b) **Collection Method:** OM.
- c) **Trigger:**
 - For a VM-based VNFC, VNFM receives one or more VNetPacketOutgoing.vNetIfId measurement(s) (see clause 7.1.11) for the Virtual Compute instances from the VIM in the collection period, and maps the received VNetPacketOutgoing.vNetIfId measurement(s) from the Virtual Compute instance to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by mapping the value of vNetIfId to the CP of the VNFC instance, and assigning the value, or summing up multiple values, of the mapped VNetPacketOutgoing.vNetIfId subcounter(s).
 - For a container-based VNFC, VNFM receives one or more NetPacketOutgoingMCIO.vNetIfId measurement(s) (see clause 7.4.9) for the groups of one or more OS containers from the CISM in the collection period, and maps the received NetPacketOutgoingMCIO.vNetIfId measurement(s) from the group of one or more OS containers to the VNF internal CP instance. The VNFM generates the measurement for the subject VNF internal CP instance by mapping the value of vNetIfId to the CP of the VNFC instance, and assigning the value, or summing up multiple values, of the mapped NetPacketOutgoingMCIO.vNetIfId subcounter(s).
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** VnfInternalCP.
- f) **Measured Object Type:** VnfIntCP.
- g) **Measurement Name:** PacketOutgoingVnfIntCp.

h) Measurement Context:

- For a VM-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VNetPacketOutgoing.vNetIfId measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of VNetPacketOutgoing.vNetIfId measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VNetPacketOutgoing.vNetIfId measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last VNetPacketOutgoing.vNetIfId measurement received from NFVI for the measured CP in the collection period is generated.
- For a container-based VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Tx_Packets measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Tx_Packets measurements received from the CIS in the collection period.

7.2.12 Number of incoming bytes of VNF external CP

a) Description: This measurement provides the number of incoming bytes received by a VNF external CP.

b) Collection Method: OM.

c) Trigger:

- The measurement is triggered based on the mapping of the measured VNF external CP (see clause 7.1.3 of ETSI GS NFV-IFA 011 [4]).
- In case the VNF external CP is mapped to a VNF internal CP (applicable to both VM-based and container-based VNF/VNFC):
 - The VNFM generates the measurement by mapping the performance measurement VNetByteIncomingVnf.vnfcInstanceId.cpId (as defined in clause 7.2.8) from VNF internal CP to VNF external CP.
- In case the VNF external CP is mapped to an internal VL (applicable only to VM-based VNF/VNFC):
 - The VNFM receives one or more ByteIncoming.vNPort measurement(s) (see clause 7.1.12) for the virtual network port(s) from VIM in the collection period, and maps the received ByteIncoming.vNPort subcounter(s) from the virtual network port firstly to the VNF internal VL and then to the VNF external CP (see note). The VNFM generates the measurement for the subject VNF external CP by assigning the value, or summing up multiple values, of the mapped ByteIncoming.vNPort subcounter(s).

NOTE: The mapping between VNF internal VL and VNF external CP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.

d) Measurement Unit: Each measurement is an integer value.

e) Measurement Group: VnfExternalCP.

f) Measured Object Type: VnfExtCP.

g) Measurement Name: ByteIncomingVnfExtCp.

h) Measurement Context:

- For the case of VM-based VNF/VNF-C:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last *VNetByteIncoming.vNetIfId* or *ByteIncoming.vNPort* measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of *VNetByteIncoming.vNetIfId* measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the *VNetByteIncoming.vNetIfId* measurements" received from NFVI for the measured CP in the collection period, or the "number of *ByteIncoming.vNPort* measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the *ByteIncoming.vNPort* measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last *VNetByteIncoming.vNetIfId* or *ByteIncoming.vNPort* measurement received from NFVI for the measured CP in the collection period is generated.
- For a container-based VNF/VNF-C:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Rxbytes measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Rxbytes measurements received from the CIS in the collection period.

7.2.13 Number of outgoing bytes of VNF external CP

a) Description: This measurement provides the number of outgoing bytes transmitted by a VNF external CP.

b) Collection Method: OM.

c) Trigger:

- The measurement is triggered based on the mapping of the measured VNF external CP (see clause 7.1.3 of ETSI GS NFV-IFA 011 [4]).
- In case the VNF external CP is mapped to a VNF internal CP (applicable to both VM-based and container-based VNF/VNF-C):
 - The VNFM generates the measurement by mapping the performance measurement *VNetByteOutgoingVnf.vnfInstanceId.cpId* (as defined in clause 7.2.9) from VNF internal CP to VNF external CP.
- In case the VNF external CP is mapped to an internal VL (applicable only to VM-based VNF/VNF-C):
 - The VNFM receives one or more *ByteOutgoing.vNPort* measurement(s) (see clause 7.1.13) for the virtual network port(s) from VIM in the collection period, and maps the received *ByteOutgoing.vNPort* subcounter(s) from the virtual network port firstly to the VNF internal VL and then to the VNF external CP (see note). The VNFM generates the measurement for the subject VNF external CP by assigning the value, or summing up multiple values, of the mapped *ByteOutgoing.vNPort* subcounter(s).

NOTE: The mapping between VNF internal VL and VNF external CP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.

d) Measurement Unit: Each measurement is an integer value.

e) Measurement Group: VnfExternalCP.

f) Measured Object Type: VnfExtCP.

g) Measurement Name: ByteOutgoingVnfExtCp.

h) Measurement Context:

- For the case of VM-based VNF/VNF-C:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last VNetByteOutgoing.vNetIfId or ByteOutgoing.vNPort measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of VNetByteOutgoing.vNetIfId measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the VNetByteOutgoing.vNetIfId measurements" received from NFVI for the measured CP in the collection period, or the "number of ByteOutgoing.vNPort measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the ByteOutgoing.vNPort measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last VNetByteOutgoing.vNetIfId or ByteOutgoing.vNPort measurement received from NFVI for the measured CP in the collection period is generated.
- For a container-based VNF/VNF-C:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last TxBytes measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the TxBytes measurements received from the CIS in the collection period.

7.2.14 Number of incoming packets of VNF external CP

a) Description: This measurement provides the number of incoming packets received by a VNF external CP.

b) Collection Method: OM.

c) Trigger:

- The measurement is triggered based on the mapping of the measured VNF external CP (see clause 7.1.3 of ETSI GS NFV-IFA 011 [4]).
- In case the VNF external CP is mapped to a VNF internal CP (applicable to both VM-based and container-based VNF/VNF-C):
 - The VNFM generates the measurement by mapping the performance measurement VNetPacketIncomingVnf.vnfInstanceId.cpId (as defined in clause 7.2.10) from VNF internal CP to VNF external CP.
- In case the VNF external CP is mapped to an internal VL (applicable only to VM-based VNF/VNF-C):
 - The VNFM receives one or more PacketIncoming.vNPort measurement(s) (see clause 7.1.14) from for the virtual network port(s) VIM in the collection period, and maps the received PacketIncoming.vNPort subcounter(s) from the virtual network port firstly to the VNF internal VL and then to the VNF external CP (see note). The VNFM generates the measurement for the subject VNF external CP by assigning the value, or summing up multiple values, of the mapped PacketIncoming.vNPort subcounter(s).

