

Technical Specification
OCC 1.0

# OCC 1.0 Reference Architecture with SDN and NFV Constructs

September, 2015

Disclaimer

The information in this publication is freely available for reproduction and use by any recipient and is believed to be accurate as of its publication date. Such information is subject to change without notice and the Open Cloud Connect (OCC) is not responsible for any errors. The OCC does not assume responsibility to update or correct any information in this publication. No representation or warranty, expressed or implied, is made by the OCC concerning the completeness, accuracy, or applicability of any information contained herein and no liability of any kind shall be assumed by the OCC as a result of reliance upon such information.

The information contained herein is intended to be used without modification by the recipient or user of this document. The OCC is not responsible or liable for any modifications to this document made by any other party.

- The receipt or any use of this document or its contents does not in any way create, by implication or otherwise:
- a)any express or implied license or right to or under any patent, copyright, trademark or trade secret rights held or claimed by any OCC member company which are or may be associated with the ideas, techniques, concepts or expressions contained herein; nor
- b)any warranty or representation that any OCC member companies will announce any product(s) and/or service(s) related thereto, or if such announcements are made, that such announced product(s) and/or service(s) embody any or all of the ideas, technologies, or concepts contained herein; nor
- c)any form of relationship between any OCC member companies and the recipient or user of this document.

Implementation or use of specific Cloud Ethernet standards or recommendations and OCC specifications will be voluntary, and no company shall be obliged to implement them by virtue of participation in the Cloud Ethernet Forum. The OCC is a non-profit international organization accelerating industry cooperation on Cloud Ethernet technology. The OCC does not, expressly or otherwise, endorse or promote any specific products or services.

© The Open Cloud Connect 2015. All Rights Reserved.

5253 List of Contributing Mer

## **Table of Contents**

53	List	of Contributing Members	ii
54	1.	Introduction	1
55	2.	Terminology and Acronyms	1
56	3.	Summary of OCC 1.0 Architecture	5
57	4.	Summary of The NFV Architecture	12
58	5.	Mapping Between NFV and OCC Reference Architecture Constructs	17
59	6.	Basic NFV Components of OCC Architecture	19
60	6.1.	NFV Components of cSUI	19
61	6.2.	NFV Components of cSC and cSCTPs	24
62	6.3.	NFV Components of cSI	27
63	6.4.	NFV Components of cSC Crossing two cSPs	31
64	7.	Summary of Software-Defined Networking (SDN) Architecture	36
65	8.	OCC Management Architecture Basic Blocks	39
66	Refe	rences	42
67 68		List of Figures	
	<b>T</b>	<del>-</del>	-
69 	0	re 1: Cloud Service Actors	
70		re 2: Cloud Service Provider access via the standard interface, cSUI	
71 72		re 3: Cloud Provider and Cloud Carrier belong to two different Operatorsre 4: cSC between two Cloud Provider entities	
72 73	Figu	re 5: Two Cloud Service Providers collectively providing Cloud Services	
73 74	_	re 6: Protocol Stacks that can be supported at external interfaces	
7 <del>4</del> 75		re 7: Multiple VM sharing a cSC	
76		re 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs),	
77		virtual networks (VNs) and IP addresses.	
78		re 9: VM supporting	
79		re 10: Cloud Service Connection Types	
80		re 11: Network Layering and interface of NFV	
81		re 12: VM Interface	
82		re 13: Bare Metal Server Interface [2]	
83		re 14: Bare Metal Server Interface [4]	



84	Figure 15: SWA-1 Interface	14
85	Figure 16: SWA-5 Interface	15
86	Figure 17: Container Interface	15
87	Figure 18: Management of Network Functions	16
88	Figure 19: NFV Orchestrator interaction with EMS and OSS/BSS [6]	
89	Figure 20: Cloud User Interface-NaaS architecture with NFV constructs	
90	Figure 21: Bare Metal Server Interface and Naas	
91	Figure 22: VM access over NaaS	
92	Figure 23: VNFs and Infrastructure for cSC and cSCTP	
93	Figure 24: VNF and Infrastructure Components of cSC between cSUI and cSI	
94	Figure 25: VNFs for cSC-csp and cSC-csp-TP	
95	Figure 26: ONF SDN Architecture [10]	
96	Figure 27: ITU-T SDN Architecture [11]	
97	Figure 28: IETF SDN Architecture [12]	
98	Figure 29: SDN Building Blocks [7]	
99	Figure 30: Cloud Services Management with Life Cycle Orchestration	
.00	Figure 31: Management of Cloud Services provided by multiple Cloud Service Operators	
.01	Figure 32: Product and Service Operations Lifecycle Stages [9]	42
.02	List of Tables	
.03	List of Tables	
.04	Table 1: Terminology and Acronyms	4
.05	Table 2: Mapping between OCC and NFV Constructs.	
.06	Table 3: VNF and Infrastructure Components of cSUI defined in [1]	
.07	Table 4: VNF and Infrastructure Components of of cScTP defined in [1]	
.08	Table 5 : VNF and Infrastructure Components of cSC defined in [1]	
.09	Table 6: VNF and Infrastructure Components of cSI defined in [1]	
10	Table 7: VNF and Infrastructure Components of cSPcSPI defined in [1]	
11	Table 8: VNF and Infrastructure Components of cSC-csp-TP defined in [1]	36
12		
.13	List of Contributing Members	
.14	Author and Editor: Mehmet Toy, Ph.D, Comcast	
.15	Contributing CEF member companies agreed to be listed:	
16	Avaya	
17	Alcatel-Lucent	
18	Verizon	
19	Wedge Networks	
20	Veryx	
.21		
.22		
.23		



## 1.Introduction

- The purpose of this document is to describe possible implementations of Cloud Services Archi-
- tectures using Software-Defined Networking (SDN) and Network Functions Virtualization
- 127 (NFV) constructs.

# 2.Terminology and Acronyms

- 129 This section defines the terms used in this document. In many cases, the normative definitions to
- terms are found in other documents. The third column in Table 1 is used to provide the reference
- for the definitions.

I	3	2	
			Г

128

Terms	Definitions	Reference
cCcPI	Cloud Carrier Cloud Provider Interface	OCC 1.0 Ref. Arch.[1]
Cloud Consumer	A person or organization that maintains a business relationship with and/or uses service from a Cloud Service Provider via a Cloud Service User Interface (cSUI).	OCC 1.0 Ref. Arch.[1]
Cloud Service User	A person or organization that maintains a business relationship with and/or uses service from a Cloud Service Provider via a Cloud Service User Interface (cSUI).	OCC 1.0 Ref. Arch.[1]
cC	Cloud Carrier (cC) is an intermediary that provides connectivity and transport between Cloud Providers and Cloud Consumers or between Cloud Providers.	OCC 1.0 Ref. Arch.[1]
CoS	Class of Service	MEF 10.3 [14]
CoS ID	Class of Service Identifier	MEF 23.1 [22]
сР	Cloud Provider is an entity that is responsible for making cloud applications available to Cloud Consumers (Cloud Service Users).	NIST Special Publication 500-291 [13]
cSC	Cloud Service Connection	OCC 1.0 Ref. Arch.[1]
cSC-c	Cloud Carrier Connection	OCC 1.0 Ref. Arch.[1]
cSC-p	Cloud Provider Connection	OCC 1.0 Ref. Arch.[1]



cSC-cp	The segment of cSC within the boundaries of a Cloud Service Provider where cSC crosses multiple Cloud Service Providers	OCC 1.0 Arch.[1]	Ref.
cSC-csp	Cloud Service Provider Connection	OCC 1.0 Arch.[1]	Ref.
cSC-csp-TP	Cloud Service Provider Connection Termination Point	OCC 1.0 Arch.[1]	Ref.
cSC-cp-TP	Cloud Carrier-Provider Connection Termination Point	OCC 1.0 Arch.[1]	Ref.
cSCTP (Cloud Service Connection Termination Point)	A logical entity that originates or terminates cSC at a logical user or machine interface.	OCC 1.0 Arch.[1]	Ref.
cSI	Cloud Service Interface (cSI) is the interface of a Cloud Service application supporting entity of a Cloud Provider such as VM.	OCC 1.0 Arch.[1]	Ref.
cSO	Cloud Service Operator is an operator that provides a part of the end-to-end Cloud Service which is provided by a Cloud Service Provider.	OCC 1.0 Arch.[1]	Ref.
cSP (Cloud Service Provider)	An entity that is responsible for the creation, delivery and billing of cloud services, and negotiates relationships among Cloud Providers, Cloud Carriers, Cloud Service Operators, and Cloud Consumers. It is the single point of contact for the consumer.	OCC 1.0 Arch.[1]	Ref.
cSPcSPI	Cloud Service Provider Cloud Service Provider Interface	OCC 1.0 Arch.[1]	Ref.
cSUI	Demarcation Point between a Cloud Consumer and Cloud Service Provider.	OCC 1.0 Arch.[1]	Ref.
DoS	Denial of Service	RFC4732	
DSCP	Differentiated Service Code Point	RFC 2474 [17]	
EMS	Element Management System		
ENNI	External Network Network Interface	MEF 4 [16]	
EVC	Ethernet Virtual Connection	MEF 10.3 [14]	
EPL	Ethernet Private Line	MEF 6.2 [19]	
EVPL	Ethernet Virtual Private Line	MEF 6.2 [19]	



