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Purpose: Admin

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Abstract: This document is the output of draft recommendation of "Cloud Computing - End-to-end fault and performance management framework of inter-cloud network services" (Y.e2efapm). It includes the discussion results during the Q19/13 meeting which was held virtually, 20 to 31 July 2020.

The following table shows discussion results for contributions.

Document Number	Source	Title	Meeting results
[918]	Ministry of Communications (India)	Draft ITU-T Recommendation Y.e2efapm: " Cloud Computing - End-to-end fault and performance management framework of inter-cloud network services": Proposal to add some terms and abbreviations	Accepted with modifications.
[965]	China Information Communication Technologies Group (CICT)	Proposed to modify clause 6 of Y.e2efapm	Accepted.
[966]	China Information Communication Technologies Group (CICT)	Proposed to modify clause 7 and use case of Y.e2efapm	Accepted.

Document Number	Source	Title	Meeting results
[967]	China Information Communication Technologies Group (CICT)	Proposed to modify clause 8 of Y.e2efapm	Accepted with modifications.

During this meeting, it was agreed as follows.

- To add two terms defined elsewhere in subclause 3.1.
- To add an abbreviation in subclause 4.
- To modify the content of subclause 6.1 to 6.4 of draft Y.e2efapm, and add a new subclause "6.5 Framework of end to end fault and performance management of network services in inter-cloud".
- To add a use case "I.3 Virtual broadband service" in Appendix I and add some functional requirements into clause 7 of draft Y.e2efapm.
- To modify the content of clause 8 of draft Y.e2efapm.
- To modify the content of bibliography.

Contributions are invited in the following aspects.

- More supportive use cases and corresponding derived functional requirements in Appendix I and Clause 7.
- Corrections for the potentially inconsistent text of the whole draft, especially for the references, definitions and abbreviations.
- Solutions for addressing the current editor's notes of the whole draft.

Introduction

Cloud computing is an essential ingredient of all modern telecommunications services, including 5G. A use case that service providers are globally interested in, is deployment of their service offerings as Network Services (NS), using Network Function Virtualization (NFV), over multiple clouds. This gives them a number of advantages including freedom from proprietary solutions, reduced time to market, agility of service, proximity to customers and lower cost of deployment and operation. However, today the virtual deployments do not match the five nines (99.999%) availability, or the performance of the traditional physical networks based on dedicated and custom-built integrated hardware and software. A standards based Fault, Configuration, Accounting, Performance and Security (FCAPS) framework for NS over multiple clouds would help attain the level of availability and performance that service providers and subscribers expect from the traditional networks. This recommendation focuses mainly on the Fault and Performance (FP) aspects of NS deployments. For these aspects alone, ensuring proper operation of the NS is more complex, as compared to traditional services, because of two main reasons: a) more layers of abstraction i.e. physical, virtual resources, virtual network functions, service function chains and NSs, and b) complex interaction of the involved management platforms, i.e., Inter-Cloud management platform (MCMP) of the cloud service provider, Operation Support Systems (OSS) of the service provider and Management and Orchestration platform (MANO) of NFV. These platforms together have the responsibility of managing the Inter-Cloud resources and the life cycles of NSs and their components. For this, the FP management functionality must collect and process all the alarms, notifications and performance metrics from different layers, e.g., NS, SFC, VNF and EMS

(**Note:** somewhere in the description we may refer to criticality of the alarms as defined in Recommendations ITU-T X.733 ~~Recommendations~~). Four Critical aspects of end-to-end fault & performance management system are:

i) Fault and Performance issues detection sub-system: carries out detection of fault & performance issues, both impending and manifest faults.. This is done in two steps: Step 1 involves classification of a situation as ‘fault’ or ‘no-fault’ and Step 2 involves further classification of fault problems as ‘manifest’ or ‘impending.

ii) Fault and performance ~~localization~~localisation sub-system: carries out ~~localization~~localisation of manifest faults in two steps: coarse-grain and fine-grain ~~localization~~localisation. For impending faults, it predicts the intensity and likely location of the problem.

iii) Performance Management: Fix the fault that degrades network performance i.e. troubleshoot fault to restore network performance to original or improved condition;

iv) Maintaining QoS (Quality of Service): Adhere to SLA (Service Level Agreement) for achieving 99.999% availability of network & business critical applications. (Availability requirement of service provider is five nines. Subscribers may have their own SLAs)

Draft new Recommendation ITU-T Y.e2efapm

Cloud Computing – End-to-end fault and performance management framework of network services in inter-cloud

Summary

This recommendation provides end-to-end fault and performance management framework of network services (NSs) in inter-cloud computing and relevant use cases. In particular, the aspects of faults detection and ~~localization~~localisation of affected area in inter-cloud environments is presented.

Keywords: inter-cloud, end-to-end,- fault, performance, management

Table of Content

Draft new Recommendation ITU-T Y.e2efapm

Cloud Computing – End-to-end fault and performance management framework of network services in inter-cloud

1. Scope

This Recommendation specifies an end-to-end fault and performance management framework and relevant use cases of network services (NSs) in inter-cloud computing. The scope of this Recommendation includes:

- overview of end-to-end fault and performance management of NSs;
- functional requirements of end-to-end fault and performance management of NSs;
- use cases relevant to end-to-end fault and performance management of NSs.

2. References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T X.733] Recommendation ITU-T X.733 (1992), *Information technology – Open Systems Interconnection – Systems Management: Alarm reporting function*

[ITU-T Y.3500] Recommendation ITU-T Y.3500 (2014) | ISO/IEC 17788:2014, *Information technology – Cloud computing – Overview and vocabulary*

[ITU-T Y.3501] Recommendation ITU-T Y.3501 (2013), *Cloud computing framework and high-level requirements*

[ITU-T Y.3502] Recommendation ITU-T Y.3502 (2014) | ISO/IEC 17789:2014, *Information technology – Cloud computing – Reference architecture*

[ITU-T Y.3503] Recommendation ITU-T Y.3503 (2014), *Requirements for Desktop As A Service*

[ITU-T Y.3510] Recommendation ITU-T Y.3510 (2016), *Cloud computing infrastructure requirements*

[ITU-T Y.3512] Recommendation ITU-T Y.3512 (2014), *Cloud computing - functional requirements of Network As A Service*

[ITU-T Y.3513] Recommendation ITU-T Y.3513 (2014), *Cloud computing - functional requirements of Infrastructure-As-A-Service*

[ITU-T Y.3515] Recommendation ITU-T Y.3515 (2017), *Cloud computing – Functional architecture of Network as a Service*

3. Definitions

3.1. Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 cloud service [ITU-T Y.3500]: One or more capabilities offered via cloud computing invoked using a defined interface. It may comprise the hardware & hypervisor layers delivering individual servers, border routers, firewalls, load balancers & switches.

3.1.2 cloud service customer [ITU-T Y.3500]: Party which is in a business relationship for the purpose of using cloud services.

3.1.3 cloud service provider [ITU-T Y.3502]: party which makes cloud services available.

3.1.4 hypervisor [ITU-T Y.3510]: A type of system software that allows multiple operating systems to share a single hardware host.

3.1.5 Infrastructure as a Service (IaaS) [ITU-T Y.3500]: Cloud service category in which the cloud capabilities type provided to the cloud service customer is an infrastructure capabilities type.

NOTE – The cloud service customer does not manage or control the underlying physical and virtual resources, but does have control over operating systems, storage, and deployed applications that use the physical and virtual resources. The cloud service customer may also have limited ability to control certain networking components (e.g., host firewalls).

3.1.6 Network as a Service (NaaS) [ITU-T Y.3500]: Cloud service category in which the capability provided to the cloud service customer is transport connectivity and related network capabilities.

NOTE – NaaS can provide any of the three cloud capabilities types.

3.1.7 network function [ITU-T Y.3515] : A function of a network infrastructure whose external interfaces and functional behaviour are well specified.

NOTE – Examples of network functions include network switches and network routers.

3.1.8 Network Functions Virtualization(NFV) [b-ETSI GSR NFV 003]: Principle of separating network functions from the hardware they run on by using virtual hardware abstraction.

3.1.89 Network Functions Virtualisation Infrastructure (NFVI) [b-ETSI GSR NFV 003]: Totality of all hardware and software components that build up the environment in which VNFs are deployed.

NOTE: The NFV-Infrastructure can span across several locations, e.g. places where data centres are operated. The network providing connectivity between these locations is regarded to be part of the NFV-Infrastructure. NFV-Infrastructure and VNF are the top-level conceptual entities in the scope of Network Function Virtualisation. All other components are sub-entities of these two main entities.

3.1.109 network point of presence (N-PoP) [b-ETSI GR NFV 003]: Location, where a Network Function is implemented as either a Physical Network Function (PNF) or a Virtual Network Function (VNF).

3.1.11 network service [ITU-T Y.3515]: A collection of network functions with a well specified behaviour.

NOTE – Examples of network services include content delivery networks (CDNs) and IP multimedia subsystem (IMS).