NOTE: The mapping between VNF internal VL and VNF external CP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.

d) Measurement Unit: Each measurement is an integer value.

e) Measurement Group: VnfExternalCP.

f) Measured Object Type: VnfExtCP.

g) Measurement Name: PacketIncomingVnfExtCp.

h) Measurement Context:

- For the case of VM-based VNF/VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last `VNetPacketIncoming.vNetIfId` or `PacketIncoming.vNPort` measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of `VNetPacketIncoming.vNetIfId` measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the `VNetPacketIncoming.vNetIfId` measurements" received from NFVI for the measured CP in the collection period, or the "number of `PacketIncoming.vNPort` measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the `PacketIncoming.vNPort` measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 GS [10]) when the last `VNetPacketIncoming.vNetIfId` or `PacketIncoming.vNPort` measurement received from NFVI for the measured CP in the collection period is generated.
- For a container-based VNF/VNFC:
 - **MeasurementEndTime:** Indicates the end time of the last `Rx_Packets` measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the `Rx_Packets` measurements received from the CIS in the collection period.

7.2.15 Number of outgoing packets of VNF external CP

- a) **Description:** This measurement provides the number of outgoing packets transmitted by a VNF external CP.
 - b) **Collection Method:** OM.
 - c) **Trigger:**
 - The measurement is triggered based on the mapping of the measured VNF external CP (see clause 7.1.3 of ETSI GS NFV-IFA 011 [4]).
 - In case the VNF external CP is mapped to a VNF internal CP (applicable to both VM-based and container-based VNF/VNFC):
 - The VNFM generates the measurement by mapping the performance measurement `VNetPacketOutgoingVnf.vnfInstanceId.cpId` (as defined in clause 7.2.11) from VNF internal CP to VNF external CP.
 - In case the VNF external CP is mapped to an internal VL (applicable only to VM-based VNF/VNFC):
 - The VNFM receives one or more `PacketOutgoing.vNPort` measurement(s) (see clause 7.1.15) for the virtual network port(s) from VIM in the collection period, and maps the received `PacketOutgoing.vNPort` subcounter(s) from the virtual network port firstly to the VNF internal VL and then to the VNF external CP (see note). The VNFM generates the measurement for the subject VNF external CP by assigning the value, or summing up multiple values, of the mapped `PacketOutgoing.vNPort` subcounter(s).
- NOTE: The mapping between VNF internal VL and VNF external CP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.
- d) **Measurement Unit:** Each measurement is an integer value.
 - e) **Measurement Group:** `VnfExternalCP`.
 - f) **Measured Object Type:** `VnfExtCP`.
 - g) **Measurement Name:** `PacketOutgoingVnfExtCp`.

h) Measurement Context:

- For the case of VM-based VNF/VNFC:
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last `VNetPacketOutgoing.vNetIfId` or `PacketOutgoing.vNPort` measurement received from NFVI for the measured CP in the collection period.
 - **MeasurementInterval:** Equals the "number of `VNetPacketOutgoing.vNetIfId` measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the `VNetPacketOutgoing.vNetIfId` measurements" received from NFVI for the measured CP in the collection period, or the "number of `PacketOutgoing.vNPort` measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the `PacketOutgoing.vNPort` measurements" received from NFVI for the measured CP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last `VNetPacketOutgoing.vNetIfId` or `PacketOutgoing.vNPort` measurement received from NFVI for the measured CP in the collection period is generated.
- For a container-based VNF/VNFC:
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last `Tx_Packets` measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the `Tx_Packets` measurements received from the CIS in the collection period.

7.3 Performance measurements produced by NFVO

7.3.1 Introduction

The performance measurements defined in this clause 7.3 are applicable to the following reference points:

- Os-Ma-nfvo.

7.3.2 Number of incoming bytes of SAP

- a) **Description:** This measurement provides the number of incoming bytes received by an SAP of an NS instance.
- b) **Collection Method:** OM.
- c) **Trigger:**
 - The measurement is triggered based on the mapping of the measured SAP.
 - In case the SAP is mapped to a VNF external CP:
 - The NFVO receives one or more `ByteIncomingVnfExtCp` measurement(s) (see clause 7.2.12) from VNF in the collection period, and maps the received `ByteIncomingVnfExtCp` measurement(s) from the VNF external CP to SAP. The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped `ByteIncomingVnfExtCp` measurement(s).
 - In case the SAP is mapped to an NS VL:
 - The NFVO receives one or more `ByteIncoming.vNPort` measurement(s) (see clause 7.1.12) for the virtual network port(s) from VIM in the collection period, and maps the received `ByteIncoming.vNPort` subcounter(s) from the virtual network port firstly to the NS VL and then to the SAP (see note). The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped `ByteIncoming.vNPort` subcounter(s).

NOTE: The mapping between NS VL and SAP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.

- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** ServiceAccessPoint.
- f) **Measured Object Type:** Sap.
- g) **Measurement Name:** ByteIncomingSap.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last ByteIncomingVnfExtCp or ByteIncoming.vNPort measurement received from NFVI for the measured SAP in the collection period.
 - **MeasurementInterval:** Equals the "number of ByteIncomingVnfExtCp measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the ByteIncomingVnfExtCp measurements" received from NFVI for the measured SAP in the collection period, or the "number of ByteIncoming.vNPort measurements" × "measurement interval (see ETSI GS NFV-TST 008 [10]) of the ByteIncoming.vNPort measurements" received from NFVI for the measured SAP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last ByteIncomingVnfExtCp or ByteIncoming.vNPort measurement received from NFVI for the measured SAP in the collection period is generated.

7.3.3 Number of outgoing bytes of SAP

- a) **Description:** This measurement provides the number of outgoing bytes transmitted by an SAP of an NS instance.
- b) **Collection Method:** OM.
- c) **Trigger:**
 - The measurement is triggered based on the mapping of the measured SAP.
 - In case the SAP is mapped to a VNF external CP:
 - The NFVO receives one or more ByteOutgoingVnfExtCp measurement(s) (see clause 7.2.13) from VNFM in the collection period, and maps the received ByteOutgoingVnfExtCp measurement(s) from the VNF external CP to SAP. The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped ByteOutgoingVnfExtCp measurement(s).
 - In case the SAP is mapped to an NS VL:
 - The NFVO receives one or more ByteOutgoing.vNPort measurement(s) (see clause 7.1.13) for the virtual network port(s) from VIM in the collection period, and maps the received ByteOutgoing.vNPort subcounter(s) from the virtual network port firstly to the NS VL and then to the SAP (see note). The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped ByteOutgoing.vNPort subcounter(s).

NOTE: The mapping between NS VL and SAP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.

- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** ServiceAccessPoint.
- f) **Measured Object Type:** Sap.
- g) **Measurement Name:** ByteOutgoingSap.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last ByteOutgoingVnfExtCp or ByteOutgoing.vNPort measurement received from NFVI for the measured SAP in the collection period.
- **MeasurementInterval:** Equals the "number of ByteOutgoingVnfExtCp measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the ByteOutgoingVnfExtCp measurements" received from NFVI for the measured SAP in the collection period, or the "number of ByteOutgoing.vNPort measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the ByteOutgoing.vNPort measurements" received from NFVI for the measured SAP in the collection period.
- **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last ByteOutgoingVnfExtCp or ByteOutgoing.vNPort measurement received from NFVI for the measured SAP in the collection period is generated.

