1	
	OpenCloud connect
2 3	connect
4	Technical Specification
5	OCC 1.0
6	
7	
8	
9	OCC 1.0 Reference Architecture with SDN and
10	NFV Constructs
11	
12	
13	
14	
15	August, 2015
16	

- 17
- 18 Disclaimer
- 19

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49

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1. ist of Contributing Members ii 1. Introduction 1 2. Terminology and Acronyms 1 3. Summary of OCC 1.0 Architecture 5 4. Summary of NFV Architecture 11 5. Mapping Between NFV and OCC Reference Architecture Constructs 16 6. Basic NFV Components of OCC Architecture 19 6.1. NFV Components of cSUI 19 6.2. NFV Components of cSC and cSCTPs 23 6.3. NFV Components of cSI 26 6.4. NFV Components of cSC crossing two cSPs 30 7. Summary of Software-Defined Networking (SDN) Architecture 35 8. OCC Management Architecture Basic Blocks 38 8. References 41 6.2 Figure 1: Cloud Service Actors 5 7. Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 7 7. Figure 4: cSC between two Cloud Provider entities. 7 7 7. Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 7. Figure 6: Protocol Stacks that can be supported at external interfaces. 8 7. Figure 7: Multiple VM sharing a cSC. 9 9 7. Figure 11: VM Interface 9	52		Table of Contents	
55 2. Terminology and Acronyms	53	List	of Contributing Members	ii
56 3. Summary of OCC 1.0 Architecture 5 57 4. Summary of NFV Architecture 11 58 57 4. Summary of NFV Architecture 16 59 6. Basic NFV Components of OCC Architecture. 19 60 6.1 NFV Components of CSU 19 61 0.1 NFV Components of cSC and cSCTPs. 23 62 6.3 NFV Components of cSC crossing two cSPs 26 63 0.1 NFV Components of cSC Crossing two cSPs 30 64 7. Summary of Software-Defined Networking (SDN) Architecture. 35 65 8. OCC Management Architecture Basic Blocks 38 66 Elist of Figures 5 67 Figure 1: Cloud Service Actors 5 68 Cloud Provider and Cloud Carrier belong to two different Operators 7 69 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8	54	1.	Introduction	1
57 4. Summary of NFV Architecture 11 58 Mapping Between NFV and OCC Reference Architecture Constructs 16 59 6. Basic NFV Components of OCC Architecture 19 60 6.1. NFV Components of cSUI 19 61 NFV Components of cSC and cSCTPs 23 62 6.3. NFV Components of cSI 26 63 6.4. NFV Components of cSC crossing two cSPs 30 64 7. Summary of Software-Defined Networking (SDN) Architecture 35 65 8. OCC Management Architecture Basic Blocks 38 66 Figure 1: Cloud Service Actors 5 7 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 7 7 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators 7 7 7 Figure 6: Protocol Stacks that can be supported at external interfaces 8 8 76 Figure 7: Multiple VM sharing a CSC. 9 9 9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 9 9 77 Figure 11: VM Interface 10 11 11 <	55	2.	Terminology and Acronyms	1
5. Mapping Between NFV and OCC Reference Architecture Constructs 16 5. Basic NFV Components of OCC Architecture 19 6. Instruction of the experiment of the experim	56	3.	Summary of OCC 1.0 Architecture	5
59 6. Basic NFV Components of OCC Architecture 19 60 6.1. NFV Components of cSUI 19 61 0.1. NFV Components of cSC and cSCTPs. 23 62 0.1. NFV Components of cSC and cSCTPs. 23 63 0.1. NFV Components of cSC crossing two cSPs 26 64 NFV Components of cSC Crossing two cSPs 30 64 7. Summary of Software-Defined Networking (SDN) Architecture 35 65 8. OCC Management Architecture Basic Blocks 38 66 References 41 67 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 6 71 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud applications. 7 74 Figure 6: Protocol Stacks that can be supported at external interfaces 8 75 Figure 7: Multiple VM sharing a cSC. 9 76 Figure 8: VMs supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 77 Figure 9: Cloud Service Connection Types	57	4.	Summary of NFV Architecture	. 11
60 6.1. NFV Components of cSUI 19 61 6.2. NFV Components of cSC and cSCTPs. 23 62 6.3. NFV Components of cSI 26 63 6.4. NFV Components of cSC Crossing two cSPs 30 64 7. Summary of Software-Defined Networking (SDN) Architecture. 35 65 8. OCC Management Architecture Basic Blocks 38 66 References 41 67 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 6 71 Figure 4: CSC between two Cloud Provider entities. 7 73 Figure 5: Two Cloud Service Providers collectively providing Cloud Services 8 74 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 8: VM supporting multiple CSL, virtual network interface controllers (vNICs), MACs, 9 75 Figure 9: Cloud Service Connection Types 11 76 Figure 11: VM Interface 12 77 Figure 11: VM Interface 12 78 Figure 12: Bare Metal Server Interface [2] 13	58	5.	Mapping Between NFV and OCC Reference Architecture Constructs	16