3.1.102 party [ITU-T Y.3500]: Natural person or legal person, whether or not incorporated, or a group of either.

3.1.113 virtualized network function [ITU-T Y.3515]: A network function that can be deployed as a software on a NaaS cloud service provider infrastructure.

NOTE – Examples of virtualized network functions include virtual switches and virtual routers.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

4. Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

API	Application Programming Interface
CDN	Content Delivery Network
CMIP	Common Management Information Protocol
CPE	Customer Premises Equipment
CSC	Cloud Service Customer
CSP	Cloud Service Provider
DaaS	Desktop as a Service
DAS	Direct-Attached storage
DoT	Department of Telecommunications
EMS	Element Management System
FC	Fibre Channel
FCAPS	Fault, Configuration, Accounting, Performance and Security
IaaS	Infrastructure as a Service
IOT	Internet of |Things
IP	Internet Protocol
N-PoP	Network Point of Presence
NaaS	Network as a Service
NF	Network Function
NFV	Network Function Virtualisation
NFVI	Network Functions Virtualisation Infrastructure
NFVIaaS	Network Function Virtualisation Infrastructure as a Service
NFV-MANO	NFV Management Orchestrator
NS	Network Service
OSS/BSS	Operations Support Systems/Business Support Systems
PaaS	Platform as a Service
P/PE router	Provider/Provider Edge router
PNF	Physical Network Function
PoP	Point of Presence
QoS	Quality of Service
SD-WAN	Software Defined Wide Area Network
SFC	Service Function Chain

SLA	Service Level Agreement
SSL	Secure Socket Layer
SVM	Support Vector Machine
TEC	Telecommunication Engineering Centre
TSP	Telecom Service |Provider
vCPE	Virtual Customer Premises Equipment
VNF	Virtual Network Function
VNFaaS	VNF as a Service
VNPaaS	Virtual Network Platform as a Service
VLAN	Virtual LAN
VM	Virtual Machine
VNFaaS	Virtual Network Function (VNF) as a Service
VPN	Virtual Private Network
WAN	Wide Area Network

5. Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is prohibited from**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

The keywords "**is not recommended**" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this specification can still be claimed even if this requirement is present.

The keywords "**can optionally**" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6. Overview of end-to end fault and performance management of inter-cloud network services

[Contributor's note] This clause is providing overview of fault and performance management of NSs.

~~[Editor's note in March 2020]: The draft Rec. Y.e2efafm should be check about references to legacy technologies and technics, which are out of scope of work this draft Recs. Especially, aspects of ITU-T standards about events and alarms should be verified. Contributions are invited.~~

~~[Editor's note in March 2020]: Figure 6-1 and Figure 6-2 should be redraw. Contributions are invited.~~

6.1. Background

The traditional telecommunication network deployment largely involves use of physical network appliances like routers, switches, broadband remote access servers, and middle-boxes like firewalls, deep packet inspectors or load balancers. These integrated hardware and software solutions are normally closed and proprietary leading to vendor lock-in, thereby making expansions and deployment of new services difficult and time consuming. Such equipment ~~are~~ is also not amenable to easy scaling or redeployment of resources. The power and space requirements as well as the total cost of operation are higher in physical element based networks.

In traditional networks, time-tested standards relating to fault, configuration, accounting, performance and security (FCAPS) are embodied in ISO Common Management Information Protocol (CMIP) and ITU TMN M.3010 and M.3400 recommendations. Network management based on relevant standards provides five nines (99.999%) availability and carrier grade reliability.

Inter-cloud computing, coupled with network function virtualization (NFV), provides numerous advantages to cloud service providers (CSPs) including ease of deployment, ease of scaling, ease of introducing and switching off services and reduced cost of operation. This may increase viability of telecommunications business and lead to thriving telecommunication sectors. However, there are a number of reasons as to why the combination of inter-cloud & NFV i.e. inter-cloud NS needs a strong fault & performance management system to be a viable replacement for traditional networks. For carrier grade availability & reliability of up-to five nines (99.999%) for inter-cloud NS, there is a need for standardization of framework~~techniques~~ for fault and performance detection and ~~localization~~localisation to deal with complexity in such networks as the anomalous behaviour could be in the hardware, virtual machines, virtual network functions (VNFs), service chains (SCs) or at the service levels.

6.2. Network Services in the virtualized environment

~~[Editor's note in March 2020] This clause introduces the concept of NS. Figure 6-1 and Figure 6-2 should be redraw. Contributions are invited.~~

According to [ITU-T Y.3515], NS is a collection of network functions with a well specified behaviour, examples of network services include content delivery networks (CDNs) and IP multimedia subsystem (IMS). NS is also defined as composition of network function(s) and/or network service(s), defined by its functional and behavioural specification (see [b-ETSI GR NFV 003]). The NS contributes to the behaviour of the higher layer service, which is characterized by at least performance, dependability, and security specifications. The end-to-end NS behaviour is the result of the combination of the individual network function behaviours as well as the behaviours of the network infrastructure composition mechanism.

When supporting for NaaS connectivity services, NS can be described as an abstracted transport connectivity between two end points in a virtualised environment where the end points may be located in one or more clouds. ~~A NS utilises a SC or Virtual Network Function Forwarding Graph (VNFFG) for interconnecting virtual network functions end to end.~~ The virtualization hierarchy of NS is shown in figure 6-1.

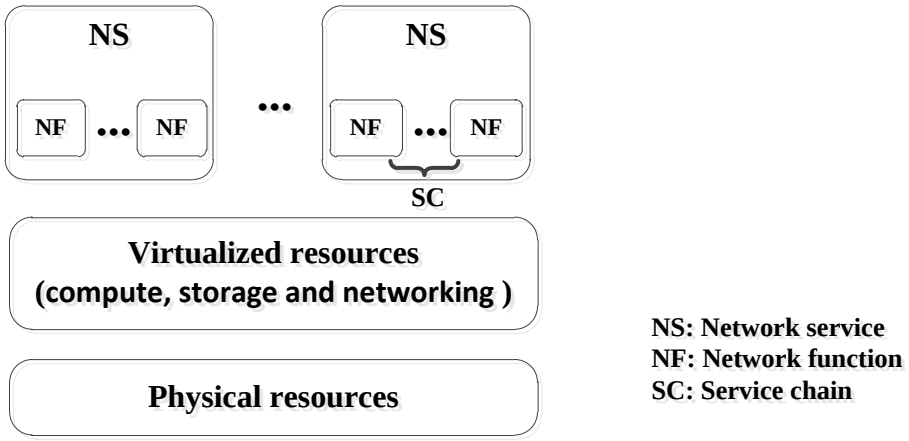


Figure 6-1 – Virtualization hierarchy of network service

A NS can be described as an end to end implementation using S~~F~~C ~~or VNFFG~~, interconnecting the virtual network resources. S~~F~~C ~~or VNFFG~~ is an ordered set of VNFs in the virtualized ~~virtual~~ environment that represent functions like routers and broadband network gateways or middle-boxes like load balancers and firewalls, which act on the traffic in the sequence they appear in the chain. Such VNFs are hosted on VMs instantiated over physical data centre and network resources. An example of end-to-end ~~I~~inter-~~C~~cloud NS is shown in figure ~~below~~6-2. This NS is composed of VNF1 to VNF5 belong to different CSPs.