7.3.4 Number of incoming packets of SAP

a) Description: This measurement provides the number of incoming packets received by an SAP of an NS instance.

b) Collection Method: OM.

c) Trigger:

- The measurement is triggered based on the mapping of the measured SAP.
- In case the SAP is mapped to a VNF external CP:
 - The NFVO receives one or more PacketIncomingVnfExtCp measurement(s) (see clause 7.2.14) from VNFM in the collection period, and maps the received PacketIncomingVnfExtCp measurement(s) from the VNF external CP to SAP. The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped PacketIncomingVnfExtCp measurement(s).
- In case the SAP is mapped to an NS VL:
 - The NFVO receives one or more PacketIncoming.vNPort measurement(s) (see clause 7.1.14) for the virtual network port(s) from VIM in the collection period, and maps the received PacketIncoming.vNPort subcounter(s) from the virtual network port firstly to the NS VL and then to the SAP (see note). The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped PacketIncoming.vNPort subcounter(s).

NOTE: The mapping between NS VL and SAP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.

d) Measurement Unit: Each measurement is an integer value.

e) Measurement Group: ServiceAccessPoint.

f) Measured Object Type: Sap.

g) Measurement Name: PacketIncomingSap.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last PacketIncomingVnfExtCp or PacketIncoming.vNPort measurement received from NFVI for the measured SAP in the collection period.

- **MeasurementInterval:** Equals the "number of PacketIncomingVnfExtCp measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the PacketIncomingVnfExtCp measurements" received from NFVI for the measured SAP in the collection period, or the "number of PacketIncoming.vNPort measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the PacketIncoming.vNPort measurements" received from NFVI for the measured SAP in the collection period.
- **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last PacketIncomingVnfExtCp or PacketIncoming.vNPort measurement received from NFVI for the measured SAP in the collection period is generated.

7.3.5 Number of outgoing packets of SAP

- a) **Description:** This measurement provides the number of outgoing packets transmitted by an SAP of an NS instance.
- b) **Collection Method:** OM.
- c) **Trigger:**
 - The measurement is triggered based on the mapping of the measured SAP.
 - In case the SAP is mapped to a VNF external CP:
 - The NFVO receives one or more PacketOutgoingVnfExtCp measurement(s) (see clause 7.2.15) from VNFM in the collection period, and maps the received PacketOutgoingVnfExtCp measurement(s) from the VNF external CP to SAP. The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped PacketOutgoingVnfExtCp measurement(s).
 - In case the SAP is mapped to an NS VL:
 - The NFVO receives one or more ByteOutgoing.vNPort measurement(s) (see clause 7.1.15) for the virtual network port(s) from VIM in the collection period, and maps the received ByteOutgoing.vNPort subcounter(s) from the virtual network port firstly to the NS VL and then to the SAP (see note). The NFVO generates the measurement for the subject SAP by assigning the value, or summing up multiple values, of the mapped ByteOutgoing.vNPort subcounter(s).

NOTE: The mapping between NS VL and SAP has dependency on the connectivity modelling between them. The exact mapping is out of scope of the present document.

- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** ServiceAccessPoint.
- f) **Measured Object Type:** Sap.
- g) **Measurement Name:** PacketOutgoingSap.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see ETSI GS NFV-TST 008 [10]) of the last PacketOutgoingVnfExtCp or ByteOutgoing.vNPort measurement received from NFVI for the measured SAP in the collection period.
 - **MeasurementInterval:** Equals the "number of PacketOutgoingVnfExtCp measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the PacketOutgoingVnfExtCp measurements" received from NFVI for the measured SAP in the collection period, or the "number of ByteOutgoing.vNPort measurements" \times "measurement interval (see ETSI GS NFV-TST 008 [10]) of the ByteOutgoing.vNPort measurements" received from NFVI for the measured SAP in the collection period.
 - **MeasurementInterfaceStatus:** Indicates the interface status (see ETSI GS NFV-TST 008 [10]) when the last PacketOutgoingVnfExtCp or ByteOutgoing.vNPort measurement received from NFVI for the measured SAP in the collection period is generated.

7.4 Performance measurements produced by CISM

7.4.1 Introduction

The performance measurements defined in this clause 7.4 are applicable to the OS container workload.

7.4.2 Mean CPU usage on OS container workload

- a) **Description:** This measurement provides the mean CPU usage on the OS container workload.
- b) **Collection Method:** SC.
- c) **Trigger:** CISM receives the CPU usage measurement for the OS container workload at the pre-defined interval, and then takes the arithmetic mean of the CPU usage metrics received in the collection period. The arithmetic mean shall be represented as a percentage with respect to the CPU resources request.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** McioComputeResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** CpuUsageMeanMcio.container, where container is equal to the resource name of the measured OS container.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last cpu usage measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the cpu usage measurements received by CISM in the collection period.
 - **ResourcesCpuLimit:** Equals to the value of CPU resources limit.
 - **ResourcesCpuRequest:** Equals to the value of CPU resources request.

7.4.3 Peak CPU usage on OS container workload

- a) **Description:** This measurement provides the peak CPU usage on the OS container workload.
- b) **Collection Method:** SC.
- c) **Trigger:** CISM receives the CPU usage measurement for the OS container workload at the pre-defined interval, and then selects the Maximum among the CPU usage metrics received in the collection period. The selected CPU usage shall be represented as a percentage with respect to the CPU resources request.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** McioComputeResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** CpuUsagePeakMcio.container, where container is equal to the resource name of the measured OS container.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last cpu usage measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the cpu usage measurements received by CISM in the collection period.

- **ResourcesCpuLimit:** Equals to the value of CPU resources limit.
- **ResourcesCpuRequest:** Equals to the value of CPU resources request.

7.4.4 Mean memory usage on OS container workload

- a) **Description:** This measurement provides the mean memory usage on the OS container workload.
- b) **Collection Method:** SC.
- c) **Trigger:** CISM receives the memory usage measurement for the OS container workload at the pre-defined interval, and then takes the arithmetic mean of the memory usage metrics received in the collection period. The arithmetic mean shall be represented as a percentage with respect to the memory resources request.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** McioComputerResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** MemoryUsageMeanMcio.container, where container is equal to the resource name of the measured OS container.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last memory usage measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the memory usage measurements received by CISM in the collection period.
 - **ResourcesMemoryLimit:** Equals to the value of memory resources limit.
 - **ResourcesMemoryRequest:** Equals to the value of memory resources request.

7.4.5 Peak memory usage on OS container workload

- a) **Description:** This measurement provides the peak memory usage on the OS container workload.
- b) **Collection Method:** SC.
- c) **Trigger:** CISM receives the memory usage measurement for the OS container workload at the pre-defined interval, and then selects the maximum among the memory usage metrics received in the collection period. The selected memory usage shall be represented as a percentage with respect to the memory resources request.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** McioComputeResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** MemoryUsagePeakMcio.container, where container is equal to the resource name of the measured OS container.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last memory usage measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the memory usage measurements received by CISM in the collection period.
 - **ResourcesMemoryLimit:** Equals to the value of memory resources limit.
 - **ResourcesMemoryRequest:** Equals to the value of memory resources request.

7.4.6 Number of incoming bytes on compute MCIO

- a) **Description:** This measurement provides the number of bytes received on the compute MCIO. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CISM receives one or more Rxbytes measurement for a virtual network interface in the collection period, and uses the last received value(s) to generate the measurement of the MCIO instance.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** McioNetworkInterface.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** NetByteIncomingMcio. *vNetIfId*, where *vNetIfId* is equal to the name of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Rxbytes measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Rxbytes measurements received by CISM in the collection period.