Hypervisor	A software, firmware or hardware running on a server that enables creation of virtual machines and runs them.	OCC 1.0 Ref. Arch.[1]
ICMP	Internet Control Message Protocol	RFC 792 [23]
IPSec ESP	Internet Protocol Security Encapsulating Security Payload	RFC 4303 [24]
L2CP	Layer Two Control Protocol	MEF 10.3 [14]
E-Line	An Ethernet Service Type that is based on a Point-to-Point EVC.	MEF 6.2 [19]
E-LAN	An Ethernet Service Type that is based on a Multipoint-to-Multipoint EVC.	MEF 6.2 [19]
LAN	Local Area Network	IEEE 802-2 [18]
LSO	Life Cycle Service Orchestration	MEF 50 [21]
LSP	Label-switched Path	MPLS Architecture[29]
MAC	Media Access Control	IEEE802-2 [18]
NE	Network Element	
NFV	Network Functions Virtualization	Draft ETSI GS NFV-INF V0.3.1 [2]
NID	Network Interface Device	MEF 4 [16]
OSS/BSS	Operation Support System/Billing Support System	
PW ID	Pseudowire Identification	RFC 4447 [31]
REST API	Representational State Transfer Application Programming Interface	RFC 6690 [25]
SDN	Software-Defined Networking	ONF White Paper [10]
S-VLAN	Service VLAN (also referred to as Provider VLAN)	IEEE802.1Q [15]
TCP-AO	Transmission Control Protocol- Authentication Option	RFC5925 [26]
TCP SYN	Transmission Control Protocol Synchronize	RFC793 [27]
TLS	Transport Layer Security	RFC5246 [28]
UNI	User Network Interface	MEF 4 [16]



VM	Virtual Machine	OCC Arch.[1]	1.0	Ref.
VN	Virtual Network			
VNF	Virtualized Network Function	Draft NFV-IN V0.3.12		GS 001
VNIC	Virtual Network Interface Controller			

**Table 1:** Terminology and Acronyms



136

137

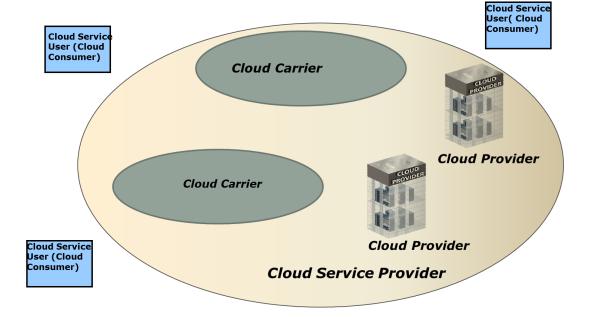
138

139

# 3. Summary of OCC 1.0 Architecture<sup>1</sup>

The key actors of the OCC architecture for Cloud Services are depicted in Figure 1 [1] where a Cloud Service Provider is responsible for providing an end-to-end Cloud Service to a Cloud Service User (i.e. a customer of Cloud Service Provider) using one or more Cloud Carrier(s) and Cloud Provider(s).

140141



142 143 144

145

Figure 1: Cloud Service Actors

146 147

148

A Cloud Consumer interfaces to a Cloud Service Provider (cSP)'s facilities via a standards interface called Cloud Service User Interface (cSUI) (Figure 2) which is the demarcation point between the Cloud Service Provider and the Cloud Consumer.

149 150 When the Cloud Provider (cP) and the Cloud Carrier (cC) are two independent entities belonging to two different operators as depicted in Figures 3 and 4, the standards interface between them is called cCcPI (Cloud Carrier Cloud Provider Interface). In this case, a cSC for cloud services can be terminated at either cCcPI or cSI.

153

151

<sup>&</sup>lt;sup>1</sup> This section copies figures and text from OCC 1.0 Reference Architecture. The Reference Architecture takes precedence if there are differences.

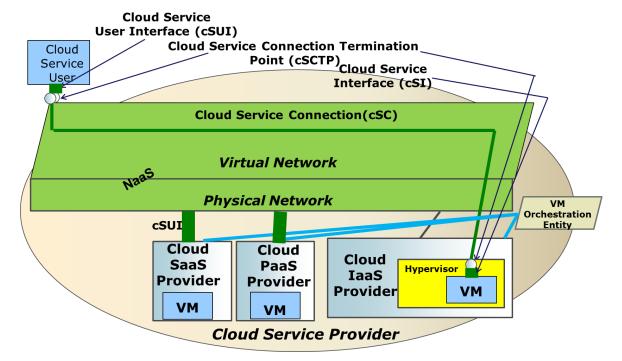


Figure 2: Cloud Service Provider access via the standard interface, cSUI.



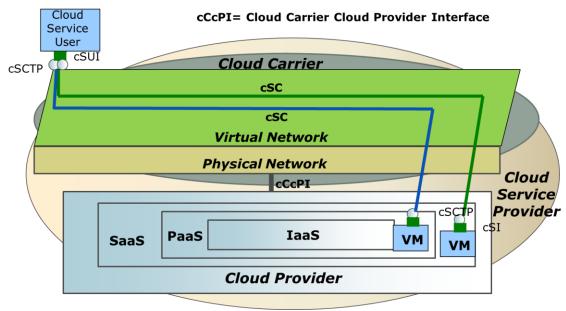


Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators

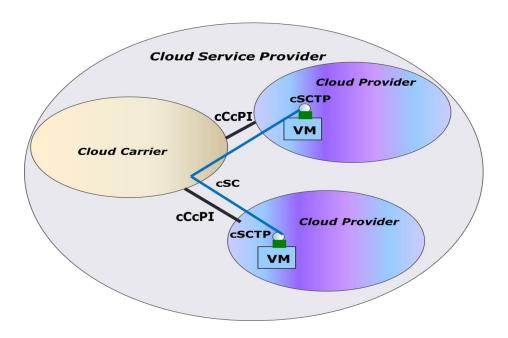


Figure 4: cSC between two Cloud Provider entities.

It is also possible for two or more cSPs to be involved in providing a cloud service to a Cloud Consumer as depicted in Figure 5 where two cSPs interface to each other via a standards inter-

168

169

170

171

172

173

174



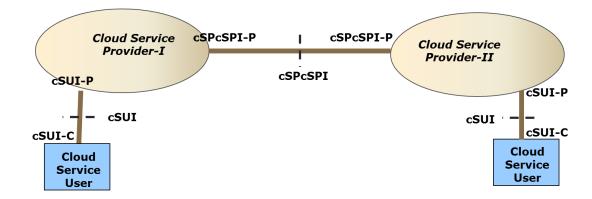
face called Cloud Service Provider Cloud Service Provider Interface (cSPcSPI). In this scenario, only one of the cSPs needs to interface to the end user, coordinate resources and provide a bill. The cSP that does not interface to the end user is called Cloud Service Operator  $(cSO)^2$ .

179

176

177

178



180 181 182

**Figure 5:** Two Cloud Service Providers collectively providing Cloud Services

183 184 185

186

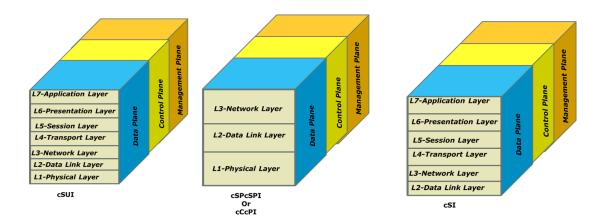
187

188

189

So far we have identified interfaces between user and cSP, between cSPs, between cP and cC, between NaaS [1] and Cloud Service application supporting entity which is cSI. The protocol stack at each interface that can be supported is depicted in Figure 6. Each of the protocol layers may be further decomposed into their data, control and management plane components.

190 191 192



**Figure 6 :** Protocol Stacks that can be supported at external interfaces

<sup>&</sup>lt;sup>2</sup> The cSO is a cSP that is not responsible for the end-to-end service. It can be a cP or a cC or an entity providing only cloud applications with cSI. It is possible that cSO may provide a bill for its part of the service, but this bill is not a bill for the end-to-end service that can be provided by the cSP.