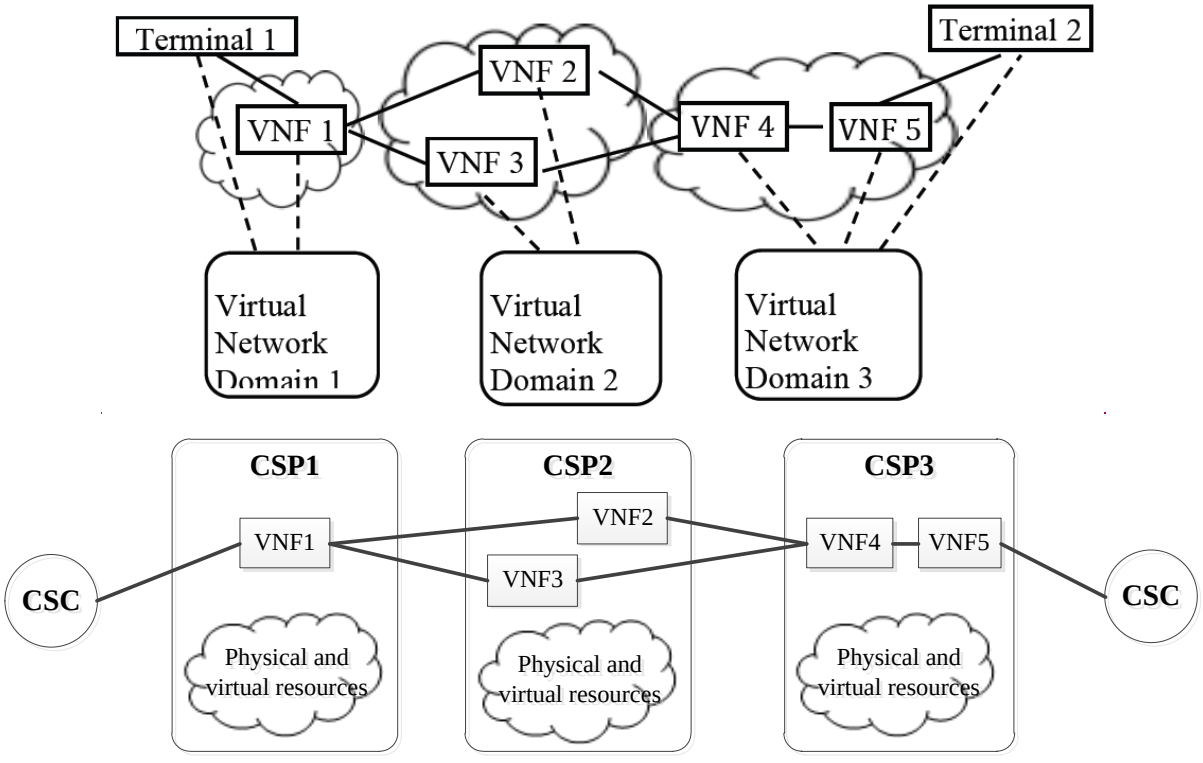
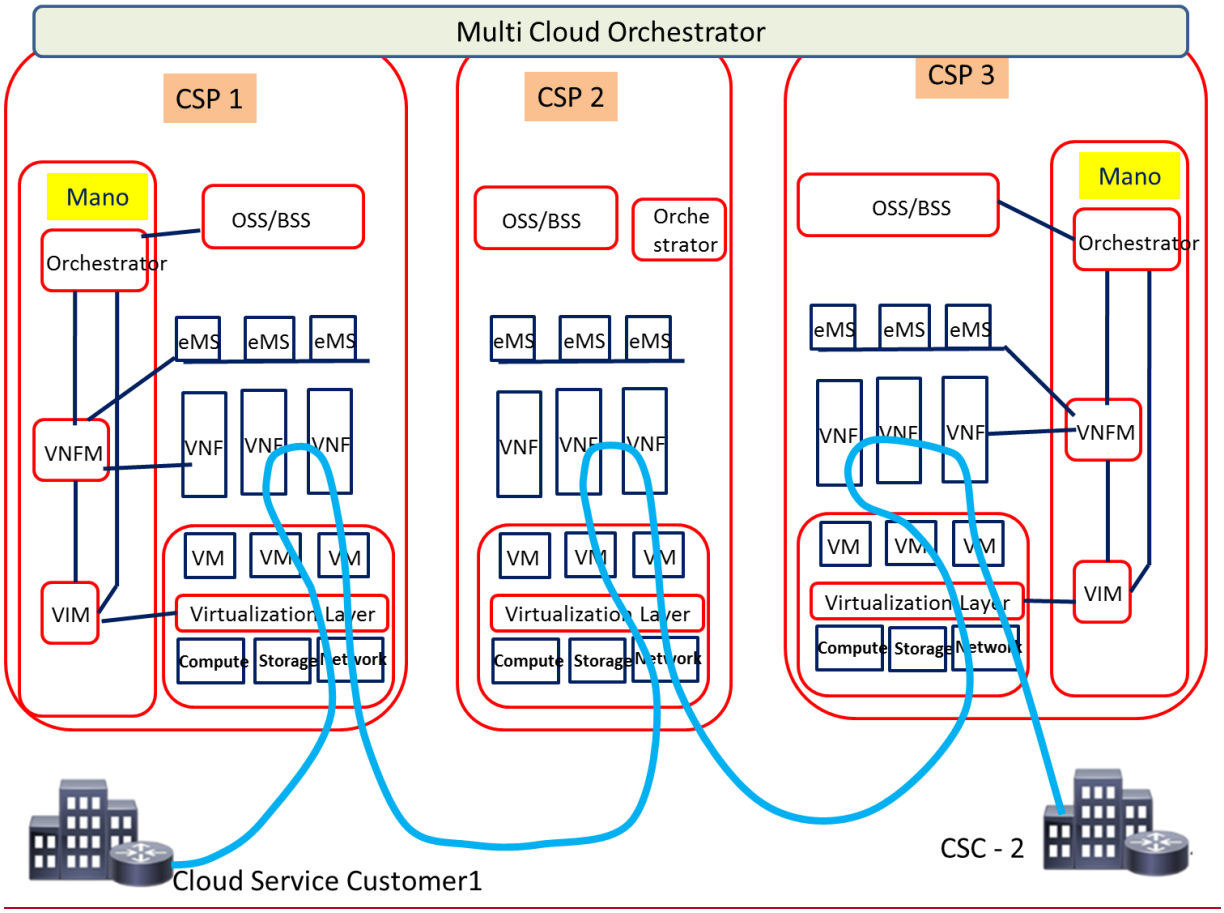


Figure 6-~~2~~1 – An ~~I~~inter-cloud ~~domain~~ end to end network service

~~The detailed network and VNF connectivity diagram in Inter-Cloud scenario is depicted below in figure-8. In this diagram, two VNFs in first cloud, two VNFs in second cloud and three VNFs in third cloud are connected as per the VNF Graph to provide the end to end network service.~~



~~**Figure 6-2 – VNF Forwarding Graph for Inter-cloud end to end service**~~

6.3. Challenges of end to end fault and performance ~~network service~~ management for network service in inter-cloud

The telecommunication's networks have traditionally been designed to provide high availability and standards-based quality of service. In inter-cloud, ~~network service~~NSs deployment over multiple clouds identifies new challenges to equip inter-cloud management systems to deal with management issues. Especially, those NSs relay over underlying both physical and "software" infrastructure ~~(NFV-based infrastructure)~~. Therefore, the end to end management is related to physical, virtual layer or the VNFs of inter-cloud environments where virtual machines are instantiated, on which particular VNFs are hosted~~.~~.

For NSs in inter-cloud, faults may occur for many more reasons compared to traditional physical telecommunication networks. The virtual resources are created on shared physical resources like server hardware, system software or network links, using virtualization software. One reason why virtual resources may fail is because of the failure of physical resources. Even if the physical resources are operational, the virtual resources may themselves fail. Furthermore, even if both physical and virtual resources are healthy, the VNFs instantiated on these virtual resources can have problems causing NSs to malfunction or totally break down. The myriad levels of malfunctions make handling of fault and performance issues in inter-cloud more complex.

~~In fact, the traditional deterministic methods fail to deliver in virtual environments in which virtual resources can be dynamically scaled, migrated or destroyed. It is important to use predictive techniques to identify and resolve management issues before or after they have occurred.~~

~~In hybrid telecommunication networks with physical and "software" infrastructures, the deterministic methods ensure carrier grade availability and reliability. On the other side, the NSs using virtual resources over multiple clouds provide a number of complex factors and make it imperative to use predictive methods for assuring carrier grade availability.~~

Some of the key challenges for end to end fault and performance management for NSs in inter-cloud are as follows:

- Absence of an standardized~~FCAPS~~ framework~~.~~;
- Non-applicability of traditional rule based techniques when used in ~~today's networks~~inter-cloud~~.~~;
- Multiple layers of implementation: physical infrastructure, ~~NFVI~~virtualized resource, ~~V~~NFs and NSs~~.~~;
- ~~—~~Massive distribution of ~~network functions~~ NFs and underlying resources over ~~disparate~~ different clouds~~.~~;
- ~~Multiple control centres: cloud management systems, operators' OSS/BSS and NFV-MANO and inter-cloud management platforms.~~

6.4. End-to-end fault and performance management of network services in inter-cloud

[Editor's note in June 2019:] This sub-clause should illustrate the overview of end-to-end fault and performance management of NSs in inter-cloud. Contributions are invited.

~~One of the main challenges identified in NFV-based systems is related to fault management (including single or cascade faults) and performance issues, which have strong impact on whole environment. The precise detection of source of fault and area affected by faults are key aspects in telecommunication's software infrastructure, whose performance starts to be comparable to performance achieved over traditional networks.~~

The goal of fault and performance management of NSs in inter-cloud can be summarized as follows:

– Detection of any condition that has already led to or could lead to degraded performance or failure. The reasons could be manifested faults, hidden faults or inconspicuous deviations. The goal of fault and performance issue detection is to sense and notify impending or actual fault and performance issues;

– Identification and localisation of manifested and impending faults. The goal of FP issue localisation is to determine the root cause of the problem by identifying the resources that are malfunctioning or the severity with which they may malfunction in the future.