61 6.2. NFV Components of cSC and cSCTPs	59	6.	Basic NFV Components of OCC Architecture	19
62 6.3. NFV Components of cSI 26 63 6.4. NFV Components of cSC Crossing two cSPs 30 64 7. Summary of Software-Defined Networking (SDN) Architecture. 35 65 8. OCC Management Architecture Basic Blocks 38 66 References 41 67 64 List of Figures 68 List of Figures 5 69 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 5 71 resources), that belong to one Operator, providing cloud applications. 6 72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. 7 73 Figure 5: Two Cloud Service Provider collectively providing Cloud Services. 8 74 Figure 5: Two Cloud Service Provider scillectively providing Cloud Services. 8 74 Figure 6: Protocol Stacks that can be supported at external interfaces. 8 75 Figure 8: VM supporting multiple CSIs, virtual network interface controllers (vNICs), MACs, 9 74 Figure 9: Cloud Service Connection Types. 10 75 Figure 10: Network Layering and inte	60	6.1.	NFV Components of cSUI	19
63 6.4. NFV Components of cSC Crossing two cSPs 30 64 7. Summary of Software-Defined Networking (SDN) Architecture. 35 65 8. OCC Management Architecture Basic Blocks 38 66 References 38 67 Elist of Figures 38 68 List of Figures 5 69 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 5 70 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators 6 71 Figure 4: cSC between two Cloud Provider entities 7 73 Figure 5: Two Cloud Service Providers collectively providing Cloud Services 8 74 Figure 6: Protocol Stacks that can be supported at external interfaces 8 75 Figure 7: Multiple VM sharing a cSC 9 76 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 79 Figure 9: Cloud Service Connection Types 11 71 Figure 10: Network Layering and interface of NFV 12 72 Figure 11: VM Interface 12 7	61	6.2.	NFV Components of cSC and cSCTPs	23
64 7. Summary of Software-Defined Networking (SDN) Architecture	62	6.3.	NFV Components of cSI	26
65 8. OCC Management Architecture Basic Blocks 38 66 References 41 67 68 List of Figures 69 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 5 71 resources), that belong to one Operator, providing cloud applications. 6 72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. 7 73 Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 74 Figure 6: Protocol Stacks that can be supported at external interfaces 8 75 Figure 7: Multiple VM sharing a cSC. 9 76 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 78 virtual networks (VNs) and IP addresses. 10 79 Figure 9: Cloud Service Connection Types 11 80 Figure 10: Network Layering and interface of NFV 12 81 Figure 11: VM Interface 12 82 Figure 12: Bare Metal Server Interface [2] 13	63	6.4.	NFV Components of cSC Crossing two cSPs	30
66 References 41 67 List of Figures 68 List of Figures 69 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 6 71 resources), that belong to one Operator, providing cloud applications. 6 72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. 7 73 Figure 4: cSC between two Cloud Provider entities. 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 7: Multiple VM sharing a cSC 9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 78 virtual networks (VNs) and IP addresses 10 79 Figure 9: Cloud Service Connection Types 11 70 Figure 10: Network Layering and interface of NFV 12 71 Figure 11: VM Interface 12 72 Figure 12: Bare Metal Server Interface [2] 13	64	7.	Summary of Software-Defined Networking (SDN) Architecture	35
67 List of Figures 68 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 5 71 resources), that belong to one Operator, providing cloud applications. 6 72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. 7 73 Figure 4: cSC between two Cloud Provider entities. 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 7: Multiple VM sharing a cSC 9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 78 virtual networks (VNs) and IP addresses. 10 79 Figure 10: Network Layering and interface of NFV 12 81 Figure 11: VM Interface 12 82 Figure 12: Bare Metal Server Interface [2] 13	65	8.	OCC Management Architecture Basic Blocks	38