7.4.7 Number of outgoing bytes on compute MCIO

- a) **Description:** This measurement provides the number of bytes transmitted on the compute MCIO. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CISM receives one or more TxBytes measurement for a virtual network interface in the collection period, and uses the last received value(s) to generate the measurement of the MCIO instance.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** McioNetworkInterface.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** NetByteOutgoingMcio. *vNetIfId*, where *vNetIfId* is equal to the name of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last TxBytes measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the TxBytes measurements received by CISM in the collection period.

7.4.8 Number of incoming packets on compute MCIO

- a) **Description:** This measurement provides the number of packets received on the compute MCIO. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CISM receives one or more RxPackets measurement for a virtual network interface in the collection period, and uses the last received value(s) to generate the measurement of the MCIO instance.
- d) **Measurement Unit:** Each measurement is an integer value.

- e) **Measurement Group:** McioNetworkInterface.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** NetPacketIncomingMcio. *vNetIfId*, where *vNetIfId* is equal to the name of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time of the last Rx_Packets measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Rx_Packets measurements received by CISM in the collection period.

7.4.9 Number of outgoing packets on compute MCIO

- a) **Description:** This measurement provides the number of packets transmitted on the compute MCIO. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CISM receives one or more TxPackets measurement for a virtual network interface in the collection period, and uses the last received value(s) to generate the measurement of the MCIO instance.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** McioNetworkInterface.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** NetPacketOutgoingMcio. *vNetIfId*, where *vNetIfId* is equal to the name of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Tx_Packets measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Tx_Packets measurements received by CISM in the collection period.

7.4.10 Mean usage of storage resource on OS container workload

- a) **Description:** This measurement provides the mean usage of storage resource on the OS container workload.
- b) **Collection Method:** SC.
- c) **Trigger:** CISM receives the storage resource usage measurement for the OS container workload at the pre-defined interval, and then takes the arithmetic mean of the storage resource usage metrics received in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** McioStorageResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** StorageUsageMeanMcio.container, where container is equal to the resource name of the measured OS container.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last storage resource usage measurement received by CISM in the collection period.

- **MeasurementInterval:** Equals to "window" (see Annex A1) of the storage resource usage measurements received by CISM in the collection period.

7.4.11 Peak usage of storage resource on OS container workload

- a) **Description:** This measurement provides the peak usage of storage resource on the OS container workload.
- b) **Collection Method:** SC.
- c) **Trigger:** CISM receives the storage resource usage measurement for the OS container workload at the pre-defined interval, and then takes the arithmetic peak of the storage resource usage metrics received in the collection period.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** McioStorageResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** StorageUsagePeakMcio.container, where container is equal to the resource name of the measured OS container.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last storage resource usage measurement received by CISM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the storage resource usage measurements received by CISM in the collection period.

7.4.12 Energy consumption on OS container workload

- a) **Description:** This measurement provides the total energy consumption of the OS container workload over the collection period.
- b) **Collection Method:** SC.
- c) **Trigger:** CISM receives the energy measurements for the OS container workload from CIS at the pre-defined interval, and then sums the energy measurement values received in the collection period.
- d) **Measurement Unit:** Each measurement is an integer value (Unit: J).
- e) **Measurement Group:** McioComputeResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** EnergyConsumptionMcio.[total,container], where "container" is equal to the resource name of the measured OS container, and "total" corresponds to the whole group of one or more OS containers conforming the OS container workload.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time of the last energy consumption measurement received from the CIS in the collection period.
 - **MeasurementInterval:** Equals the measurement interval utilized by the CIS (e.g. 1 second) for providing energy consumption measurements in the collection period.

7.4.13 Mean energy consumption on OS container workload

- a) **Description:** This measurement provides the mean energy consumption of the OS container workload over the collection period.
- b) **Collection Method:** SC.

- c) **Trigger:** CISM receives the energy measurements for the OS container workload from CIS at the pre-defined interval, and then takes the arithmetic mean of the energy measurement values received in the collection period.
- d) **Measurement Unit:** Each measurement is an integer value (Unit: J).
- e) **Measurement Group:** McioComputeResource.
- f) **Measured Object Type:** Mcio-c.
- g) **Measurement Name:** EnergyConsumptionMeanMcio.[total,container], where "container" is equal to the resource name of the measured OS container, and "total" corresponds to the whole group of one or more OS containers conforming the OS container workload.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time of the last energy consumption measurement received from CIS in the collection period.
 - **MeasurementInterval:** Equals the measurement interval utilized by the CIS (e.g. 1 second) for providing energy consumption measurements in the collection period.

7.5 Performance measurements produced by CCM

7.5.1 Introduction

The performance measurements defined in this clause 7.5 are applicable to the CIS cluster.

7.5.2 Mean CPU usage on CIS cluster node

- a) **Description:** This measurement provides the mean CPU usage on the CIS cluster node.
- b) **Collection Method:** SC.
- c) **Trigger:** CCM receives the CPU usage measurement for the CIS cluster node at the pre-defined interval, and then takes the arithmetic mean of the CPU usage metrics received in the collection period. The arithmetic mean shall be represented as a percentage with respect to the total CPU resources capacity of the CIS cluster node.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** CisNodeComputeResource.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** CpuUsageMeanCisNode.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last cpu usage measurement received by CCM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the cpu usage measurements received by CCM in the collection period.
 - **ResourcesCpuCapacity:** Equals to the value of CPU resources capacity.
 - **ResourcesCpuAllocated:** Equals to the value of allocated CPU resource.

7.5.3 Peak CPU usage on CIS cluster node

- a) **Description:** This measurement provides the peak CPU usage on the CIS cluster node.
- b) **Collection Method:** SC.

- c) **Trigger:** CCM receives the CPU usage measurement for the CIS cluster node at the pre-defined interval, and then selects the Maximum among the CPU usage metrics received in the collection period. The selected CPU usage shall be represented as a percentage with respect to the total CPU resources capacity of the CIS cluster node.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** CisNodeComputeResource.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** CpuUsagePeakCisNode.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last cpu usage measurement received by CCM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the cpu usage measurements received by CCM in the collection period.
 - **ResourcesCpuCapacity:** Equals to the value of CPU resources capacity.
 - **ResourcesCpuAllocated:** Equals to the value of allocated CPU resources.

7.5.4 Mean memory usage on CIS cluster node

- a) **Description:** This measurement provides the mean memory usage on the CIS cluster node.
- b) **Collection Method:** SC.
- c) **Trigger:** CCM receives the memory usage measurement for the CIS cluster node at the pre-defined interval, and then takes the arithmetic mean of the memory usage metrics received in the collection period. The arithmetic mean shall be represented as a percentage with respect to the total memory resources capacity of the CIS cluster node.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** CisNodeMemoryResource.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** MemoryUsageMeanCisNode.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last memory usage measurement received by CCM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the memory usage measurements received by CCM in the collection period.
 - **ResourcesMemoryCapacity:** Equals to the value of memory resources capacity.
 - **ResourcesMemoryAllocated:** Equals to the value of allocated memory resources.

7.5.5 Peak memory usage on CIS cluster node

- a) **Description:** This measurement provides the peak memory usage on the CIS cluster node.
- b) **Collection Method:** SC.