~~6.4.1. Fault management of network services in inter-cloud~~

~~The fault management of NSs in inter-cloud would be a collaborative process among the elements constituting the service and the management systems involved. Modern communication systems produce large volumes of high-dimensional operational data. In such a case, analysing the data to get an actionable understanding of the situation becomes difficult. The fault management should be able to identify a fault that would require resources to restore the service parameters. In particular,~~

~~the key challenges of fault management in virtualized environments are related to proper classification of reasons of fault in proper service operation:~~

- ~~Fault detection to notify impending or actual fault and performance issues caused by resource failure.~~
- ~~Determination of the root cause of the problem by identifying the inter-cloud resources that are malfunctioning or the severity with which they may malfunction in the future.~~
- ~~Performance detection to notify impending or actual performance issues caused by service overload.~~
- ~~Determination of the root cause of the problem by identifying the inter-cloud resources that are overloaded or the severity with which they may be overloaded in the future.~~
- ~~Configuration detection to notify impending or actual performance issues caused by service configuration.~~
- ~~Determination of the root cause of the problem by identifying the service configuration parameters that cause the severity or which they may cause it in the future.~~

~~6.4.2. Performance management of network services in inter-cloud~~

~~Performance management of NSs in inter-cloud is based on monitoring of certain Key Performance Indicators (KPIs), that are to be maintained at certain level of values e.g. above the threshold, below the threshold, between or outside the boundaries. KPIs are described by metrics, which are defined as measurable items. Dedicated capabilities which are implemented in functionalities allow to monitor the KPI's values in real time or in defined points in time. Changes of the values depend on the two groups of reasons:~~

- ~~Performance constraints: service provider defines particular values for provided services to assure technical parameters e.g. throughput, delay, CPU load, capacity. Reaching the limit of the value results in degradation of performance parameters and triggers appropriate lifecycle operations like scaling.~~
- ~~Failure constraints: service provider defines particular values for provided services to assure technical parameters e.g. throughput, delay, CPU load, capacity. In case of technical failure of elements of cloud environment the performance parameters may be degraded and should be properly identified to trigger the appropriate lifecycle operation like healing.~~

~~The problem of detection and diagnostic for given conditions that degrade network performance deals with the detection of any condition that has already led to or could lead to degraded performance or failure as well as identification and localization of manifest and impending faults or elements to be scaled. The performance management is based on Quality of Service (QoS) metrics, which measure if the network behaves according to expectations, or Quality of Experience (QoE) metrics, which ensure the user perception of the network and service quality.~~

6.5. Framework of end to end fault and performance management of network services in inter-cloud

The fault and performance management of NSs in inter-cloud is a collaborative process among the elements constituting the service and the management functional components involved. The fault and performance management related responsibilities are jointly implemented by some functional components of the operations support systems(OSSs) defined in the multi-layer functions. These

functional components include OSS-NS, OSS-NF, OSS-CCS, OSS NC and OSS-PR. Their interrelationship in the context of NSs is illustrated in Figure 6-3. For more information about these functional components, please see clause 7.8 and 8.3 of [ITU-T Y.3515].

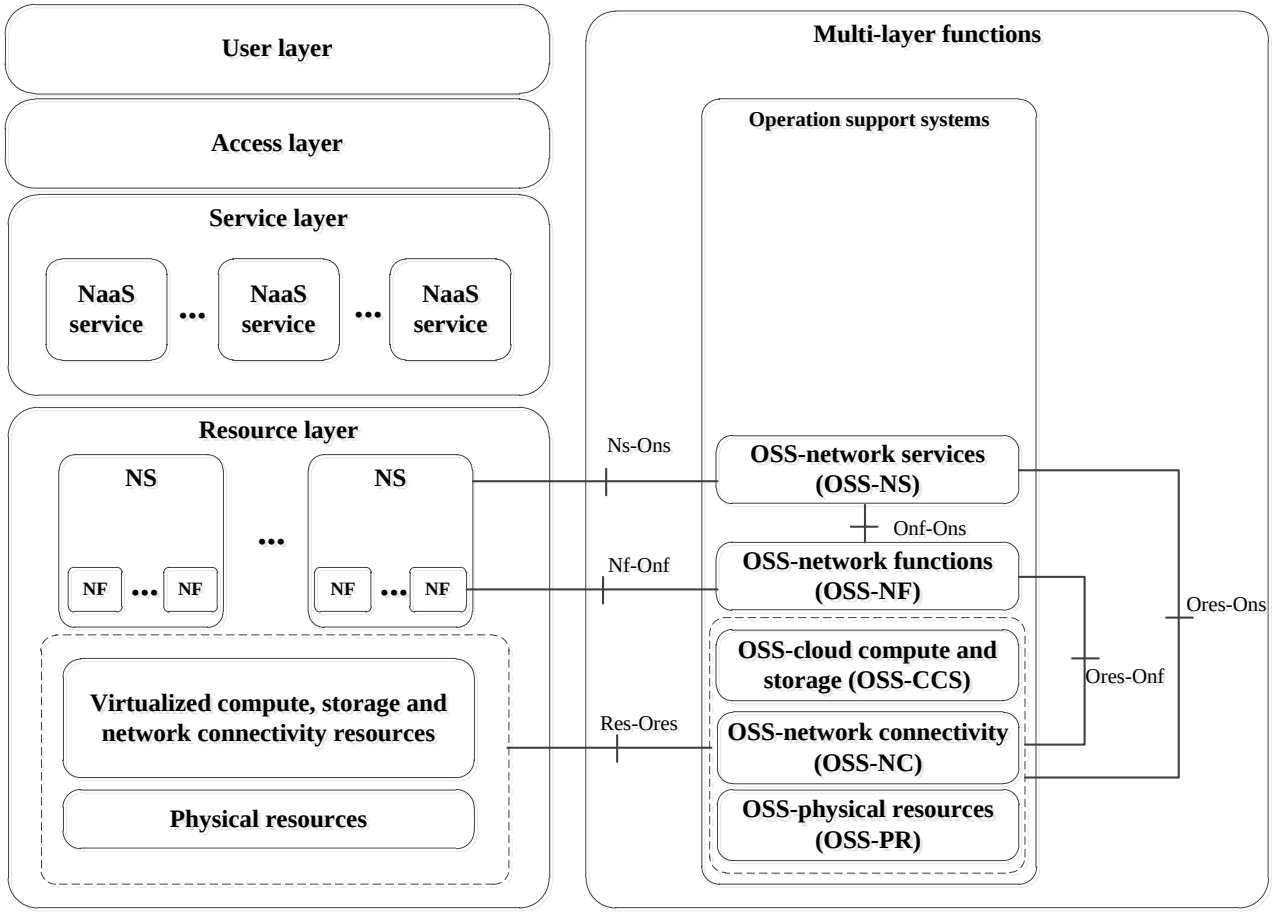


Figure 6-3 – OSS functionalities and reference points for fault and performance management of network services in inter-cloud

The responsibilities of functional components related to fault and performance management of NSs are:

– **OSS-NS**: which is responsible for managing the lifecycle of NSs and using available resources or requesting additional resources to maintain the required performance. For handling fault and performance issues, it monitors NSs and resources and detects anomalous conditions. It gets NF level alarms from OSS-NF and resource level alarms from OSS-CCS, OSS-NC and OSS-PR. It correlates alarms from various sources to localize faults and performance conditions;

– **OSS-NF**: which is responsible for managing the lifecycle of NFs. For handling fault and performance issues, it interacts with NF instances to obtain NF related fault and performance information. It also collects NF instance related resource information. It sends information to OSS-NS for fault detection and localisation;

– **OSS-CCS, OSS-NC and OSS-PR**: which are responsible for collecting alarms related to physical and virtual resources. They forward fault and performance alarms to OSS-NS and OSS-NF for broader correlation and root cause analysis. The fault information may include VM crashes, virtual port malfunction, storage failure, resource unavailability, etc.

The reference points related to fault and performance management of NSs are:

– **Res-Ores**: This reference point covers the interactions between the virtual and physical resources and the functional components about virtual and physical resource management, i.e., OSS-CCS, OSS-NC and OSS-PR. It includes the interaction related to reporting resource level fault and performance issues;

– **Nf-Onf**: This reference point covers the interactions between the NFs and OSS-NF. It includes the interaction related to reporting NF level fault and performance issues;

– **Ns-Ons**: This reference point covers the interactions between the NSs and OSS-NS. It includes the interaction related to reporting NS level fault and performance issues;

– **Onf-Ons**: This reference point covers the interactions between the OSS-NF and OSS-NS. It includes the interaction related to exchanging information about the creation and modification of NFs, and forwarding fault and performance issues related to NFs;

– **Ores-Onf**: This reference point covers the interactions between the OSS-NF and the functional components about virtual and physical resource management. It includes the interaction related to exchanging information about resource level fault and performance issues;

– **Ores-Ons**: This reference point covers the interactions between the OSS-NS and the functional components about virtual and physical resource management. It includes the interaction related to exchanging information about resource level fault and performance issues.

7. Functional requirements for end-to-end fault and performance management of network services

[Contributor's note] This clause will provide~~s~~ functional requirements related to end-to-end fault and performance management of network services based on ones derived from use cases.