68 List of Figures 69 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 71 resources), that belong to one Operator, providing cloud applications. 6 72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. 7 73 Figure 4: cSC between two Cloud Provider entities. 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 9 78 virtual networks (VNs) and IP addresses. 10 79 Figure 10: Network Layering and interface of NFV. 12 81 Figure 11: VM Interface 12 82 Figure 12: Bare Metal Server Interface [2] 13	66	Refe	rences	41
69 Figure 1: Cloud Service Actors 5 70 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage 71 resources), that belong to one Operator, providing cloud applications. 6 72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. 7 73 Figure 4: cSC between two Cloud Provider entities. 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 7: Multiple VM sharing a cSC 9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 79 Figure 9: Cloud Service Connection Types 11 70 Figure 10: Network Layering and interface of NFV 12 71 Figure 11: VM Interface 12 72 Figure 12: Bare Metal Server Interface [2] 13			List of Figures	
 Figure 2: Virtual resources (i.e. VMs) and Physical resources (i.e. computing and storage resources), that belong to one Operator, providing cloud applications. Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. Figure 4: cSC between two Cloud Provider entities. Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 Figure 6: Protocol Stacks that can be supported at external interfaces 8 Figure 7: Multiple VM sharing a cSC 9 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, virtual networks (VNs) and IP addresses. 10 Figure 10: Network Layering and interface of NFV 12 Figure 11: VM Interface 13 			-	_
71 resources), that belong to one Operator, providing cloud applications. 6 72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators. 7 73 Figure 4: cSC between two Cloud Provider entities. 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 7: Multiple VM sharing a cSC 9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 78 virtual networks (VNs) and IP addresses. 10 79 Figure 10: Network Layering and interface of NFV 12 81 Figure 11: VM Interface 12 82 Figure 12: Bare Metal Server Interface [2] 13		0		5
72 Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators 7 73 Figure 4: cSC between two Cloud Provider entities 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 7: Multiple VM sharing a cSC 9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 10 78 virtual networks (VNs) and IP addresses 10 79 Figure 9: Cloud Service Connection Types 11 80 Figure 10: Network Layering and interface of NFV 12 81 Figure 11: VM Interface 12 82 Figure 12: Bare Metal Server Interface [2] 13		0		6
73 Figure 4: cSC between two Cloud Provider entities. 7 74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services. 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces				
74 Figure 5: Two Cloud Service Providers collectively providing Cloud Services 8 75 Figure 6: Protocol Stacks that can be supported at external interfaces 8 76 Figure 7: Multiple VM sharing a cSC 9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, 9 78 virtual networks (VNs) and IP addresses 10 79 Figure 9: Cloud Service Connection Types 11 80 Figure 10: Network Layering and interface of NFV 12 81 Figure 11: VM Interface 12 82 Figure 12: Bare Metal Server Interface [2] 13				
75 Figure 6 : Protocol Stacks that can be supported at external interfaces .8 76 Figure 7: Multiple VM sharing a cSC .9 77 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, .10 78 virtual networks (VNs) and IP addresses .10 79 Figure 9: Cloud Service Connection Types .11 80 Figure 10: Network Layering and interface of NFV .12 81 Figure 11: VM Interface .12 82 Figure 12: Bare Metal Server Interface [2] .13		0		
 Figure 7: Multiple VM sharing a cSC		-		
 Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, virtual networks (VNs) and IP addresses. Figure 9: Cloud Service Connection Types. Figure 10: Network Layering and interface of NFV Figure 11: VM Interface Figure 12: Bare Metal Server Interface [2]. 				
 virtual networks (VNs) and IP addresses. Figure 9: Cloud Service Connection Types. Figure 10: Network Layering and interface of NFV Figure 11: VM Interface Figure 12: Bare Metal Server Interface [2]. 				
 Figure 9: Cloud Service Connection Types Figure 10: Network Layering and interface of NFV Figure 11: VM Interface Figure 12: Bare Metal Server Interface [2] 				
 Figure 10: Network Layering and interface of NFV				
 Figure 11: VM Interface				
Figure 12: Bare Metal Server Interface [2]				
		Figm	re 12: Bare Metal Server Interface [2]	13