- c) **Trigger:** CCM receives the memory usage measurement for the CIS cluster node at the pre-defined interval, and then selects the maximum among the memory usage metrics received in the collection period. The selected memory usage shall be represented as a percentage with respect to the total memory resources Capacity of the CIS cluster node.
- d) **Measurement Unit:** Each measurement is a real value (Unit: %).
- e) **Measurement Group:** CisNodeMemoryResource.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** MemoryUsagePeakCisNode.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last memory usage measurement received by CCM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the memory usage measurements received by CCM in the collection period.
 - **ResourcesMemoryCapacity:** Equals to the value of memory resources capacity.
 - **ResourcesMemoryAllocated:** Equals to the value of allocated memory resources.

7.5.6 Number of incoming bytes of a network on CIS cluster node

- a) **Description:** This measurement provides the number of bytes received on the CIS cluster node. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CCM receives one or more Rxbytes measurement for virtual network interface on the CIS cluster node in the collection period, and generates the measurement by recording last received values of each virtual network interface.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** CisNodeNetworkInterface.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** NetByteIncomingCisNode.vNetIfId, where vNetIfId is equal to the name of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Rxbytes measurement received by CCM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Rxbytes measurements received by CCM in the collection period.

7.5.7 Number of outgoing bytes of a network on CIS cluster node

- a) **Description:** This measurement provides the number of bytes transmitted on the CIS cluster node. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CCM receives one or more Txbytes measurement for virtual network interface on the CIS cluster node in the collection period, and generates the measurement by recording last received values of each virtual network interface.
- d) **Measurement Unit:** Each measurement is an integer value.

- e) **Measurement Group:** CisNodeNetworkInterface.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** NetByteOutgoingCisNode.vNetIfId, where vNetIfId is equal to the name of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Txbytes measurement received by CCM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the Txbytes measurements received by CCM in the collection period.

7.5.8 Number of incoming packets of a network on CIS cluster node

- a) **Description:** This measurement provides the number of packets received on the CIS cluster node. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CCM receives one or more RxPackets measurement for virtual network interface on the CIS cluster node in the collection period, and generates the measurement by recording last received values of each virtual network interface.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** CisNodeNetworkInterface.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** NetRxPacketIncomingCisNode.vNetIfId, where vNetIfId is equal to the name of the measured virtual network interface.
- h) **Measurement Context:**
 - **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Rx_Packets measurement received by CCM in the collection period.
 - **MeasurementInterval:** Equals to "window" (see Annex A1) of the RxPackets measurements received by CCM in the collection period.

7.5.9 Number of outgoing packets of a network on CIS cluster node

- a) **Description:** This measurement provides the number of packets transmitted on the CIS cluster node. This measurement is split into subcounters per virtual network interface.
- b) **Collection Method:** TF.
- c) **Trigger:** CCM receives one or more TxPackets measurement for virtual network interface on the CIS cluster node in the collection period, and generates the measurement by recording last received values of each virtual network interface.
- d) **Measurement Unit:** Each measurement is an integer value.
- e) **Measurement Group:** CisNodeNetworkInterface.
- f) **Measured Object Type:** CisClusterNode.
- g) **Measurement Name:** NetPacketOutgoingCisNode.vNetIfId, where vNetIfId is equal to the name of the measured virtual network interface.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last Tx_Packets measurement received by CCM in the collection period.
- **MeasurementInterval:** Equals to "window" (see Annex A1) of the Tx_Packets measurements received by CCM in the collection period.

7.5.10 Mean usage of storage resource on CIS cluster node

a) **Description:** This measurement provides the mean usage of storage resource on the CIS cluster node.

b) **Collection Method:** SC.

c) **Trigger:** CCM receives the storage resource usage measurement for the CIS cluster node at the pre-defined interval, and then takes the arithmetic mean of the storage resource usage metrics received in the collection period.

d) **Measurement Unit:** Each measurement is a real value (Unit: %).

e) **Measurement Group:** CisNodeStorageResource.

f) **Measured Object Type:** CisClusterNode.

g) **Measurement Name:** StorageUsageMeanCisNode.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last storage resource usage measurement received by CCM in the collection period.
- **MeasurementInterval:** Equals to "window" (see Annex A1) of the storage resource usage measurements received by CCM in the collection period.

7.5.11 Peak usage of storage resource on CIS cluster node

a) **Description:** This measurement provides the mean peak of storage resource on the CIS cluster node.

b) **Collection Method:** SC.

c) **Trigger:** CCM receives the storage resource usage measurement for the CIS cluster node at the pre-defined interval, and generates the measurement by taking the maximum of multiple values of the received measurement(s).

d) **Measurement Unit:** Each measurement is a real value (Unit: %).

e) **Measurement Group:** CisNodeStorageResource.

f) **Measured Object Type:** CisClusterNode.

g) **Measurement Name:** StorageUsagePeakCisNode.

h) Measurement Context:

- **MeasurementEndTime:** Indicates the end time (see Annex A1) of the last storage resource usage measurement received by CCM in the collection period.
- **MeasurementInterval:** Equals to "window" (see Annex A1) of the storage resource usage measurements received by CCM in the collection period.

Annex A (informative): Mapping of ETSI GS NFV-TST 008 to OpenStack® measurements

Table A.1-1 provides the mapping of ETSI GS NFV-TST 008 [10] metrics to OpenStack® compute measurements in Mitaka release [i.1].

Table A.1-1: ETSI GS NFV-TST 008 [10] to OpenStack® measurements mapping table

NFV-TST 008 metrics	OpenStack® Telemetry measurements						
	Name	Type	Unit	Resource	Origin	Support	Note
Processor Utilization (see note 1)	<i>cpu_util</i>	Gauge	%	instance ID	Pollster	vSphere®	Average CPU utilization
Memory Buffered, Memory Cached, Memory Free, Memory Slab (see note 2)	<i>memory.usage</i> (see note 5)	Gauge	MB	instance ID	Notification	Libvirt, Hyper-V	Volume of RAM allocated to the instance
Memory Buffered, Memory Cached, Memory Free, Memory Slab (see note 2)	<i>memory.usage</i> (see note 5)	Gauge	MB	instance ID	Pollster	vSphere®	Volume of RAM used by the instance from the amount of its allocated memory
(see note 3)	<i>disk.allocation</i> (see note 6)	Gauge	B	instance ID	Pollster	Libvirt	The amount of disk occupied by the instance on the host machine
(see note 4)	<i>disk.usage</i> (see note 6)	Gauge	B	instance ID	Pollster	Libvirt	The physical size in bytes of the image container on the host
Octet Count received	<i>network.incoming.bytes</i>	Cumulative	B	interface ID	Pollster	Libvirt, Hyper-V	Number of incoming bytes
Octet Count transmitted	<i>network.outgoing.bytes</i>	Cumulative	B	interface ID	Pollster	Libvirt, Hyper-V	Number of outgoing bytes
Packet Count received	<i>network.incoming.packets</i>	Cumulative	packet	interface ID	Pollster	Libvirt, Hyper-V	Number of incoming packets
Packet Count transmitted	<i>network.outgoing.packets</i>	Cumulative	packet	interface ID	Pollster	Libvirt, Hyper-V	Number of outgoing packets
NOTE 1: The size of the memory allocated to an instance can be derived from VirtualMemory (see clause 8.4.3.5 in ETSI GS NFV-IFA 006 [2]).							
NOTE 2: The size of the memory used by an instance can be computed from the sum of Memory Buffered, Memory Cached, Memory Free, and Memory Slab.							
NOTE 3: The size of the disk allocated to an instance can be derived from VirtualStorageData (see clause 8.4.6.3 in ETSI GS NFV-IFA 006 [2]).							
NOTE 4: No corresponding metric is defined in ETSI GS NFV-TST 008 [10].							
NOTE 5: <i>memory.usage</i> and <i>memory</i> can be used to compute $memory_utilization = 100 \times memory_usage/memory$.							
NOTE 6: <i>disk.usage</i> and <i>disk.allocation</i> can be used to compute $disk_utilization = 100 \times disk_usage/disk.allocation$.							