196 197

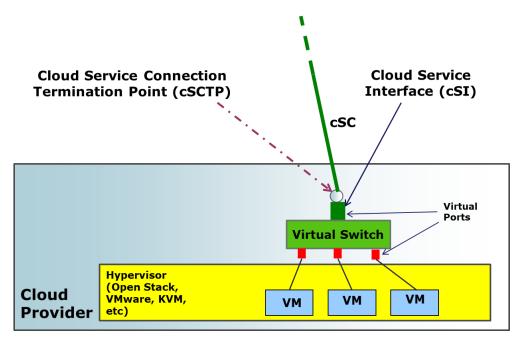
198

The cSC provides connectivity between two or more cSCTPs. The cSC could be an EVC, LSP or IP VPN connection.

199200201

A cSC can support accessing multiple VMs via multiple sessions as depicted in Figure 7 where a virtual switch routes traffic to a destination VM.

202203



204 205

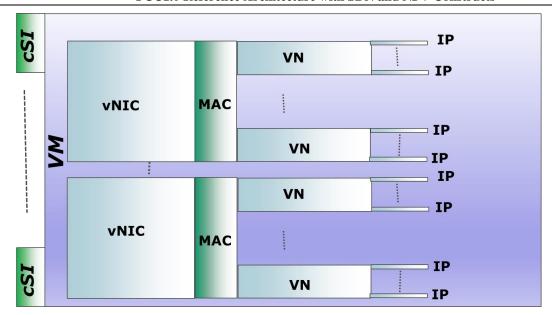
Figure 7: Multiple VM sharing a cSC

206207208

209

210

Furthermore, a VM may consist of multiple virtual network interface controllers (VNICs) where each VNIC can be identified by a soft MAC address, as depicted in Figure 8. In this case, a VNIC interface may map to a cSI.

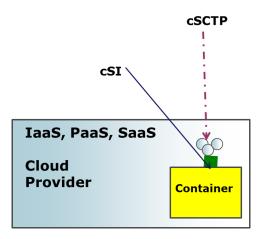


**Figure 8:** VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, virtual networks (VNs) and IP addresses

214215216

The cSI can be supported by a container providing virtualization as depicted in Figure 9. It is also possible to support cSI without a virtualization platform.

217218



219220221

Figure 9: VM supporting

222223224

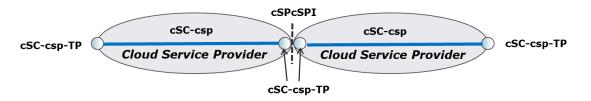
Cloud service connection types are depicted in Figure 10. The connection can be between two termination points of a cSP. If the connection crosses multiple cSPs, the connection segment within a cSP is called Cloud Service Provider Connection (cSC-csp). If the connection crosses a cP and cC, the connection segment within the cP is called Cloud Provider Connection (cSC-p) and the connection segment within the cC is called Cloud Carrier Connection (cSC-c).

226227228

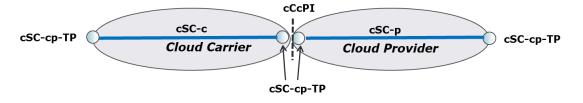




(a) cSC between two termination points residing on the resources of one cSP



(b)cSC between two termination points residing on the resources of two different cSPs (i.e. one of them is acting as a cSO)



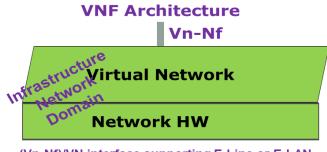
(c) cSC between a termination point residing on cC and a termination point residing on a cP

**Figure 10:** Cloud Service Connection Types

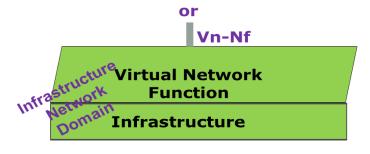


## 4. Summary of The NFV Architecture

- NFV [2, 3] divides the network into two layers, Network Hardware (or Infrastructure) and Virtu-
- 262 al Network (or Virtual Network Function) as depicted in Figure 11 below. Furthermore, NFV
- represents each system component as a functional block. The interactions between blocks are
- represented as interfaces.
- 265 (Vn-Nf)/VN interface is identified as the virtual interface for the network. The E-Line and E-
- LAN services of MEF are being considered as examples of (Vn-Nf)/VN.



(Vn-Nf)/VN interface supporting E-Line or E-LAN



267

268

269

270

271

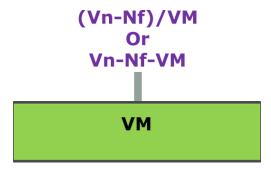
260

Figure 11: Network Layering and interface of NFV

NFV also identifies a VM interface [2] as (Vn-Nf)/VM or Vn-Nf-VM, which the OCC Reference Architecture refers to as the cSI. Given there is no description of (Vn-Nf)/VM in [2], we consider it to be an equivalent of cSI.

272





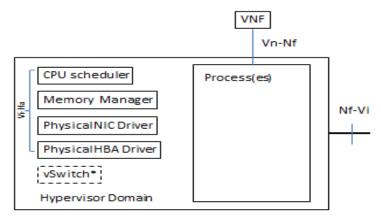
274275

Figure 12: VM Interface

277

NFV identified an interface to hardware [4] as Vi-Ha and interface to Bare Metal OS as depicted in Figures 13 and 14. This interface can be a subset of cSUI or cCcPI or cSPcSPI.

# Bare Metal OS



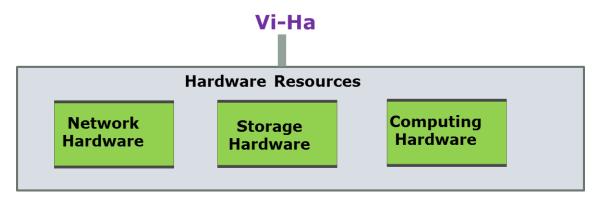
\* vSwitch is an implementation option for the Encapsulation Switch NF defined in Infrastructure Networking Domain

280

**Figure 13:** Bare Metal Server Interface [2]

282





283284

285

**Figure 14:** Bare Metal Server Interface [4]

286

287

288

289290

NFV identifies SWA (Software Architecture)-1 interface [5] as depicted in Figure 15 to enable communication between various network functions within the same or different network service. They may represent data and/or control plane interfaces of the network functions (VNF, Physical Network Function-PNF). SWA-1 can be an equivalent of the virtual component of MEF UNI.



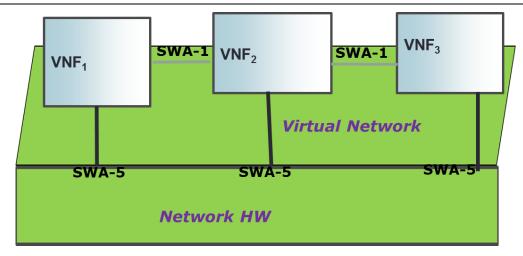
291292

Figure 15: SWA-1 Interface

NFV identifies SW-5 interfaces which are an abstraction of all sub-interfaces between the NFV Infrastructure (NFVI) and the VNF, including VNF inter-switch connectivity services such as E-LAN, E-Line [5], as depicted in Figure 16.

296





298299

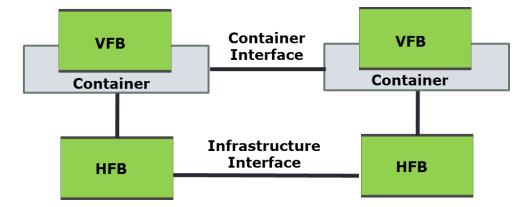
Figure 16: SWA-5 Interface

301 302

NFV divides functional blocks as Host Functional Block (HFB) and Virtualization Functional Block (VFB) [30, 32] as depicted in Figure 17. The interface between HFB and VFB is called Container Interface which is the virtual interface between two containers.

304305

303



306 307 308

Figure 17: Container Interface

309310311

312

313

VNFs are managed by the "Management and Orchestration Function" [4] (Figure 18). The interaction of this orchestrator with Element Management System (EMS) and OSS/BSS [6] is depicted in Figure 19.