~~[Editor's note in March 2020]: The text in this clause comes from the original clause 6.4.3. The style of the text should be modified as requirements and the related use case should be provided . Contributions are invited.~~

~~Faults happen due to physical or algorithmic causes. Faults may occur for a number of reasons, prominent amongst which are malfunctioning or failed devices because of hardware or software failures in VMs or VNFs, failure of links and configuration errors. There could be other reasons like cyber-attacks, disasters or environment factors. Faults appear as errors. Errors in turn are deviations of a system from normal operations. Errors are reported through system alarms. Alarms are notifications about specific events that may or may not be errors. The degradation of a service can be detected through notifications, counters or meters. The Fault detection and Performance Management system should be able to identify which issues are potential performance hazards or may result in a fault that would require resources to rectify.~~

~~Four levels of severity of events & alarms have been defined in ITU standard X.733: Critical, Major, Minor, and Warning [ITU92]. The critical alarm comes when the service can no longer be provided to the user. Major alarm indicates the service affected condition while minor means no current degradation is there, but if not corrected may develop into a major fault. A warning is an impending service affecting fault or performance issue. It is for the predictive capabilities of the Fault detection and Performance Management system to predict what faults will develop and with what severity levels.~~

~~Communication networks are widely distributed and are complex. The variety of FCAPS issues that can afflict them is large. The system to detect, diagnose and localize any condition that degrades network performance requires:~~

~~- Detection of any condition that has already led to or could lead to degraded performance or failure. The reasons could be manifest faults, hidden faults or inconspicuous deviations. The goal of such detection would be to sense and notify impending or actual fault and performance issues.~~

~~- Identification and localization of manifest and impending faults as well as performance problems. The goal of such localization would be to determine the root cause of the problem by identifying the resources that are malfunctioning or the severity with which they may malfunction in the future.~~

~~Any end-to-end fault and performance management system should take into account all the markers including alarms, notifications, warnings, observed behaviour, counter readings and measured values of performance indicators to carry out the above functions.~~

This clause identifies functional requirements applicable for end to end fault and performance management of network services in inter-cloud.

7.1. Fault and performance data collection

It is required that a CSP supports collecting the fault and performance data from all of the resources even in different CSPs which supporting the implementation of the NS.

7.2. Fault and performance problems detection

It is required that a CSP supports detect unavailability and failures of physical and virtual resources that might cause faults or performance problems in NFs running on top of them.

It is required that a CSP supports filter out dependent and routine operational events, i.e., no fault, so that resources are not wasted in localizing these problems.

It is recommended that a CSP supports classifying the detected faults into manifested or impending so that further action can be accordingly taken.

7.3. Fault and performance problems localisation

It is required that a CSP supports determining the root cause of a manifest fault by identifying the resources that are malfunctioning.

It is recommended that a CSP supports determining the severity an impending fault with which they may malfunction in the future.

7.4. Fault and performance problems correlation

It is required that a CSP supports mapping each fault to the impacted components of the NS, e.g., the CSP is required to identify unavailability of virtualized resources that are or will be affected by failures on the physical resources under them, or identify VNF instances that are or will be affected by failures of the virtualized resources.

8. A predictive model for fault and performance issues detection and localisation ~~Framework of end-to-end fault and performance management of network services in inter-cloud~~

[Contributor's note] This clause will provide framework of end-to-end fault and performance management of network services in inter-cloud. At the moment, existing material is illustration only and allows better positioning aspects of network services in general network architecture. This material will be updated accordingly. Contributions are invited.

~~[Editor's note in March 2020]:The aspects of AI/ML should be considered as optionally here, as scope of work this draft Rec. is broad enough. Please consider to start new work item on ML for network management (including e.g. fault prediction) as alternative option. Contributions are invited.~~

~~[Editor's note in March 2020]: The number of subclauses (especially for clause 8) should be reduced to make the structure of this draft more simple and clear. Contributions are invited.~~

For NSs in inter-cloud,~~In NFV~~, faults and performance issues can have complex geneses within virtual resources, compute, storage and networking, as well as virtual network functions~~ and cannot be effectively handled by traditional rule-based systems~~. ~~To be able to make use of the Inter-Cloud paradigm effectively, it is more important to fix Fault and Performance issues. Without a robust mechanism for handling Fault and Performance, service providers would find meeting service level agreements (SLAs) difficult and growth of the promising technology of NFV might get hampered. The framework should contain mechanisms for handling both manifest and latent fault and performance issues.~~ In such a case, it would be very difficult to capture the intricate relationships among the features (e.g., the location of the fault, resources involved, markers produced, etc.) and the corresponding labels (faulty, non-faulty, impending fault, manifested, fault-severity, etc.) through traditional deterministic methods.

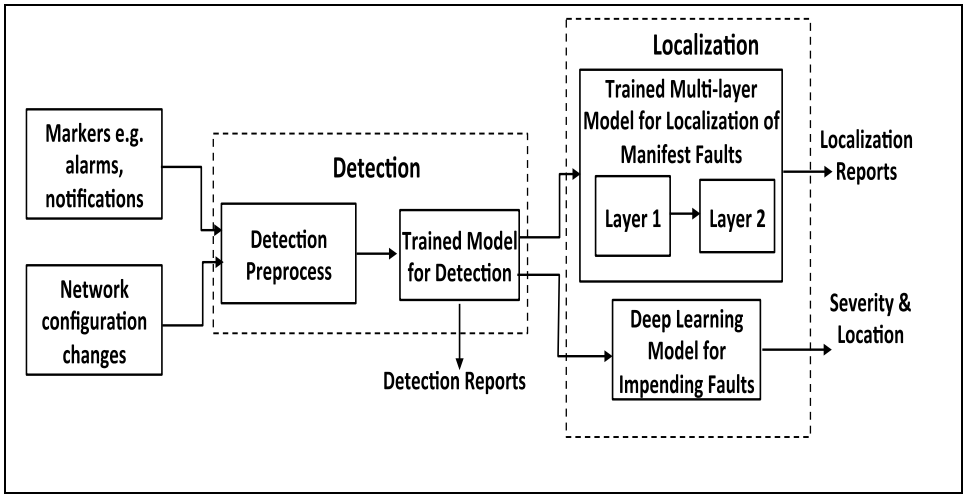
Traditional failure detection methods depend on probing or running tests on hardware, which are not accessible to the NSs deployed on virtual resources. Too much of probing or software testing may overload the VMs that have been optimized for the network function hosted on them. Attempts to apply other traditional methods, like rule-based approaches involving direct correlation of the markers with the faults, get mired in complexity and prove to be inadequate.

The traditional deterministic methods fail to deliver in virtual environments in which virtual resources can be dynamically scaled, migrated or destroyed. Predictive techniques are needed to identify and resolve management issues before or after they have occurred.

~~The framework is intended to facilitate effective end-to-end fault and performance management in Inter-Cloud NSs. In telecommunication networks with physical appliances, deterministic methods ensure carrier grade availability and reliability. However, when telecom service providers' SCs are using virtual resources over multiple clouds, a number of complex factors make it imperative to use predictive methods for assuring carrier grade availability and reliability.~~ This recommendation provide a model based on a judicious combination of shallow as well as deep structures / architectures in machine learning for assuring carrier grade availability and reliability~~to ensure this objective~~.

8.1. f~~F~~ault and performance issues ~~D~~detection and ~~L~~localisation

~~In general, predictive approach is recommended that takes a learning route to solve the problem of the complex interaction of features of fault detection and localization. More specifically, however, a model based on a judicious combination of shallow as well as deep structures / architectures in machine learning, can be used for prediction of fault & performance issues along with the severity levels of impending faults with a high level of accuracy.~~The model approach has predictive and deductive properties to meet the fault and performance management requirements. Run time monitoring and measurements, alarms, notifications and warnings, configuration changes, measurements and environmental factors are all used along with the models trained with historical data to draw inferences about the manifest performance and fault issues. Additionally, decision about impending faults is taken using these inputs and the predictive properties of machine learning models.