Annex A1 (informative): Kubernetes[®] resource management and monitoring

A1.0 Introduction

This annex provides simplified information about resource management and monitoring, all the contents are simplified copy from Kubernetes[®] document and github.

A1.1 Resource Management for Pods and Containers

A1.1.1 Requests and limits

For each container, it is supported to specify resource limits and requests. For a particular resource, a Pod resource request/limit is the sum of the resource requests/limits of that type for each container in the Pod. Supported resource limits and requests includes following listed and other extended resources which is not in following list.

- `spec.containers[].resources.limits.cpu`
- `spec.containers[].resources.limits.memory`
- `spec.containers[].resources.requests.cpu`
- `spec.containers[].resources.requests.memory`
- `spec.containers[].resources.limits.ephemeral-storage`
- `spec.containers[].resources.requests.ephemeral-storage`
- `spec.containers[].resources.requests.hugepages-<size>`
- `spec.containers[].resources.limits.hugepages-<size>`

If the node where a Pod is running has enough of a resource available, it is possible (and allowed) for a container to use more resource than its request for that resource specifies. However, a container is not allowed to use more than its resource limit.

A1.1.2 Resource units in Kubernetes[®]

"CPU" and "memory" are each a resource type. A resource type has a base unit.

- CPU resource units

CPU resources are measured in **CPU** units. In Kubernetes[®], **1 CPU unit** is equivalent to **1 physical CPU core**, or **1 virtual core**, depending on whether the node is a physical host or a virtual machine running inside a physical machine.

Fractional requests are allowed. Table A1.1.2-1 provides examples of CPU resource fractional requests.

Table A1.1.2-1: Examples of CPU resource fractional requests

<pre>Comparing to request 1 CPU: spec.containers[].resources.requests.cpu = 1 spec.containers[].resources.requests.cpu = 0.5. It means half as much CPU time is requested. spec.containers[].resources.requests.cpu = 0.1 or 100m. It means 1/10 as much CPU time is requested. It can be read as "one hundred millicpu", or "one hundred millicores".</pre>
--

CPU resource is always specified as an absolute amount of resource, never as a relative amount. For example, 500m CPU represents the roughly same amount of computing power whether that container runs on a single-core, dual-core, or 48-core machine.

- Memory resource units

Memory are measured in **bytes**. Memory can be expressed as a plain integer or as a fixed-point number using one of these quantity suffixes: E, P, T, G, M, k. The power-of-two equivalents can also be used: Ei, Pi, Ti, Gi, Mi, Ki.

A1.2 Monitoring resource usage

A1.2.1 Measuring resource usage

- CPU

CPU is reported as the average core usage measured in cpu units. This value is derived by taking a rate over a cumulative CPU counter provided by the kernel (in both Linux[®] and Windows kernels). The time window used to calculate CPU is shown under window field in Metrics API.

- Memory

Memory is reported as the working set, measured in bytes, at the instant the metric was collected. In an ideal world, the "working set" is the amount of memory in-use that cannot be freed under memory pressure.

A1.2.2 Monitoring and reporting resource usage

The kubelet gathers metric statistics at the node, volume, pod and container level, and emits this information in the [Summary API](#) [i.7]. The kubelet reports the resource usage of a Pod as part of the Pod status. If optional tools for monitoring [i.6] are available in cluster, then Pod resource usage can be retrieved either from the [Metrics API](#) directly or from monitoring tools.

In [CNCF Landscape](#), there are a number of monitoring projects that can work with Kubernetes[®] by scraping metric data and using that to help observe a cluster. In a production environment, Prometheus Server or some other metrics scraper can be configured to periodically gather metrics and make them available in some kind of time series database.

NOTE: The details of selection metric reporting solution and implementation is out of the present document.

A1.2.3 Examples of getting resource usage

Table A1.2.3-1 provides an example of using Metric API to retrieve metrics of a specific pod [i.4].

Table A1.2.3-1: Using Metric API to retrieve metrics of a specific pod

```
request:
curl http://localhost:8080/apis/metrics.k8s.io/v1beta1/namespaces/kube-system/pods/kube-scheduler-minikube

response:
{
  "kind": "PodMetrics",
  "apiVersion": "metrics.k8s.io/v1beta1",
  "metadata": {
    "name": "kube-scheduler-minikube",
    "namespace": "kube-system",
    "selfLink": "/apis/metrics.k8s.io/v1beta1/namespaces/kube-system/pods/kube-scheduler-
minikube",
    "creationTimestamp": "2022-01-27T19:25:00Z"
  },
  "timestamp": "2022-01-27T19:24:31Z",
  "window": "30s",
  "containers": [
    {
      "name": "kube-scheduler",
      "usage": {
        "cpu": "9559630n",
        "memory": "22244Ki"
      }
    }
  ]
}
```

Table A1.2.3-2 provides an example of using API to retrieve information of a specific cluster node [i.3].

Table A1.2.3-2: Using API to retrieve information of a specific cluster node

```

request:
kubectll describe nodes e2e-test-node-pool-4lw4

response:
Name:      e2e-test-node-pool-4lw4

[ ... lines removed for clarity ...]

Capacity:

cpu:      2

memory:   7679792Ki

pods:     110

Allocatable:

cpu:      1800m

memory:   7474992Ki

pods:     110

[ ... lines removed for clarity ...]

Non-terminated Pods:  (5 in total)

Namespace   Name                               CPU Requests  CPU Limits    Memory Requests  Memory Limits
-----
kube-system  fluentd-gcp-v1.38-28bv1           100m (5%)    0 (0%)        200Mi (2%)      200Mi (2%)
kube-system  kube-dns-3297075139-61lj3         260m (13%)   0 (0%)        100Mi (1%)      170Mi (2%)
kube-system  kube-proxy-e2e-test-...           100m (5%)    0 (0%)        0 (0%)          0 (0%)
kube-system  monitoring-influxdb-grafana       200m (10%)   200m (10%)    600Mi (8%)      600Mi (8%)
kube-system  node-problem-detector-v0.1         20m (1%)     200m (10%)    20Mi (0%)       100Mi (1%)

Allocated resources:

(Total limits can be over 100 percent, i.e. overcommitted.)

CPU Requests  CPU Limits  Memory Requests  Memory Limits
-----
680m (34%)    400m (20%)   920Mi (11%)     1070Mi (13%)

```

Table A1.2.3-3 provides examples of resource related metric definition from stable metrics list [i.5].