314315



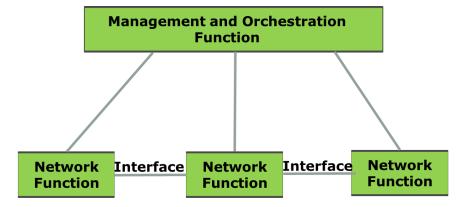


Figure 18: Management of Network Functions

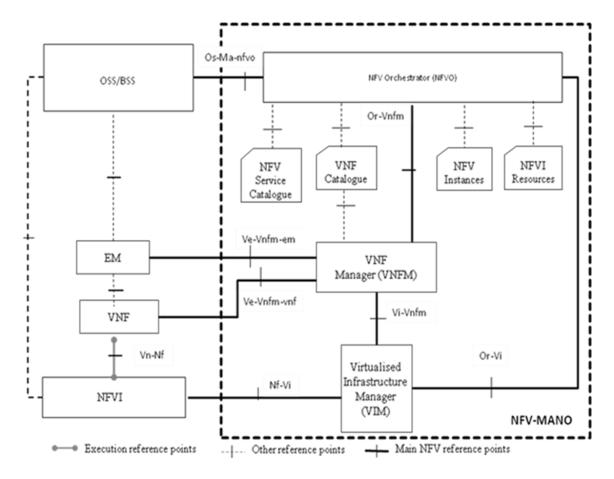


Figure 19: NFV Orchestrator interaction with EMS and OSS/BSS [6]

324325

322323

317318319

320



# 5. Mapping Between NFV and OCC Reference Architecture Constructs

Given there is no formal or informal descriptions of NFV interfaces in ETSI/NFV documents, it is difficult to map the constructs. Table 2 and the following figures describe the recommended mappings between NFV and OCC architectural constructs.

331	
332	

326327

328

329

330

Architectural Construct	NFV Construct	OCC Construct
User Interface	(Vi-Ha)+(Vn-Nf)/VN	cSUI
VM Interface	(Vn-Nf)/VM	cSI
Container Interface	Container Interface	cSI
SWA-1	Software Architecture-1	cSI
Cloud Carrier-Cloud Provider Interface		cCcPI
Cloud Service Provider-Cloud Service		cSPcSPI
Provider Interface		
Connection between Users or between a	VNF Forwarding Graph	cSC
User and VM or between VMs		
Connection Termination Point		cSCTP

333

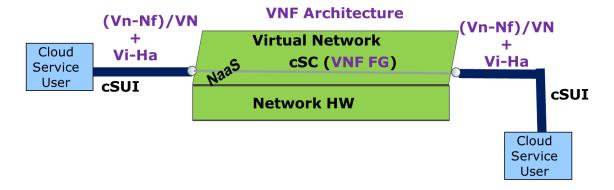
Table 2: Mapping between OCC and NFV Constructs

334335336

NaaS and Cloud User interfaces to NaaS are depicted in Figure 20 using NFV constructs. Since cSUI represents both physical and logical components of NaaS, we map the cSUI to the combination of Vi-Ha and (Vn-Nf)/VN.

338339

337



340341342

Figure 20: Cloud User Interface-NaaS architecture with NFV constructs

343344345

346

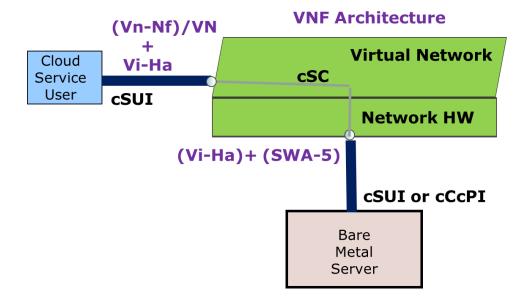
347

348

Cloud user access to bare metal servers over NaaS is depicted in Figure 21, using NFV constructs. As described in [1], bare metal servers can interface to NaaS using cSUI or cCcPI. We map this interface to the combination of Vi-Ha and SWA-5 since this interface can support both physical and logical components.

351

352



353 354

Figure 21: Bare Metal Server Interface and Naas

355 356

357 358 359

360 361 362

363 364 Cloud user access to VMs over NaaS is depicted in Figure 22, using NFV constructs where Vi-Ha is defined as reference point interfacing the virtualization layer to the hardware resources including compute and storage [3]. The functions of the cSI interface which is an equivalent of (Vn-NF)/VM ride over cCcPI. Although VNF forwarding may map to cSC, there is no concept of connection termination point in VNF. The End Point as depicted in [4] does not correspond to a connection termination point. The End Point is more like a device such as Customer Edge (CE) or an NE.

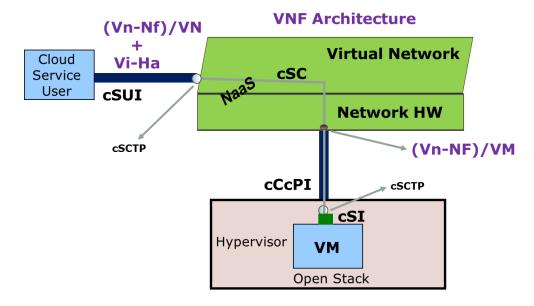


Figure 22: VM access over NaaS

368369

# 6. Basic NFV Components of OCC Architecture

370371

372

373

374

Neither NFV nor SDN architectures define necessary interfaces between a network and its user, between service providers, between a Cloud Provider and Cloud carrier. Furthermore they do not have connection and connection termination concepts as mentioned before. However, it is possible to build these Cloud Services components using VNFs and infrastructure components.

375376

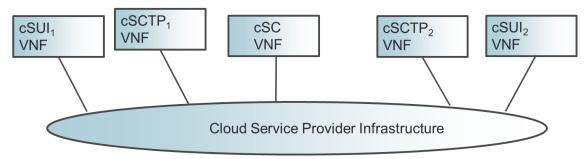
# 6.1. NFV Components of cSUI

377378379

VNF and infrastructure components of a point-to-point cSC and its cSCTPs in support of cloud services between two cSUIs are depicted in Figure 23.

381 382

## **VNF Implementation**



384385386

383

Figure 23: VNFs and Infrastructure for cSC and cSCTP

387 388

In Table 3, possible NFV and infrastructure components of cSUI are identified.

390391

cSUI attributes	Descriptions and Recommended Val- ues of Attributes	Component of VNF or Infra- structure or Both
cSUI Id	Arbitrary text string to identify cSUI	VNF
Tenant ID	ID of a tenant that cSUI belongs to, If an overlay network is supported at this interface.  It is globally unique in a given domain and based on virtual network (VN) identifier such as VLAN IDs. Multiple VN identifiers can belong to a tenant [38].	VNF
NaaS Identifier		VNF
Physical Interface		



Ethomat if armout d	amand made about		Infrastructure
Ethernet if supported	speed, mode, physical medium		Infrastructure
	MAC Layer		Infrastructure
DOCSIS if supported	speed, mode, physi-		Infrastructure
B o colo il supporteu	cal medium		
EPON if supported	speed, physical me-		Infrastructure
	dium		
GPON if supported	speed, physical me-		Infrastructure
	dium		
WDM if supported	speed, physical		Infrastructure
	medium		
SONET/SDH if supported	speed, physical me-		Infrastructure
0 1 1 1 1 1	dium		T.C.
Optical Transport Network	speed, physical me-		Infrastructure
(OTN)  Maximum Transmission Unit (M	dium	> 1500 hystag	Both
Connection Multiplexing	110)	$\geq$ 1522 bytes Yes or No	Both
Maximum number of Connection	n Termination	1 es of No	Both
Points(or End Points)	i Termination		Dom
L2 Ethernet configuration attribu	ıtes		
MEF UNI Service attributes			VNF
for Ethernet Private Services			V1\1
in Table 11 of MEF 6.2			
MEF UNI L2CP Service At-			VNF
tributes for UTA in Table 18			V1\1
of MEF 45			
MEF UNI Service attributes			VNF
in Table 4 of MEF 6.2			V 1 V 1
MEF UNI L2CP Service At-			VNF
tribute for vNID Case A in			VINI
Table 23 of MEF 45			
MEF UNI L2CP Service At-			VNF
tribute for vNID Case B in			VINI
Table 26 of MEF 45			
			VNE
MEF UNI Service attributes for EPL in Table 7 of MEF			VNF
6.2			
MEF UNI Service attributes			VNF
			VING
in Table 4 of MEF 6.2			
MEF UNI Service attributes			
for EVPL in Table 10 of			
MEF 6.2			
MEF UNI Service attributes			VNF
in Table 4 of MEF 6.2			
<u> </u>	1	1	1