OCC1.0 Reference Architectur	e with SDN and NFV	Constructs
-------------------------------------	--------------------	------------

84	Figure 14: SWA-1 Interface	
85	Figure 15: SWA-5 Interface	
86	Figure 16: Management of Network Functions	
87	Figure 17: NFV Orchestrator interaction with EMS and OSS/BSS [6]	
88	Figure 18: Cloud User Interface-NaaS architecture with NFV constructs	
89	Figure 19: Bare Metal Server Interface and Naas	
90	Figure 20: VM access over NaaS	
91	Figure 21: Cloud Services management with SDN orchestrator and controllers	Error!
92	Bookmark not defined.	
93	Figure 22: VNFs and Infrastructure for cSC and cSCTP	
94	Figure 23: VNF and Infrastructure Components of cSC between cSUI and cSI	
95	Figure 24: VNFs for cSC-csp and cSC-csp-TP	
96	Figure 25: ONF SDN Architecture [10]	
97	Figure 26: ITU SDN Architecture [11]	
98	Figure 27: IETF SDN Architecture [12]	
99	Figure 28: SDN Building Blocks [7]	
100	Figure 29: Cloud Services Management with Life Cycle Orchestration	
101	Figure 30: Management of Cloud Services provided by multiple Cloud Service Opera	
102	Figure 31: Product and Service Operations Lifecycle Stages [9]	
103		
104	List of Tables	

Table 1: Terminology and Acronyms 4 105 106 **Table 3 :** VNF and Infrastructure Components of cSUI defined in [1] 23 107 108 109 Table 6 : VNF and Infrastructure Components of cSI defined in [1] 30 110 111 **Table 8 :** VNF and Infrastructure Components of cSC-csp-TP defined in [1] 35 112

- 113
- 114

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124 **1.Introduction**

125 The purpose of this document is to describe possible implementations of Cloud Services Archi-

tectures using Software-Defined Networking (SDN) and Network Functions Virtualization (NFV) constructs.