Table A1.2.3-3: Resource related metric definition from stable metrics list

Metric Name	Type	Help
container_cpu_usage_seconds_total	Custom	Cumulative cpu time consumed by the container in core-seconds.
container_memory_working_set_bytes	Custom	Current working set of the container in bytes.
pod_cpu_usage_seconds_total	Custom	Cumulative cpu time consumed by the pod in core-seconds.
pod_memory_working_set_bytes	Custom	Current working set of the pod in bytes.
kube_pod_resource_request	Custom	Resources requested by workloads on the cluster, broken down by pod. This shows the resource usage the scheduler and kubelet expect per pod for resources along with the unit for the resource if any.
kube_pod_resource_limit	Custom	Resources limit for workloads on the cluster, broken down by pod. This shows the resource usage the scheduler and kubelet expect per pod for resources along with the unit for the resource if any.
node_cpu_usage_seconds_total	Custom	Cumulative cpu time consumed by the node in core-seconds.
node_memory_working_set_bytes	Custom	Current working set of the node in bytes.

Table A1.2.3-4 provides an example for NodeStats and PodStats definition [i.7].

Table A1.2.3-4: NodeStats and PodStats definition

type NodeStats struct	<pre>{ [... lines removed for clarity ...] // Stats pertaining to CPU resources. CPU *CPUStats `json:"cpu,omitempty"` // Stats pertaining to memory (RAM) resources. Memory *MemoryStats `json:"memory,omitempty"` // Stats pertaining to network resources. Network *NetworkStats `json:"network,omitempty"` // Stats pertaining to total usage of filesystem resources on the // rootfs used by node k8s components. // NodeFs.Used is the total bytes used on the filesystem. Fs *FsStats `json:"fs,omitempty"` [... lines removed for clarity ...] }</pre>
type PodStats struct	<pre>{ [... lines removed for clarity ...] // Stats of containers in the measured pod. Containers []ContainerStats `json:"containers" patchStrategy:"merge" patchMergeKey:"name"` // Stats pertaining to CPU resources consumed by pod cgroup (which includes // all containers' resource usage and pod overhead). CPU *CPUStats `json:"cpu,omitempty"` // Stats pertaining to memory (RAM) resources consumed by pod // cgroup (which includes all containers' resource usage and pod overhead). Memory *MemoryStats `json:"memory,omitempty"` // Stats pertaining to network resources. Network *NetworkStats `json:"network,omitempty"` // Stats pertaining to volume usage of filesystem resources. // VolumeStats.UsedBytes is the number of bytes used by the Volume VolumeStats []VolumeStats `json:"volume,omitempty" patchStrategy:"merge" patchMergeKey:"name"` // EphemeralStorage reports the total filesystem usage for the containers and // emptyDir-backed volumes in the measured Pod. EphemeralStorage *FsStats `json:"ephemeral-storage,omitempty"` }</pre>

<pre>type ContainerStats struct</pre>	<pre>{ [... lines removed for clarity ...] // Stats pertaining to CPU resources. CPU *CPUStats `json:"cpu,omitempty"` // Stats pertaining to memory (RAM) resources. Memory *MemoryStats `json:"memory,omitempty"` // Stats pertaining to container rootfs usage of filesystem resources. // Rootfs.UsedBytes is the number of bytes used for the container write layer. Rootfs *FsStats `json:"rootfs,omitempty"` // Stats pertaining to container logs usage of filesystem resources. // Logs.UsedBytes is the number of bytes used for the container logs. Logs *FsStats `json:"logs,omitempty"` // User defined metrics that are exposed by containers in the pod. Typically, only one container in the pod is expected to be exposing user defined metrics. In the event of multiple containers exposing metrics, they will be combined here. UserDefinedMetrics []UserDefinedMetric `json:"userDefinedMetrics,omitempty" patchStrategy:"merge" patchMergeKey:"name"` }</pre>
<pre>type CPUStats struct</pre>	<pre>// CPUStats contains data about CPU usage. { // The time at which these stats were updated. Time metav1.Time `json:"time"` // Total CPU usage (sum of all cores) averaged over the sample window. // The "core" unit can be interpreted as CPU core-nanoseconds per second. UsageNanoCores *uint64 `json:"usageNanoCores,omitempty"` // Cumulative CPU usage (sum of all cores) since object creation. UsageCoreNanoSeconds *uint64 `json:"usageCoreNanoSeconds,omitempty"` }</pre>
<pre>type MemoryStats struct</pre>	<pre>// MemoryStats contains data about memory usage. { // The time at which these stats were updated. Time metav1.Time `json:"time"` // Available memory for use. This is defined as the memory limit - workingSetBytes. // If memory limit is undefined, the available bytes is omitted. AvailableBytes *uint64 `json:"availableBytes,omitempty"` // Total memory in use. This includes all memory regardless of when it was accessed. UsageBytes *uint64 `json:"usageBytes,omitempty"` // The amount of working set memory. This includes recently accessed memory, // dirty memory, and kernel memory. WorkingSetBytes is <= UsageBytes WorkingSetBytes *uint64 `json:"workingSetBytes,omitempty"` // The amount of anonymous and swap cache memory (includes transparent // hugepages). RSSBytes *uint64 `json:"rssBytes,omitempty"` // Cumulative number of minor page faults. PageFaults *uint64 `json:"pageFaults,omitempty"` // Cumulative number of major page faults. MajorPageFaults *uint64 `json:"majorPageFaults,omitempty"` }</pre>
<pre>type NetworkStats struct</pre>	<pre>// NetworkStats contains data about network resources. { // The time at which these stats were updated. Time metav1.Time `json:"time"` // Stats for the default interface, if found InterfaceStats `json:",inline"` Interfaces []InterfaceStats `json:"interfaces,omitempty"` }</pre>

<pre>type InterfaceStats struct</pre>	<pre>// InterfaceStats contains resource value data about interface. { // The name of the interface Name string `json:"name"` // Cumulative count of bytes received. RxBytes *uint64 `json:"rxBytes,omitempty"` // Cumulative count of receive errors encountered. RxErrors *uint64 `json:"rxErrors,omitempty"` // Cumulative count of bytes transmitted. TxBytes *uint64 `json:"txBytes,omitempty"` // Cumulative count of transmit errors encountered. TxErrors *uint64 `json:"txErrors,omitempty"` }</pre>
---------------------------------------	---

Table A1.2.3-5 provides an example for network interface statistics definition in Linux® [i.8].

Table A1.2.3-5: Network interface statistics definition

<pre>struct rtnl_link_stats6 4</pre>	<pre>{ __u64 rx_packets; __u64 tx_packets; __u64 rx_bytes; __u64 tx_bytes; __u64 rx_errors; __u64 tx_errors; __u64 rx_dropped; __u64 tx_dropped; __u64 multicast; __u64 collisions; __u64 rx_length_errors; __u64 rx_over_errors; __u64 rx_crc_errors; __u64 rx_frame_errors; __u64 rx_fifo_errors; __u64 rx_missed_errors; __u64 tx_aborted_errors; __u64 tx_carrier_errors; __u64 tx_fifo_errors; __u64 tx_heartbeat_errors; __u64 tx_window_errors; __u64 rx_compressed; __u64 tx_compressed; __u64 rx_nohandler; }</pre>
--------------------------------------	--

Annex B (informative): Security and Regulatory Concerns

B.1 Risk analysis and assessment

Table B.1-1 is the output of the Threat, Risk, and Vulnerability Analysis according to ETSI GS NFV-SEC 006 [7].