		<del>-</del>
MEF UNI Service attributes		
for EP-LAN in Table 13 of		
MEF 6.2		
MEF UNI Service attributes		VNF
in Table 4 of MEF 6.2		A LAI.
MEF UNI Service attributes		
for EVP-LAN in Table 16 of		
MEF 6.2		TDIE.
MEF UNI Service attributes		VNF
in Table 4 of MEF 6.2		
MEF UNI Service attributes		
for EP-Tree in Table 19 of		
MEF 6.2		
MEF UNI Service attributes		VNF
in Table 4 of MEF 6.2		
MEF UNI Service attributes		
for EVP-Tree in Table 22 of		
MEF 6.2		
Other L2 Protocols such as Point	-to-Point Protocol	Both
(PPP) and Point-to-Point Tunnel	ing Protocol (PPTP) if	
supported		
L3 attributes if L3 protocol such	as IP and/or MPLS	Both
is supported		
MPLS UNI attributes if MPLS	LSP ID, Pseudo-	Both
is supported	wire (PW) ID,	
	MTU, Ingress	
	Bandwidth Profile,	
	Egress Bandwidth	
	Profile, MPLS Link	
	Down, MPLS Link	
	Up, AIS, RDI, Lock	
ID-4 A 11	Status	XXXIII
IPv4 Address		VNF VNF
DSCP Marking IPv6 Address		VNF
IPv6 Address IPv4 VPN[31]		VNF
IPv6 VPN [32]		VNF
L4 attributes if L4 protocols		Both
such as Transmission Con-		Don
trol Protocol (TCP), User		
Datagram Protocol (UDP)		
and Stream Control Trans-		



1 (0 000)			
mission Protocol (SCTP) are			
supported			
L5 attributes if L5 protocols			Both
such as NFS, NetBios			
names, RPC and SQL are			
supported.			
L6 attributes if L6 protocols			Both
such as ASCII, EBCDIC,			
TIFF, GIF, PICT, JPEG,			
MPEG, MIDI are supported			
L7 attributes if L7 proto-			Both
cols/applications such as			2011
WWW browsers, NFS, SNMP,			
Telnet, HTTP, FTP are sup-			
ported.			
Operational State		Enabled or Disa-	VNF
		bled	
Admin State		Enabled or Disa-	VNF
1 10111111 2 0000		bled	, 1, 1
Interface Level Security		oled	
ACL (Access Control List) att	ributes		VNF
Packet Encryption			Both
Facket Encryption	IPSec Encapsulat-		Don
	ing Security Pay-		
	load (ESP) attrib-		
	utes		<u> </u>
	SSL VPN (Secure		Both
	Sockets Layer		
	Virtual Private		
	Network)		
Connection Authentication			
	IPSec Authentica-		VNF
	tion Header (AH)		
	attributes		
	TCP- Authentica-		VNF
	tion Option (TCP-		
	AO) attributes		
Service Level Security			
	Rate limiting for		Infrastructure
	DoS attacks: Rate		
	limiting of TCP		
	SYN packets and		
	ICMP/Smurf attrib-		
	utes.		
Dilli	Keys for API		
Billing			



Recurring Charges	VNF
Non-recurring	VNF
Charges	

**Table 3 :** VNF and Infrastructure Components of cSUI defined in [1]

392393394

# 6.2.NFV Components of cSC and cSCTPs

395 396

Table 4 and Table 5 identify possible NFV and infrastructure components of cSCTP and cSC.

cSCTP attributes		Descriptions and Recommended Val-	Component of VNF or Infra-
		ues of Attributes	structure or Both
cSCTP Id		Arbitrary text string to identify the cSCTP	VNF
cSUI Ids and cSI Ids <sup>3</sup>		Arbitrary string	VNF
cSC Id			VNF
Overlay Network Attributes	Virtual Access Point (VAP) Id		VNF
	NVE Interface Id	4 decimal digits	VNF
L2 Ethernet attributes			
MEF EVC per UNI Service attributes in Table 5 of MEF 6.2			Both
MEF EVC per UNI Service attributes for EPL Service in Table 8 of MEF 6.2			Both
MEF EVC per UNI Service attributes for EVPL Service in Table 11 of MEF 6.2			Both
MEF EVC per UNI Service attributes for EP-LAN Service in Table 14 of MEF 6.2			Both
MEF EVC per UNI Service attributes for EVP-LAN Service in Table 18 of MEF 6.2			Both
MEF EVC per UNI Service attributes for EP-Tree Service in Table 20 of MEF 6.2			Both
MEF EVC per UNI Service attributes for EVP-Tree Service in Table 23 of MEF 6.2			Both
MEF EPL Option 2 L2CP Processing Requirements in Table 8 of MEF 45			Both

<sup>&</sup>lt;sup>3</sup> cSUI Id and cSI Ids are included to identify cSUI and cSI that cSCTP is related to. The cSUI-cSCTP and cSI-cSCTP relationships maybe represented via association in the information model instead of an attribute of the cSCTP object.



MEF EPL Option 2 L2CP Processing			Both
Recommendations in Table 9 of MEF			Both
45			
Protection (via redundant cSCTP	1:1or 1+1		Both
on a different physical port of the			
same CE or different CE at cSUI,			
and on a different VM at cSI)			
L2 Ethernet SOAM attributes [25]			
Maintenance Entity Group			VNF
(MEG) Id			V 1 V 1
Maintenance End Point (MEP)			VNF
Id			, , , ,
MEP Level			VNF
L3 attributes if interface is L3			, , , ,
IPv4 Subnet Address			VNF
IPv6 Subnet Address			VNF
DSCP Mapping			VNF
Bandwidth Profile	CIR		Both
Build width 1 forme	CBS		Both
	EIR		Both
	EBS		Both
Protection (via redundant	1:1or 1+1		Both
cSCTP on a different port	1.101 111		2011
of the			
same CE or different CE			
providing			
the cSUI, and on a different			
VM of			
the application entity			
providing cSI)			VAID
LSP Label			VNF VNF
EXP Mapping		E 11 1 E 11 1	
Operational State		Enabled or Disabled	Infrastructure
Administrative State		Enabled or Disabled	VNF
cSCTP Level Security	TDG FGB		ADIE
Packet encryption	IPSec ESP		VNF
	SSL VPN		VNF
Connection Authentication	IPSec AH		VNF
	TCP-AO		VNF
Data confidentiality/privacy	Logical separation		Both
	of cSTPs, limiting		
	DoS and excessive		
	resource consump-		
	tion via rate limit-		
	ing		
t		1	



Service Level Security	Rate limiting of	Infrastructure
	DoS attacks and	
	excessive resource	
	consumption	

**Table 4 :** VNF and Infrastructure Components of of cScTP defined in [1]

cSC attributes		Descriptions and recom-	Component of VNF or
		mended values of attributes	Infrastructure or Both
cSC Id		Arbitrary text string to identify the cSC	VNF
List of associated cSCTP Ids <sup>4</sup>			VNF
Overlay Network Attributes	VNI ID	•	VNF
Type	Point-to-Point		VNF
	Point-to- Multipoint		VNF
	Multipoint-to- Multipoint		VNF
Protection	1:1 or 1+1	cSC needs to be protected for path protection	VNF
L2 Ethernet connection attribu	ites [71,47]		
MEF EVC Service attributes			Both
in Table 6 of MEF 6.2			
MEF EVC Service attributes			Both
of EPL in Table 9 of MEF			
6.2			
MEF EVC Service attributes			Both
of EVPL in Table 12 of			
MEF 6.2			
MEF EVC Service attributes			Both
of EP-LAN in Table 15 of			
MEF 6.2 MEF EVC Service attributes			Both
of EVP-LAN in Table 18 of			Both
MEF 6.2			
MEF EVC Service attributes			Both
of EP-Tree in Table 21 of			Dotti
MEF 6.2			
MEF EVC Service attributes			Both
of EVP-Tree in Table 24 of			
MEF 6.2			
MEF EVC Perfromance			Both
attributes and Parameters			

<sup>&</sup>lt;sup>4</sup> cSCTP Ids are included to identify termination points associated with this cSC. This cSC-cSCTP relationship may be rep-resented via association in the information model instead of an attribute of the cSC object..



per CoS in Table 25 of MEF 6.2			
L3 connection attributes (if supported)	Service Level Objectives (SLOs)	Delay, jitter, loss	Both
	MTU		Both
	Туре	Point-to-Point, Multipoint- to-Multipoint, Rooted Mul- tipoint	VNF
Connection Start Time	Connection Start Time		VNF
rameter to indicate the accepta	Connection Start Interval (Start Interval parameter to indicate the acceptable interval after the Start Time during which the service attribute modifications can be made.) [80]		VNF
Connection Duration		Specified in days, minutes or seconds.	VNF
Connection Period		Specified in daily, weekly or monthly	VNF
Operational State		Enabled or Disabled	Infrastructure
Administrative State		Enabled or Disabled	VNF
Billing Options	Monthly, Hourly		VNF

**Table 5 :** VNF and Infrastructure Components of cSC defined in [1]

# 6.3. NFV Components of cSI

VNF and infrastructure components of a point-to-point cSC and its cSCTPs in support of cloud services between a cSUI and a cSI are depicted in Figure 24.