128 **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

- 131 for the definitions.
- 132

Terms	Definitions	Reference
сСсРІ	Cloud Carrier Cloud Provider Interface	OCC 1.0 Ref. Arch.[1]
Cloud Consumer	A person or organization that maintains a business rela- tionship 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 rela- tionship 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 con- nectivity and transport between Cloud Providers and Cloud Consumers or between Cloud Providers.	OCC 1.0 Ref. Arch.[1]
cCcPI	Cloud Carrier Cloud Provider Interface	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 mak- ing cloud applications available to Cloud Consumers (Cloud Service Users).	NIST Special Publi- cation 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 Arch.[1]	Ref.
cSC-cp	The segment of cSC within the boundaries of a Cloud Service Provider where cSC crosses multiple Cloud Ser- vice Providers	OCC 1.0 Arch.[1]	Ref.
cSI	Cloud Service Interface (cSI) is the interface of a Cloud Service application supporting entity of a Cloud Provid- er 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 relation- ships 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.
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	Demarcation Point between Cloud Service Providing entity such as a server or VM, and Cloud Service Pro- vider.	OCC 1.0 Arch.[1]	Ref.
cSPcSPI	Cloud Service Provider Cloud Service Provider Interface	OCC 1.0 Arch.[1]	Ref.
cSC-c	Cloud Carrier Connection	OCC 1.0 Arch.[1]	Ref.
cSC-p			
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.
cSC-p	Cloud Provider Connection	OCC 1.0 Arch.[1]	Ref.



Demarcation Point between a Cloud Consumer and Cloud Service Provider.	OCC 1.0 Ref. Arch.[1]
Denial of Service	RFC4732
Differentiated Service Code Point	RFC 2474 [17]
Element Management System	
External Network Network Interface	MEF 4 [16]
Ethernet Virtual Connection	MEF 10.3 [14]
Ethernet Private Line	MEF 6.2 [19]
Ethernet Virtual Private Line	MEF 6.2 [19]
A software, firmware or hardware running on a server that enables creation of virtual machines and runs them.	OCC 1.0 Ref. Arch.[1]
Internet Control Message Protocol	RFC 792 [23]
Internet Protocol Security Encapsulating Security Pay- load	RFC 4303 [24]
Layer Two Control Protocol	MEF 10.3 [14]
An Ethernet Service Type that is based on a Point-to- Point EVC.	MEF 6.2 [19]
An Ethernet Service Type that is based on a Multipoint- to-Multipoint EVC.	MEF 6.2 [19]
Local Area Network	IEEE 802-2 [18]
Life Cycle Orchestration	MEF 50 [21]
Label-switched Path	MPLS Architec- ture[29]
Media Access Control	IEEE802-2 [18]
Network Element	Not Applicable
Network Functions Virtualization	Draft ETSI GS NFV-INF V0.3.1 [2]
Network Interface Device	MEF 4 [16]
Operation Support System/Billing Support System	Not Applicable
Pseudowire Identification	RFC 4447 [31]
	Cloud Service Provider.Denial of ServiceDifferentiated Service Code PointElement Management SystemExternal Network Network InterfaceEthernet Virtual ConnectionEthernet Virtual ConnectionEthernet Virtual Private LineA software, firmware or hardware running on a server that enables creation of virtual machines and runs them.Internet Control Message ProtocolInternet Protocol Security Encapsulating Security Pay- loadLayer Two Control ProtocolAn Ethernet Service Type that is based on a Point-to- Point EVC.An Ethernet Service Type that is based on a Multipoint- to-Multipoint EVC.Local Area NetworkLife Cycle OrchestrationLabel-switched PathMedia Access ControlNetwork ElementNetwork Functions VirtualizationNetwork Interface DeviceOperation Support System/Billing Support System



REST API	Representational State Transfer Application Program- ming 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 1.0 Ref. Arch.[1]
VN	Virtual Network	Not Applicable
VNF	Virtualized Network Function	Draft ETSI GS NFV-INF 001 V0.3.12 [4]
VNIC	Virtual Network Interface Controller	Not Applicable

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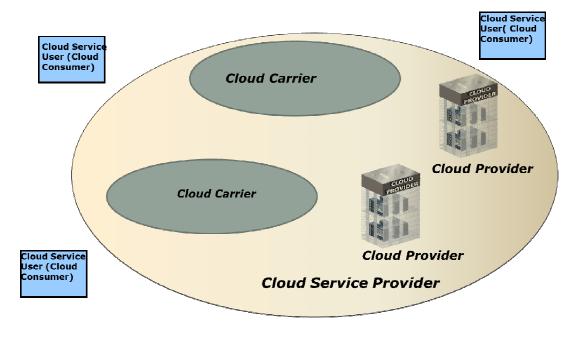
Table 1: Terminology and Acronyms