Table B.1-1: Threat, Risk, and Vulnerability Analysis

A Security Environment		
a.1 Assumptions		
a.1.1	A new set of management and orchestration functions in addition to existing EM and OSS functions is introduced by NFV. Such NFV-MANO functions have the role to manage the NFVI to control the collection of virtualised resources consumed by VMs.	See clause 4.1.
a.1.2	NFV-MANO management functions include performance Management that is capable of controlling and collecting performance metrics.	See clause 4.1.
a.1.3	An NFV-MANO service is one or more capabilities that are offered via NFV-MANO functional blocks (i.e. NFVO, VNFM, and VIM) and invoked using a defined interface.	See clause 4.1.
a.2 Assets		
a.2.1	NFVO: it is responsible for processing the VNFM and VIM performance metrics to generate the NS related performance metrics to be sent to OSS/BSS.	See clauses 4.1 and 7.3.
a.2.2	VNFM: it is responsible for processing the VIM performance metrics to generate the VNF related performance measurements to be sent to EM and NFVO.	See clauses 4.1 and 7.2.
a.2.3	VIM: it is responsible for processing the NFVI performance metrics to generate the Virtualised resource related performance measurements to be sent to NFVO and VNFM.	See clauses 4.1 and 7.1.
a.2.4	NFVI: it is responsible for collecting the NFVI performance metrics, and reporting them to VIM.	See clause 4.1.
a.2.5	Performance metrics: performance information that need to be reported/acquired.	See clauses 4 and 7.
a.3 Threat agents		
a.3.1	Unauthorized user of assets (e.g. reports, notifications, queries, fault information, resource information).	
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 all threat agents a.3. Refer to all assets in a.2.
a.4.2	Unauthorized write action (Masquerade ("spoofing"), Forgery, Loss or corruption of information).	Refer to all threat agents a.3. Refer to all assets in a.2.
a.4.3	Unauthorized access.	Refer to threat agents a.3.1, a.3.2 and a.3.3. Refer to all assets in a.2.
a.4.4	Repudiation (end point and threat agents).	Refer to threat agent a.3.1, a.3.2, a.3.3, and a.3.4. Refer to all assets a.2.
a.4.5	Denial of service.	Refer to threat agents a.3.1, a.3.2 and a.3.3. Refer to all assets in a.2.

B Security Objectives		
b.1 Security objectives for the asset		
b.1.1	The system should ensure that only authorized and authenticated entities can access (read or write) the provided interfaces and that data is exchanged in a confidential manner. Therefore, requirements for access controls and communications security (see clauses 8.5 and 8.6 in ETSI GS NFV-SEC 012 [9]) should be followed.	
b.1.2	The system should ensure the authenticity and integrity of all data exchanged on the interfaces. Therefore, requirements for authentications controls (see clause 8.4 in ETSI GS NFV-SEC 012 [9]) should be followed.	
b.1.3	The system should prevent replay of any data. Therefore, requirements for authentications controls (see clause 8.4 in ETSI GS NFV-SEC 012 [9]) should be followed.	
b.1.4	The system should be accountable for the data provided, that is why the system should ensure collected data (e.g. performance metrics, timestamps) is authentic.	
b.1.5	The system should ensure that interception is possible where required to support regulatory requirements (such as Lawful Interception ETSI GS NFV-SEC 004 [6] and Retained Data ETSI GS NFV-SEC 010 [8]) and not possible otherwise.	
b.1.6	The system should provide means to detect and mitigate denial of service attacks.	

Annex C (informative): Change history

Date	Version	Information about changes
2016-12	0.1.0	Implemented NFVIFA-F2F#43 approved contributions; NFVIFA(16)0001456r2, NFVIFA(16)0001457r1.
2017-06	0.2.0	Implemented approved contributions: NFVIFA(17)000333r1, NFVIFA(17)000335r1, NFVIFA(17)000336r1, NFVIFA(17)000384r1, NFVIFA(17)000385r2, NFVIFA(17)000386r3, NFVIFA(17)000521r1.
2017-08	0.3.0	Implemented approved contributions: NFVIFA(17)000602r2, NFVIFA(17)000603r6.
2017-08	0.4.0	Implemented approved contributions: NFVIFA(17)000604r5, NFVIFA(17)000605r5, NFVIFA(17)000708.
2017-09	0.5.0	Implemented approved contributions: NFVIFA(17)000728r1, NFVIFA(17)000780r2, NFVIFA(17)000781r2, NFVIFA(17)000782r2.
2017-09	0.5.1	Implemented the changes of the approved contributions that were not implemented in 0.5.0: NFVIFA(17)000728r1, NFVIFA(17)000781r2, NFVIFA(17)000782r2.
2017-10	0.6.0	Implemented the changes of the approved contributions: NFVIFA(17)000606r7, NFVIFA(17)000857r1.
2017-11	0.7.0	Implemented the changes of the approved contributions: NFVIFA(17)001023, NFVIFA(17)001024, NFVIFA(17)001042, NFVIFA(17)001045.
2017-12	0.8.0	Implemented the changes of the approved contributions: NFVIFA(17)0001043r3, NFVIFA(17)0001044r3.
2018-02	0.9.0	Implemented the changes of the approved contribution: NFVIFA(18)0000062r2.
2018-04	0.9.1	Implemented some editorial changes, and leftover changes from NFVIFA(18)0000062r2, and the changes of the approved contributions: NFVIFA(18)000261, NFVIFA(18)000194r4, NFVIFA(18)000204r1, NFVIFA(18)000330r1.
2019-11	2.4.3	Implemented the changes of the approved contribution: NFVIFA(19)000720, NFVIFA(19)000721, NFVIFA(19)000722.
2020-02	3.0.1	Implemented the change #3 and #4 in NFVIFA(19)000721 Rapporteur action: aligning "VdiskUsage*" and "Measured Object Type: SAP" to naming conventions.
2020-11	4.0.2	Implemented the changes of the approved contribution: NFVIFA(20)000582r1.
2022-05	4.3.2	Starting version for 2H2022 specification work. Unmodified with respect to published version v4.3.1.
2022-08	4.3.3	Implemented the changes of the approved contribution: NFVIFA(22)00497.

Date	Version	Information about changes
2023-04	4.4.2	Starting version for 1H2023 specification work. Unmodified with respect to published version v4.4.1.
2023-05	4.4.3	Implemented the changes of the approved contribution: NFVIFA(23)000339r2, NFVIFA(23)000340r2, NFVIFA(23)000341r3, NFVIFA(23)000342r3
2023-09	4.4.4	Implemented the changes of the approved contribution: NFVIFA(23)000630r2, NFVIFA(23)000631r1, NFVIFA(23)000632r1, NFVIFA(23)000633r1, NFVIFA(23)000634r1, NFVIFA(23)000635r2, NFVIFA(23)000636r2, NFVIFA(23)000637r1.
2023-11	5.0.1	Release 5 initial draft version. Unmodified with respect to version 4.4.4.
2024-01	5.0.2	Implemented the changes of the approved contribution NFVIFA(23)000830r1.
2024-03	5.0.3	Implemented the changes of the approved contribution: NFVIFA(24)000204r1, NFVIFA(24)000184 Rapporteur action: aligning styles in different sub-bullets; adding a missed sub-bullet name in clause 7.2.15 bullet h).
2024-04	5.0.4	Implemented the changes of the contribution NFVIFA(24)000245. Rapporteur action: deleting redundant blanks in clause 7.4.2 and 7.5.2, deleting redundant point in clause 7.4.11 and updating "Contents" part.

History

Document history		
V5.1.1	June 2024	Publication