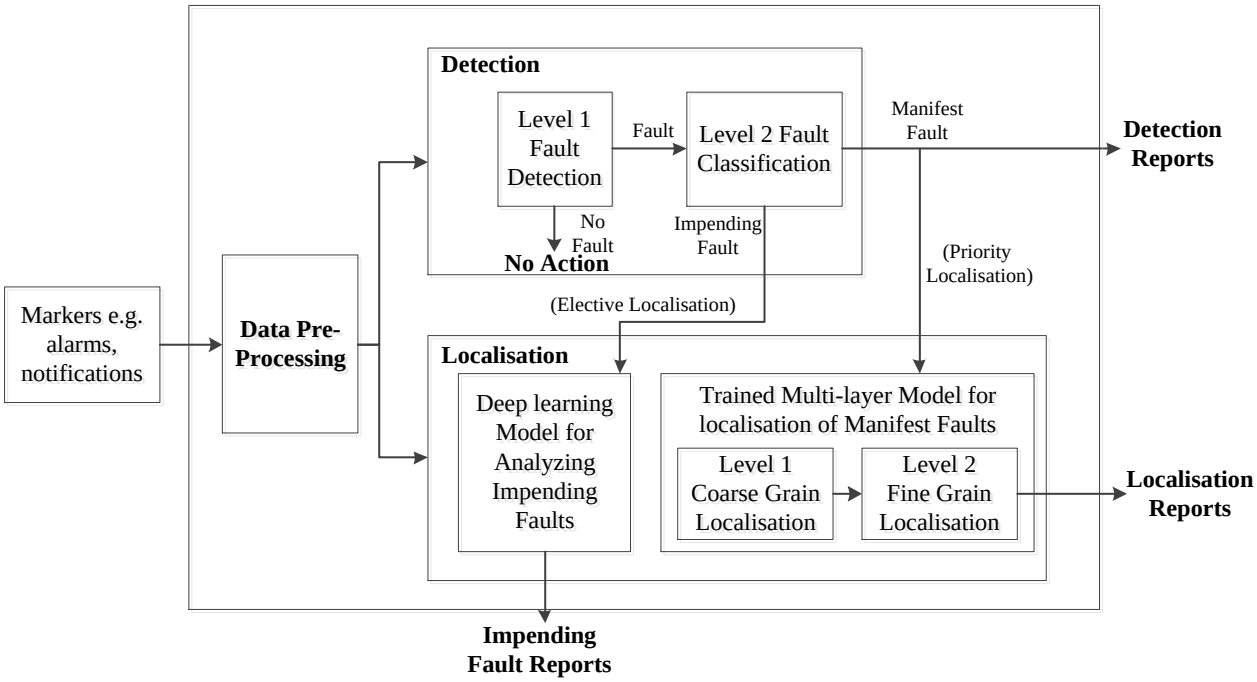


Figure 8-1 – Model for ~~F~~ffault and ~~P~~pperformance ~~I~~issues ~~D~~ddetection and ~~L~~llocali~~z~~zsation ~~Model~~

~~The proposed model approach has predictive and deductive properties to meet the fault and performance management requirements. Run time monitoring and measurements, alarms, notifications and warnings, configuration changes, measurements and environmental factors are all used along with the models trained with historical data to draw inferences about the manifest performance and fault issues. Additionally, decision about impending faults is taken using these inputs and the predictive properties of machine learning models. The detection system first decides whether there is a manifest or an impending fault or a performance issue. Based on this, the system will launch into identification and localization. Detection is essentially a two-stage binary classification problem that first classifies the outcome into 'normal performance' and 'abnormal performance' or 'faulty' and 'not faulty' classes. Then for the 'faulty' or 'abnormal' cases, it decides whether the problem is manifest or impending. Failure prediction needs to be accompanied with a high probability of correctness as actions following such a prediction involve cost. For localization, the model uses a multi-layered strategy. First, the broad category of the fault is determined (Layer 1). The system then does fine grain localisation (Layer 2) within the broad category and identifies the actual device(s) having a fault or suffering from performance degradation as well as their severity levels. Location & Severity of impending faults need deeper predictive structures.~~

The model shown in Figure 8-1 consists of three main sub-systems: data pre-processing, detection and localisation. Data pre-processing involves collation and normalization of the dataset to remove biases. The pre-processing policy may also involve the reduction of features based on some criterion like correlation with the labels.

The detection sub-system ~~first~~ decides whether there is a manifest or an impending fault or a performance issue. Detection is essentially a two-stage binary classification problem that first classifies the outcome into 'normal performance' and 'abnormal performance' or 'faulty' and 'not faulty' classes. Then for the 'faulty' or 'abnormal' cases, it decides whether the problem is manifest, i.e., it has already occurred somewhere in the network in some form, or impending, i.e., it might happen in the near future.

The localisation sub-system fulfils the localisation of the detected faults. Localisation of manifested faults is taken up on priority while for the impending faults it is elective, nevertheless important. For the manifested faults, the model uses a multi-layered localisation strategy using machine learning classification models. At localisation layer 1, the broad category of the manifested fault is determined, e.g., network performance problem. At localisation layer 2, the system makes a finer identification of the problem to assist in the identification of the root cause of the problem, i.e., malfunctioning resources or resources suffering from performance degradation. For the impending faults, a deep learning strategy uses the markers to predict the severity and location of faults.

8.2. Markers and ~~M~~metrics for ~~F~~fault and performance issues ~~D~~detection and ~~L~~localisation

During their operation, CSP's networks produce large volumes of high dimensional data in the form of markers like alarms, notifications, observed behaviour, warnings, counter values and measurement of performance indicators. The markers used by CSPs are predominantly at the service and network function level.

There are a large number of markers that are directly or indirectly related to the occurrence of an fault and performance issue. Events, that produce these markers, relate~~There are events relating~~ to communication, quality of service, processing, equipment and environment ~~that produce alarms, notifications, warning or error messages, measurements, counter values and conditions.~~ Not only each fault and performance issue would usually have multiple markers, but also many of the markers would appear in more than one type of issue. Also, at any given time the markers produced a result of more than one fault and performance issue. This means that when using machine learning for fault detection and localisation, feature engineering, i.e., selection of appropriate markers would be required to get better results.~~Of course, many of the markers will appear in more than one type of fault or performance issue. Once, trained, detection and localisation algorithms would be able to pick out relevant markers and use them to predict the type of condition that may have arisen.~~

The metrics used by CSPs to measure the health of the network provide important information about the fault and performance problems at the macro level. Use of these as features in the training dataset would help learning algorithms to narrow down the scope of localisation effort.

~~Some of the markers related to mobile, fixed and broadband networks are given in Table 8-1 below.~~

~~**Table 8-1 – Illustrative list of markers**~~

~~**Mobile Network**~~	~~**Fixed Network**~~	~~**Broadband**~~
~~Carrier/Interference Ratio~~	~~No Dial Tone~~	~~Intermittent Connection~~
~~Radio Link Time Out~~	~~Channel Noisy~~	~~Low Data Rate~~
~~Time Slot Shortage~~	~~MDF Jumper Disconnection~~	~~Phone Works Broadband Down~~

Occupied Bandwidth	Line Card Port Faulty	Repeated Training
RX Noise Floor	Primary Cable Fault	LAN Lamp Off
Radio Power	Distribution Cable Fault	Line Noisy
Frequency Error	DP Fault	DSLAM Port Mismatch
Antenna Tilt	House Wiring	No Ping
Signal Strength	MDF Fuse Blown	ADSL Lamp Flashes/Off
BTS Down	Customer Instrument Faulty	No Line Sync
Handover Failure	Dis in One Limb	Browsing Issues
Roaming Failure	Earth Contact	Micro-Filter Faulty
Packet Loss	Drop Wire Fault	No Comms
Hypervisor Alarm	Ring Tone Fault	Dropouts
Registration Failure	Message Fault	No Authentication
Low CSSR	Delayed Dial Tone	

Many of the markers could appear in more than one type of fault or performance issue. Some examples are shown in table 8-2.

Table 8-2 – Example showing many-to-many relationship between faults and markers

	Phase Error	Power	EVM	Rx Noise Floor	Origin Offset	Occupied BW	Frequency Error	C/I Ratio
Call Drop*	Y	Y	Y	Y	Y		Y	Y
Call Blocked**		Y	Y	Y	Y	Y		
*Radio link timeout; **Time Slot Short; EVM: Error Vector Magnitude; Rx: Receiver; C/I: Carrier to Interference Ratio; Y: Marker Present								

8.3. Training Datasets

The quality & quantity of the datasets affect the learning and prediction performance of machine learning algorithms. Information about faults, observations and restoration details in the telecommunication networks is contained in the fault dockets, test reports, central office system logs, outdoor maintenance staff logs, cable maintenance staff diaries and docket closure reports. Fault severity has three categories with 0 indicating no faults, 1 indicating a few faults and 2 indicating many faults. There are datasets for event type, the features logged, the resource affected and the severity type. The severity type is different from fault severity and classifies the warning given by the system.

8.4. Shallow and Deep Learning Methods

Shallow structures are simpler with one stage of non-linear operation, e.g., one hidden layer in neural networks. Here, the Support Vector Machine (SVM) Learning Method is a supervised learning method that analyses data and recognizes patterns. However, Deep learning architectures through stacked auto encoders would have more than one level of the composition of non-linear operations in the function learned. One of the key advantages of deep learning is the automatic extraction of high-level features from the given dataset. This is a distinct advantage over the difficult feature engineering in shallow structures that require human intervention. In deep learning, higher-level features are learned as a composite of lower level features. In this way, features are learned at many levels of abstraction, making it easier to grasp complex functions that map the input to the output directly from data.

In the above model for detection & localization of manifest & impending fault & performance issues of NSs in inter-cloud, some of the aspects of detection and localization of faults could be implemented using shallow and deep structures respectively. Simpler detection can effectively be handled by shallow machine learning structures like SVM. However, deeper structure i.e. the stacked auto encoder can be used for a more complex localization function where a large amount of information needs to be worked through to get to the root cause of the problem.