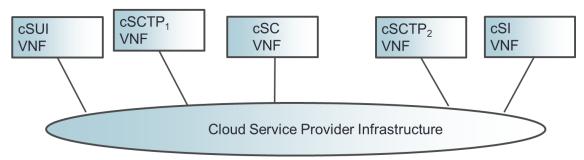
402

403 404

405 406

407

## **VNF Implementation**



411412413

410

Figure 24: VNF and Infrastructure Components of cSC between cSUI and cSI

414415

Table 6 identifies possible NFV and infrastructure components of cSI.

cSI attributes	Descriptions and Recommended Values of Attribute	Component of VNF or Infrastructure or Both
cSI Id	Arbitrary text string to identify cSI	VNF
VM ID	http://www.ietf.org/id/draft-ietf-opsawg-vmm-mib-00.txt [53] uses 128-bit Universally Unique ID (UUID) [36] as a unique identifier for a VM in an administrative region.	VNF
List of NaaS	List of NaaS employing this VM or server (i.e. application entity is shared or dedicated)	VNF
Interface Protection	1+1 or 1:1 or None	
Connection Multiplexing	Yes or No	
Maximum number of Connection Termination Points		Both
L2 Ethernet configuration attributes[17, 71, 66]		
MEF UNI Service attributes in Table 4 of MEF 6.2		Both
MEF UNI Service attrib-		Both



utes for EPL in Table 7		
of MEF 6.2		
MEF UNI Service attrib-		Both
utes in Table 4 of MEF		Dom
6.2		
MEF UNI Service attrib-		
utes for EVPL in Table 10		
of MEF 6.2		
MEF UNI Service attrib-		Both
utes in Table 4 of MEF 6.2		
MEF UNI Service attrib-		
utes for EP-LAN in Table		
13 of MEF 6.2		
MEF UNI Service attrib-		Both
utes in Table 4 of MEF 6.2		DOM
utes III Table 4 Of MEF 6.2		
MEETINI C. 1 4 1		
MEF UNI Service attrib-		
utes for EVP-LAN in Table		
16 of MEF 6.2		
MEF UNI Service attrib-		Both
utes in Table 4 of MEF		
6.2		
MEF UNI Service attrib-		
utes for EP-Tree in Table		
19 of MEF 6.2		
MEF UNI Service attrib-		Both
utes in Table 4 of MEF		
6.2		
MEF UNI Service attrib-		
utes for EVP-Tree in Ta-		
ble 22 of MEF 6.2		
Other L2 Protocols such as		Both
Point-to-Point Protocol		
(PPP) and Point-to-Point		
Tunneling Protocol (PPTP)		
if supported		
VM Protection (if support-	This would be redun-	Both
ed)	dant VM or redundant	
<b>'</b>	server or redundant	
	resource offering the	
	service	
	SCIVICC	l .



VM Portability <sup>5</sup>		Yes or No	VNF
L3 attributes if L3 protocol such as IP and MPLS are			
supported			
MPLS UNI attributes	LSP ID, PW ID, MTU,		Both
[49] if MPLS is support-	Ingress Bandwidth		
ed	Profile, Egress Band-		
	width Profile, MPLS Link Down, MPLS		
	Link Up, AIS, RDI,		
	Lock Status		
IPv4 Address	Lock Status		VNF
DSCP Marking			Infrastructure
IPv6 Address			VNF
IPv4 VPN			VNF
IPv6 VPN			VNF
NAT			VNF
L4 attributes if L4 protocols			VNF
Control Protocol (TCP), User			
(UDP) and Stream Control T	ransmission Protocol		
(SCTP) are supported	22111 (TICD)		VAID
General Ports	32111 (TCP)		VNF
	9427 (TCP)		VNF
	) <del>1</del> 27 (1C1)		V 1 (1
PCoIP (PC over IP) Ports	50002(TCP/UDP)		VNF
	4172 (TCP/UDP)		VNF
RDP (Remote Desktop	3389 (TCP)		VNF
Protocol) Ports			
Connection server Ports	4001 (TCP)		VNF
L5 attributes if L5 protoco			VNF
Bios names, RPC and SQL			
L6 attributes if L6 protoco			VNF
EBCDIC, TIFF, GIF, PICT	I, JPEG, MPEG,		
MIDI are supported			V 10 170
L7 attributes if L7 protocols/applications such			VNF
as WWW browsers, NFS, SNMP, Telnet, HTTP,			
FTP are supported.		F 11 1 B: 11 1	<b>7</b> C
Operational State		Enabled or Disabled	Infrastructure
Admin State		Enabled or Disabled	VNF
Security			

<sup>&</sup>lt;sup>5</sup> VM Portability is being able to move VM to another site/zone or moving data/applications from one server to another. A VM could be moved across different hypervisors, such as VMware's ESXi, the Apache Software Foundation's Xen, Microsoft's Hyper-V and the open source KVM (kernel-based virtual machine).



SSL (Secure Socket Layer) Termination	Terminating SSL traffic for services such as load balancer	VNF
ACL		VNF
Packet encryption	IPSec ESP (Encapsulating Security Payload)	Both
	SSL VPN	VNF
Connection Authentication	IPSec AH	VNF
	TCP-AO	VNF
Service Level Security	Rate limiting of DoS attacks and excessive resource consumption	Both
Data confidentiali- ty/privacy	Prevent tenants from eavesdropping on each other via logi- cal separation	VNF
Session Layer Security	REST API (Representational State Transfer Application Programming Interface) over SSL (Secure Sockets Layer) /TLS (Transport Layer Security) API keys	VNF
Billing	Recurring Charges	VNF
0	Non-recurring Charges	VNF

**Table 6 :** VNF and Infrastructure Components of cSI defined in [1]

420 421

418

419

# 6.4.NFV Components of cSC Crossing two cSPs

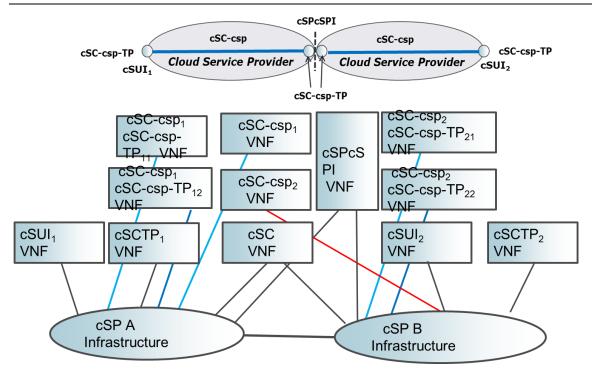
422 423 424

VNF and infrastructure components of a point-to-point cSC crossing two cSPs and its cSCTPs in support of cloud services between two cSUIs are depicted in Figure 25.

425 426 427

.\_,





428 429 430

Figure 25: VNFs for cSC-csp and cSC-csp-TP

431 432

Table 7 identifies possible NFV and infrastructure components of cSPcSPI.

cSPcSPI attributes		Descriptions and	Component of
		Recommended At-	VNF or Infra-
		tribute Values	structure or
			Both
cSPcSPI Id		Arbitrary text string	VNF
		to identify the	
		cSPcSPI	
Name of cSPs interfacing each other		Arbitrary text string	VNF
		to identify the cSP	
Physical Interface		<u>.                                      </u>	
L2 Ethernet			Infrastructure
	speed, mode, phys-		
	ical medium		
	MAC Layer		Infrastructure
DOCSIS if supported	speed, physical me-		Infrastructure
	dium		
EPON if supported	speed, physical me-		Infrastructure
^*	dium		
GPON if supported	speed, physical me-		Infrastructure
••	dium		
WDM if supported	speed, physical me-		Infrastructure



	dium		
SONET/SDH if supported	speed, physical medium		Infrastructure
Optical Transport Network (OTN)			Infrastructure
MTU		≥ 1522 bytes	<u>Both</u>
Connection Multiplexing		Yes or No	VNF
Maximum number of Connection Termina	ation Points (or End		VNF
Points)			
L2 Ethernet configuration attributes[20,22	2]		
MEF ENNI Service attributes in Table 2 of MEF 26.1			Both
MEF ENNI L2CP Service Attributes for Access EPL in Table 17 of MEF 45			Both
MEF ENNI L2CP Service Attributes for UTA in Table 20 of MEF 45			Both
MEF ENNI L2CP Service Attributes for			Both
vNID Case A in Table 25 of MEF 45			D 4
MEF ENNI L2CP Service Attributes for vNID Case B in Table 28 of MEF 45			Both
L2 Ethernet SOAM attributes [25]			
Maintenance Entity Group (MEG) Id			VNF
Maintenance End Point (MEP) Id			VNF
MEP Level			VNF
Maintenance Intermedi-			VNF
ate			
Point (MIP) Id			
LAG MEG			Both
LAG Link MEG			VNF
Operator MEG			VNF
Other L2 Protocols such as Point-to-Point Protocol (PPP) and Point-to-Point Tunneling Protocol (PPTP) if support-			Both
ed	` / 11		
L3 attributes if L3 protocol such as IP	and MPLS are sup-		
ported	Р		
MPLS UNI attributes if MPLS is su-	LSP ID, PW ID,		Both
ported	MTU, Ingress		
1	Bandwidth Pro-		
	file, Egress		
	Bandwidth Pro-		
	file, MPLS Link		
	Down, MPLS		
	Link Up, AIS,		
	RDI, Lock Status		