8.5. Detection of Fault and Performance

Fault and Performance issues may range from simple single point failures to multiple correlated or uncorrelated events. A fault presents itself in the form of system malfunction and notifications from faulty and other connected devices. The failure detection mechanism should be able to filter out dependent and routine operational events so that resources are not wasted in localizing these problems. In NFV, the faults in VM, VNF & Virtual Network cause NS to behave abnormally. For example, failure of a Gigabit Ethernet interface on the core router may cause some or all of the virtual private network (VPN) links of many customers to be non-functional. In this context, the goal of the Fault & Performance detection mechanism is to correlate alarms, notifications, measurements and other markers generated by events to infer manifest or predict impending performance and fault conditions. Some errors may be cleared by the system, others may produce warnings that may signal impeding problems while still another may produce faults that bring down functionalities and make themselves evident. The trained shallow machine learning models learn from the past events relating to faults and their resolutions. The models work in two stages: the first stage just makes a decision between ‘fault’ and ‘no-fault’ conditions, while the second stage does a more detailed examination of the markers to choose between ‘manifest’ and ‘impending’ faults. Minor faults & warnings would be the main contributors to the impending faults and need to be analysed to make this decision. With correct segregation, the localization stage would be able to carry out its functions properly.

8.6. Localization of Fault and Performance

The severity level of the faults indicates whether they are warnings, minor, major or critical. In the case of major & critical faults, devices degrade performance or stop working and need immediate action. Minor faults do not affect service and can be scheduled for localization accordingly. Warnings, along with the state information, provide insight into the degrading health of devices and could signal a major impending fault. In multi-layer fault identification and localization system, at Layer I, it detects the brand category of fault and then at Layer 2, does a fine grain classification. In the case of impending faults, the system predicts the locations and severity levels of the developing faults.

9. Security consideration

Security aspects for consideration within the cloud computing environment, including inter-cloud computing, are described in [ITU-T X.1601], which analyses security threats and challenges, and describes security capabilities that could mitigate these threats and meet the security challenges.

Appendix I

Use case of end-to-end fault and performance management of network services in inter-cloud

(This appendix does not form an integral part of this Recommendation.)

I.1 Use case template

The use cases developed in Appendix I should adopt the following unified format for better readability and convenient material organization.

Title	Note: The title of the use case
Description	Note: Scenario description of the use case
Roles	Note: Roles involved in the use case
Figure (optional)	Note: Figure to explain the use case, but not mandatory
Pre-conditions (optional)	Note: The necessary pre-conditions that should be achieved before starting the use case.
Post-conditions (optional)	Note: The post-condition that will be carried out after the termination of current use case.
Derived requirements	Note: Requirements derived from the use cases, whose detailed description is presented in the dedicated chapter

[Editor's note in March 2020]:The use cases should be reconsidered to provide the derived requirements for clause 7. Contributions are invited.

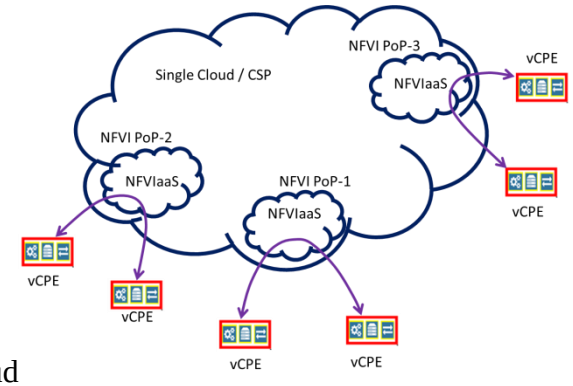
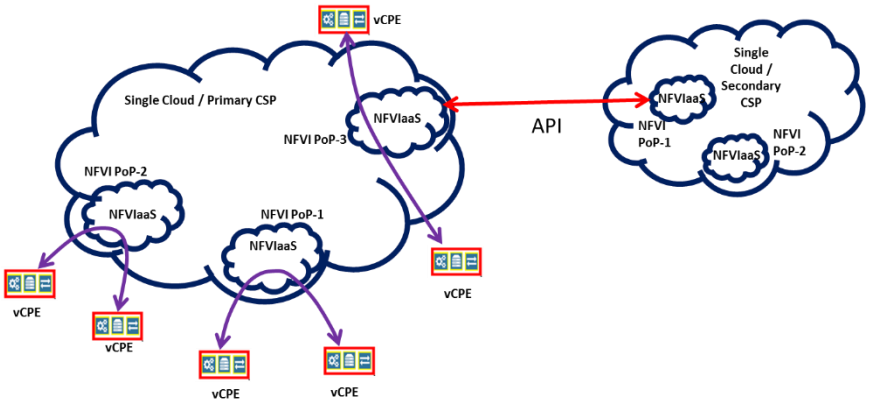
I.2. NS in inter-cloud scenario

I.2.1 NS within a NFVI-PoP in a single CSP cloud

This use case illustrates the NS built between two virtual Customer Premises equipment (vCPEs), which are placed at different CSC locations, and are connected to the same NFVI-PoP of a CSP. A single CSP cloud is the cloud infrastructure owned by one CSP.

Table I.2.1 NS within the same NFVI-PoP in a single CSP cloud

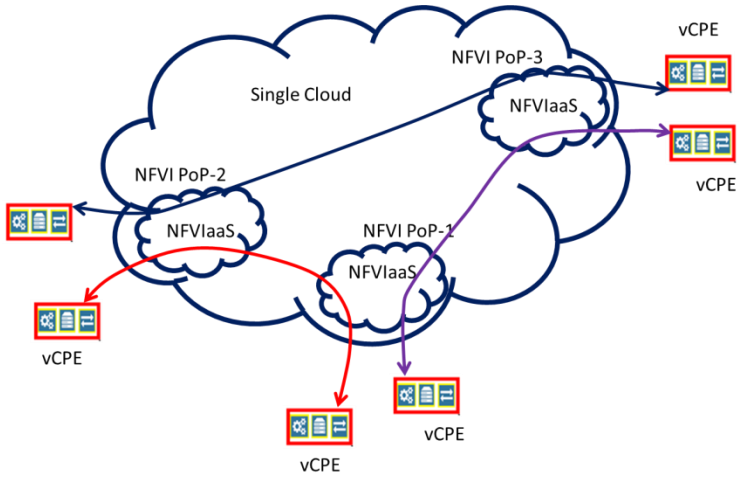
Title	NS within a NFVI-PoP in a single CSP cloud

Description	A CSP is fully responsible for the creation, scaling, termination (life cycle management) of a NS. A primary CSP may avail NFVIaaS from secondary CSP. A CSP shall be responsible for the Fault and performance management of the NS which includes the CSC links.
Relevant roles	CSC and CSP
High-level figure describing the use case	 Fig – A (above) : Single Cloud  Fig – B (above): Single cloud availing NFVIaaS from secondary CSP
Pre-conditions	
Post-conditions	
Derived requirements for the cloud capability	

I.2.2. NS among different NFVI-PoPs in a single CSP cloud

This use case illustrates NS built between two vCPEs connected to different NFVI-PoPs within a single CSP cloud.

Table I.2.2 NS among different NFVI-PoPs in a single CSP cloud

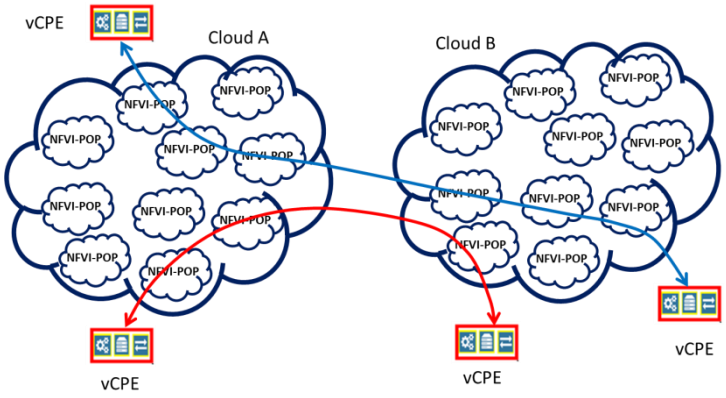
Title	NS among different NFVI-PoPs in a single CSP cloud
Description	A CSP is fully responsible for the creation, scaling, termination (life cycle management) of a NS. A primary CSP may avail NFVIaaS from secondary CSP. A CSP (primary) shall be responsible for the Fault and performance management of the NS which includes the CSC links.
Relevant roles	CSC and CSP
High-level figure describing the use case	
Pre-Conditions	
Post-Conditions	
Derived requirements for the cloud capability	

I.2.3. NS among NFVI-PoPs in separate clouds

This use case illustrates the NS built between two vCPEs connected to NFVI-PoPs located in two separate clouds administered by two different CSPs.

Table I.2.3 NS among NFVI-PoPs in separate clouds

Use case title	NS among NFVI-PoPs in separate clouds
Use case description	Both the CSPs responsible for the creation, scaling, termination (life cycle management) of a NS. Both CSPs shall be responsible for the Fault and performance management of the NS in their administrative domain area including the CSC link connected to their cloud.
Relevant roles	CSC and CSP

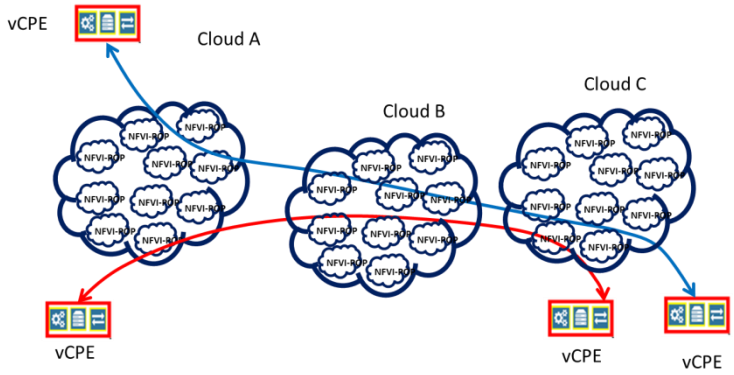
High-level figure describing the use case	
Pre-Conditions	
Post-Conditions	
Derived requirements for the cloud capability	

I.2.4. NS among NFVI-PoPs in separate clouds with an intermediary cloud

This use case illustrates the NS built between two vCPEs connected to NFVI-PoPs located in two separate clouds with another cloud as an intermediary.

Table I.2.4 NS among NFVI-PoPs in separate clouds with an intermediary cloud

Title	NS among NFVI-PoPs in separate clouds with an intermediary cloud
Use case description	All the CSPs responsible for the creation, scaling, termination (life cycle management) of a NS. All the CSPs shall be responsible for the Fault and performance management of the NS in their administrative domain area. All the intermediary CSPs are not responsible for the CSC links.
Relevant roles	CSC and CSP

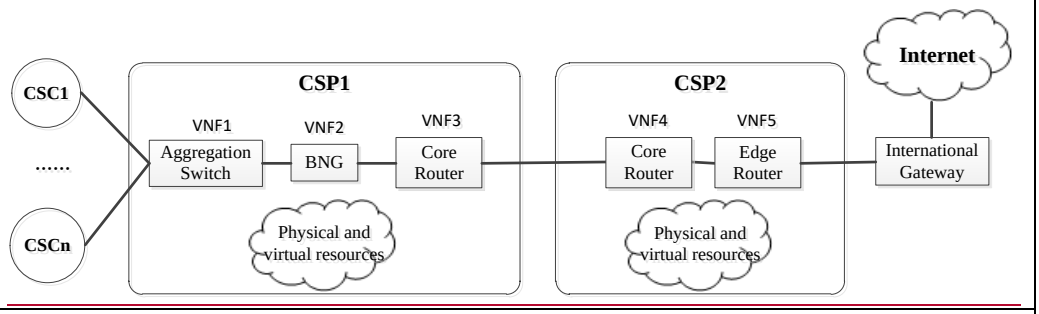
High-level figure describing the use case	
Pre-conditions	
Post-conditions	
Derived requirements for the cloud capability	

I.3 Virtual broadband service

This use case illustrates reputation-based trust evaluation in inter-cloud. The intermediary pattern of inter-cloud used to illustrate the use case is an example only.

Table I.3 Virtual broadband service

Title	Virtual broadband service
Description	CSP1 provides broadband service to CSC. The broadband service is a NS which is composed of VNFs realized as VNF1 to VNF5. VNF1 to VNF3 are deployed in CSP1, VNF4 and VNF5 are deployed in CSP2. CSP1 is the primary CSP in the inter-cloud intermediary pattern. As the operator of this NS, CSP1 should have the comprehensive topology of the NS and the relationship between of the elements, e.g., the virtual resources and their supporting physical resources, and the VNF instances and their supporting virtual resources. During the operation of this service, large volumes of high dimensional data in the form of markers like alarms, notifications, warnings, and measurement of performance indicators are produced from both CSP1 and CSP2. As the operator of this NS, CSP1 has the responsibility for managing the fault and performance issues to meet SLAs. For achieving this, CSP1 should collect all markers from CSP1and CSP2 which related to the fault and performance problems of the NS. Based on these data, CSP1 should detect of any condition that has already led to or could lead to degraded performance or failure，identify and localize of manifested and impending faults.
Roles	CSC , CSP

Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Fault and performance data collection (refer to clause 7.1) – Fault and performance problems detection (refer to clause 7.2) – Fault and performance problems localisation (refer to clause 7.3) – Fault and performance problems correlation (refer to clause 7.4)

[Editor's note in June 2019:] The content of Appendix II comes from C34 in June 2019's SG13 meeting. Although we agree to remove NFVIaaS and VNFaaS related content from clause 6, some experts think the relationship of NFVIaaS and VNFaaS with NaaS capabilities is critical for this draft Rec. So we added this Appendix to remind this issue and decide whether it should be reserved in the future.

Appendix II

Clarification on NFVIaaS, VNFaaS and the relationships with NaaS capabilities

II.1 Concept of NFVIaaS and VNFaaS

Both NFVIaaS and VNFaaS are use cases describing service models (or cloud service categories) which are defined by ETSI. These use cases are intended to clarify the roles and interactions of the various types of commercial entities acting in a marketplace for services delivered by CSPs. But these two cloud service categories are not defined in ITU-T yet.

In NFVIaaS, the NFV Infrastructure(NFVI) can be considered as a service providing the capability or functionality to support an environment in which VNFs can execute, and a CSP could run VNF instances inside an NFVI which is operated as a service by a different CSP. From the cloud capabilities type of view, NFVIaaS provides the infrastructure capabilities type.

In VNFaaS, the VNF can be considered as a service provided by CSP to CSC. From the cloud capabilities type of view, VNFaaS provides the application capabilities type.

II.2 Concept of NaaS

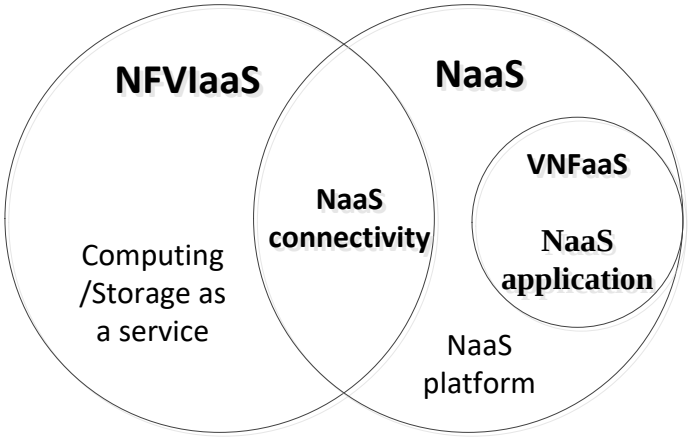
NaaS is a cloud service category in which the capability provided to the CSC is transport connectivity and related network capabilities. NaaS can provide any of the three cloud capabilities types(i.e. infrastructure capabilities type, platform capabilities type, application capabilities type). NaaS services are therefore divided into NaaS application service, NaaS platform service and NaaS connectivity service.

NaaS application: application capabilities type of service where NaaS CSC can use network applications provided by NaaS CSP. These network applications are considered and used as a VNF provided by NaaS CSP. Examples of NaaS applications include virtual router, virtual content delivery network (vCDN), virtualised evolved packet core (vEPC) and virtual firewall (vFW).

NaaS connectivity: infrastructure capabilities type of service where NaaS CSC can provision and use networking connectivity resources provided by NaaS CSP. This includes for example flexible and extended VPN, bandwidth on demand (BoD), etc.

II.3 The relationships of NFVIaaS and VNFaaS with NaaS capabilities

Base on the above's discussion, we can see there are some overlaps existing in NFVIaaS , VNFaaS and NaaS. The relationships of NFVIaaS and VNFaaS with NaaS are illustrated in below figure:



[Editor's note in June 2019:]Some expert suggests that NaaS application is one of the VNFaaS similar to~~ly~~ as NaaS Connectivity is one of the NFVIaaS. Discussion about this issue will be based on subsequent contributions. Contributions are invited.

NFVIaaS, VNFaaS and NaaS are among various types of cloud service categories. They can provide different types of cloud services to CSC. The overlap between NFVIaaS service and NaaS service is NaaS connectivity which is an infrastructure capabilities type of service where CSC can use networking connectivity resources provided by CSP. And VNFaaS service is almost as same as NaaS application service which CSC can use network applications/VNFs provided by CSP.

II.4 Conclusion

Base on the above's discussion, we can summarize the relationships of NFVIaaS and VNFaaS with NaaS as below:

- NFVIaaS ,VNFaaS and NaaS are different kind of cloud service category;
- The capabilities of NFVIaaS and NaaS have an overlap as both of them can provide transport connectivity and related network capabilities;
- The capability of VNFaaS is almost as same as NaaS application capability which can provide network applications/VNFs.

Bibliography

[b-DMTF OVF] DMTF Standard DSP0243 Version 1.0.0 (2009), Open virtualization format specification.

[b-ETSI GSR NFV 003] ETSI GSR NFV 003 V1.45.1 (20182020), *Network functions virtualisation (NFV); Terminology for main concepts in NFV*.

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