Fast Reroute		Both
NAT		VNF
IPv4 Subnet Address		VNF
IPv6 Subnet Address		VNF
DSCP Marking		Infrastructure
IPv4 VPN [31]		VNF
IPv6 VPN [32]		VNF
Security between cSPs (if supported)	_	
ACL		VNF
Packet encryption	IPSec ESP	Both
	SSL VPN	VNF
Connection Authentication	IPSec AH	VNF
Service Level Security	Rate limiting of	Both
-	DoS attacks and	
	excessive re-	
	source consump-	
	tion	

435

Table 7: VNF and Infrastructure Components of cSPcSPI defined in [1]

436 437

Table 8 identifies possible NFV and infrastructure components of cSC-csp-TP.

cSC-csp-TP attributes		Descriptions and Recommended Val- ues of Attributes	Component of VNF or Infra- structure or Both
cSC-csp-TP Id		Arbitrary text string to identify the cSC-csp-TP	VNF
cCScSPI Ids			VNF
Overlay Network Attributes	Virtual Access Point (VAP) Id		VNF
	NVE Interface Id	4 decimal digits	VNF
L2 Ethernet attributes			
MEF OVC End Point per ENNI Ser-			Both
vice Attributes in Table 17 of MEF			
26.1			
MEF OVC End Point per UNI Service			Both
Attrib-utes in Table 18 of MEF 26.1			
MEF OVC L2CP Service Attributes			Both
for Access EVPL in Table 13 of MEF			
45			
MEF OVC L2CP Service Attributes			Both
for Access EPL in Table 16 of MEF 45			
MEF OVC L2CP Service Attributes			Both



for LITA in Table 10 of MEE 45		T	T
for UTA in Table 19 of MEF 45 MEF OVC L2CP Service Attributes			Doth
for vNID Case A in Table 24 of MEF			Both
45			
OVC L2CP Service Attributes for			Both
vNID Case B in Table 27 of MEF 45			Dom
Protection (via redundant cSC-	1:1or 1+1		Both
csp-TP on a different port of the	1.101 1+1		Both
same cSPcSPI Gateway			
MEF OVC End Point per ENNI Ser-			Both
vice Attributes in Table 17 of MEF			Dom
26.1			
MEF OVC End Point per UNI Service			Both
Attrib-utes in Table 18 of MEF 26.1			
L2 Ethernet SOAM attributes [25]	l		VNF
Maintenance Entity Group			VNF
(MEG) Id			
Maintenance End Point (MEP)			
Id			
MEP Level			
Maximum Number of MEPs			VNF
Maintenance Intermediate			VNF
Point (MIP) Id			
L3 attributes if interface is L3			VAID
IPv4 Subnet Address			VNF
IPv6 Subnet Address			VNF
DSCP Mapping	CVP.		Both
Bandwidth Profile	CIR		Both
	CBS		Both
	EIR		Both
Dustaction (via nadam dant	EBS 1:1or 1+1		Both Both
Protection (via redundant	1:101 1+1		DOIII
cSCTP on a different port of the			
same cSPcSPI Gateway			
LSP Label			
EXP Mapping		E. 11.1 . D' 11.1	
Operational State		Enabled or Disabled	VAIC
Administrative State		Enabled or Disabled	VNF
cSC-csp-TP Level Security	IDG EGD		VAIE
Packet encryption	IPSec ESP		VNF
	SSL VPN		VNF
Connection Authentication	IPSec AH		VNF
	TCP-AO		VNF
Service Level Security	Rate limiting of		VNF
	DoS attacks and		
	limiting excessive		



	resource consumption	
Data confidentiality/privacy	Preventing eaves- dropping between cSC-csp-TPs via logical separa- tion.	Infrastructure

**Table 8:** VNF and Infrastructure Components of cSC-csp-TP defined in [1]

441442

440

# 7. Summary of Software-Defined Networking (SDN) Architecture

443444445

446

447

448

Software-Defined Networking (SDN) is defined by ONF as an emerging architecture that is dynamic, manageable, cost-effective, and adaptable [10]. This architecture decouples the network control and forwarding functions (Figure 26) enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services.

449450451

Abstracting the control plane from the network elements allows network-platform-specific characteristics and differences that do not affect services to be hidden. In addition, applications can request needed resources from the network via interfaces to the control plane.

453454455

456

452

ITU-T keeps the ONF layer separation and adds orchestration between application layer and control layer as depicted in Figure 27 to provide automated control and management of network resources and coordination of requests from the application layer [11].

457458459

The IETF also keeps the ONF layer separation (Figure 28) and adds a management plane which is responsible for monitoring, configuring, and maintaining network devices, in parallel to control plane [12].

461 462 463



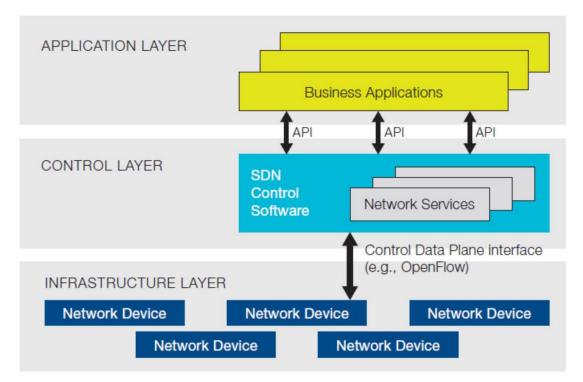


Figure 26: ONF SDN Architecture [10]

Application Application Layer

Application Control Interface

Application Support

Orchestration

Abstraction

Resource-Control Interface

Control Support

Data Transport and Processing

Replication Layer

Application Control Interface

Resource-Control Interface

Figure 27: ITU-T SDN Architecture [11]

464

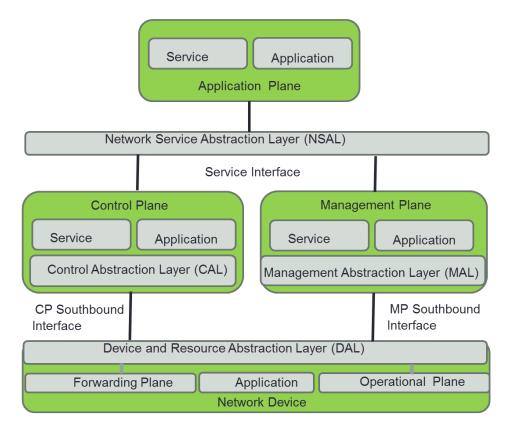
465

466

OCC 1.0

471 472

473



474 475 476

477

478

Figure 28: IETF SDN Architecture [12]

479

480 481

482 483 484

485 486

487

SDN building blocks are summarized in Figure 29. The application layer sits on top of services layers. The services layer interacts with an orchestrator which can interact with multiple controllers via a north bound API. The north bound interface between applications/services allows the applications to authenticate and learn of which objects they have authorization to manipulate, or to interact with objects belonging to controlling software. The SDN Orchestrator requests object models from each of the controlling software which is responsible for managing and manipulating them. The Southbound API provides abstraction for the controller to manage the devices in its domain.

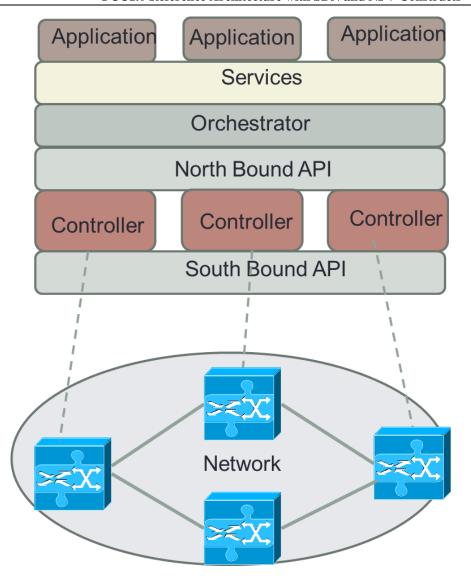


Figure 29: SDN Building Blocks [7]

# 8. OCC Management Architecture Basic Blocks

authorized to modify any of the information contained herein.

A high level management architecture is depicted in Figure 30 and Figure 31. Applications are expected to be mapped to services via a Cloud Services Catalog. For example, a voice call application between two users can be mapped to an Ethernet Virtual Private Line (EVPL) in H category [8]. The Cloud Orchestrator configures the EVPL between two users by translating this request to appropriate commands to NFV Orchestrator and Controllers via "North Bound API".

488 489

490

491

492 493

494

495

496



The NFV Orchestrator is expected to perform service chaining of VNFs and infrastructure components associated with virtualized Network Elements (NEs) while Controllers automate provisioning of non-virtualized components of the network. It is possible to have non-SDN NEs in the network. They will be managed by Element Management Systems (EMSs).

503504505

506

507

508

509

510

511

512

513

514

515

516

517

518

500

501

502

The Cloud Orchestrator may perform Life Cycle Service Orchestration (LSO) as described in [9] for each service ordered and provisioned via User Portal and Operation Support System/Billing Support System (OSS/BSS). Some of the LSO functionalities are as depicted in Figure 32:

- Market Analysis and Product Strategy
- •Service and Resource Design
- •Launch products
- Marketing Fulfillment Response
- •Sale Proposal and Feasibility
- •Capture Customer Order
- Service Configuration & Activation
- •End-to-End Service Testing
- •Service Problem Management
- •Service Quality Management
- •Billing and Revenue Management
- •Terminate Customer Relationship

519520521

522

523

524

525

In Figure 30, a Cloud Orchestrator performs Life Cycle Orchestration for Cloud services by a Cloud Service Operator. On the other hand, in Figure 31 where multiple operators are involved in providing cloud services, multiple Cloud Orchestrators might perform Life Cycle Orchestration. In this case, a Cloud Orchestrator of the Cloud Service Provider which is responsible from the end-to-end service [1] is expected to perform Life Cycle Orchestration end-to-end.

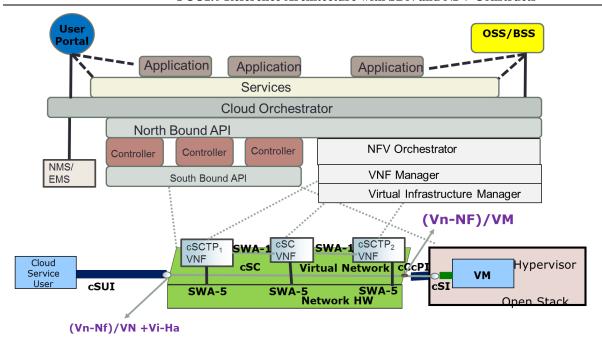
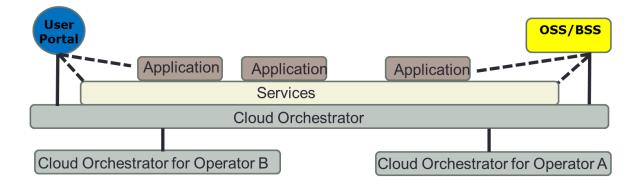


Figure 30: Cloud Services Management with Life Cycle Orchestration

532533



534535536

Figure 31: Management of Cloud Services provided by multiple Cloud Service Operators

537538539

540

541

The management architectures and distribution of management functionalities among layers in Figure 30 and Figure 31 are examples. Further architectural details need to be worked by OCC Technical Committee.

542543544

545

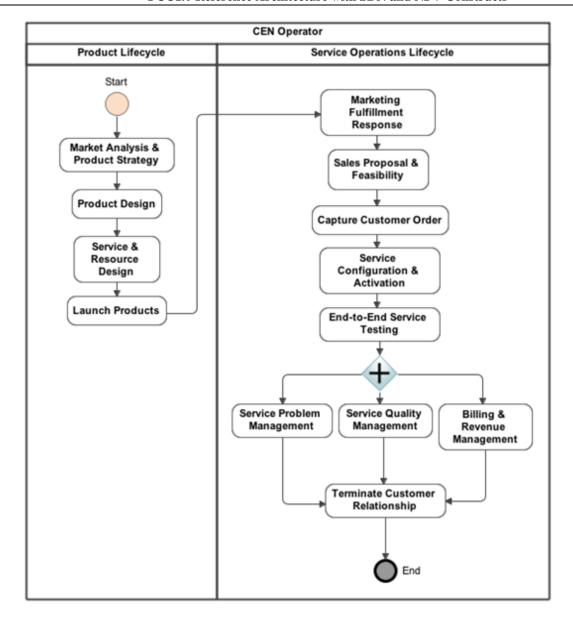


Figure 32: Product and Service Operations Lifecycle Stages [9]

550551

552

555

556

557

549

## References

- 553 [1] OCC, "OCC 1.0 Reference Architecture", December, 2014. 554 [2] Draft ETSI GS NFV-INF V0.3.1 (2014-05), "Network Fund
  - [2] Draft ETSI GS NFV-INF V0.3.1 (2014-05), "Network Functions Virtualisation; Infrastructure Architecture; Architecture of the Hypervisor Domain"
  - [3] DGS NFV-INF003 V0.34 (2014-11-18), "Network Functions Virtualisation; Part 1:Infrastructure Architecture; Sub-Part 3: Architecture of Compute Domain"



561

562

563

564

565

566

567

568

569

570

571

572

573

574

575

576

577

578

579

580

581

582

583

584

585

586

587

588

589

591

592

597

598

- 558 [4] Draft ETSI GS NFV-INF 001 V0.3.12 (2014-11), "Network Functions Virtualisation; Infrastructure Overview"
  - [5] Draft ETSI GS NFV-SWA 001 v0.2.4 (2014-11), "Network Functions Virtualisation; Virtual Network Functions Architecture"
  - [6] ETSI GS NFV-MAN 001 v1.1.1 (2014-12), Network Functions Virtualisation (NFV); Management and Orchestration
  - [7] M. Toy. "Cable Networks, Services and Management", J. Wiley-IEEE Press, 2015.
  - [8] MEF 23.1, Carrier Ethernet Class of Service Phase 2, January 2012.
  - [9] MEF 50, Carrier Ethernet Service Lifecycle Process Model, December 2014.
  - [10] ONF (Open Networking Foundation), "Software-Defined Networking: The New Norm for Networks", ONF White Paper, April 13, 2012.
  - [11] ITU-Y Y.3300, "Framework of software-defined networking", 6/2014.
  - [12] RFC7426, "Software-Defined Networking (SDN): Layers and Architecture Terminology", January 2015.
    - [13] National Institute of Standards and Technologies (NIST) Special Publication 500-291, NIST Cloud Computing Roadmap, July 2013
    - [14] MEF 10.3 Ethernet Services Attributes Phase 3, October 2013.
    - [15] IEEE Std. 802.1Q-2011, Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks (PDF; 6.0 MiB). ISBN 978-0-7381-6708-4.
    - [16] MEF 4 Metro Ethernet Network Architecture Framework Part 1: Generic Framework, May 2004.
    - [17] RFC2474, K. Nichols, et al., Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers, December 1998
    - [18] ISO/IEC 8802-2:1998, Information technology Telecommunications and information exchange between systems Local and metropolitan area networks Specific requirements Part 2: Logical link control.
    - [19] MEF 6.2 Ethernet Service Definitions Phase 3, August 2014.
    - [20] MEF 23.1 Class of Service Phase 2 Implementation Agreement
    - [21] MEF 50, Carrier Ethernet Service Lifecycle Process Model, December 2014.
  - [22] MEF 23.1, Class of Service Phase 2 Implementation Agreement, January 2012.
  - [23] RFC 792, INTERNET CONTROL MESSAGE PROTOCOL, September 1981.
    - [24] RFC 4303, IP Encapsulating Security Payload (ESP), December 2005.
- 590 [25] RFC 6690, Constrained RESTful Environments (CoRE) Link Format, August 2012.
  - [26] RFC 5925, The TCP Authentication Option, June 2010.
  - [27] RFC 793, TRANSMISSION CONTROL PROTOCOL, September 1981.
- 593 [28] RFC 5246, The Transport Layer Security (TLS) Protocol Version 1.2, August 2008.
- [29] RFC 3031, Multiprotocol Label Switching Architecture, January 2001.
- 595 [30] GS NFVINF 0007 v0.3.1 (2013-11-15), Network Function Virtualisation Infrastructure Architecture: Interfaces and Abstractions.
  - [31] RFC 4447, Pseudowire Setup and Maintenance Using the Label Distribution Protocol (LDP), April 2006
- [32] ETSI GS NFV-INF 007 V1.1.1 (2014-10) Network Functions Virtualisation (NFV); Infrastructure; Methodology to describe Interfaces and Abstractions.