¹³⁶ 3. Summary of OCC 1.0 Architecture¹

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

- 140 Cloud Provider(s).
- 141



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Figure 1: Cloud Service Actors

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 be-

147 Tace cancer Croud Service Oser Interface (CSOF) (Figure 2) which 148 tween the Cloud Service Provider and the Cloud Consumer.

149 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

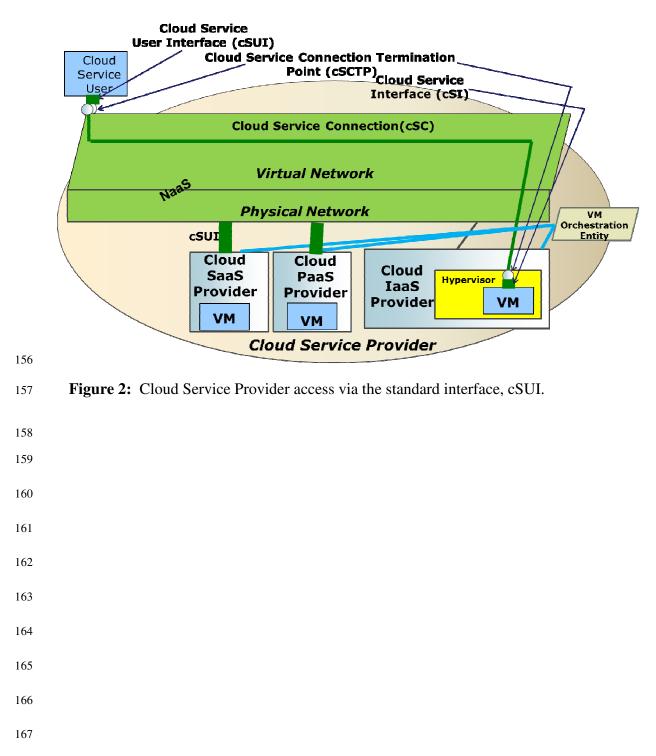
called cCcPI (Cloud Carrier Cloud Provider Interface). In this case, a cSC for cloud services can

be terminated at either cCcPI or cSI.

¹ This section copies figures and text from OCC 1.0 Reference Architecture. The Reference Architecture takes precedence if there are differences.

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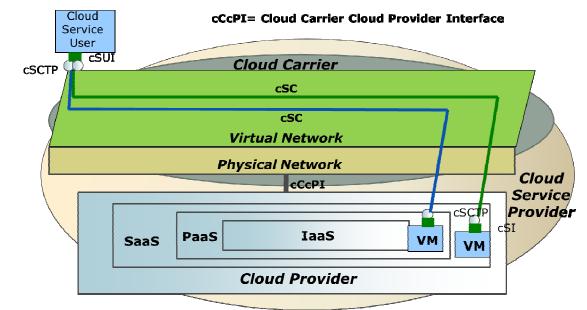
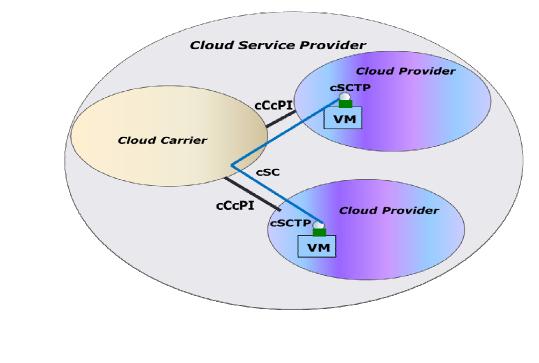




Figure 3: Cloud Provider and Cloud Carrier belong to two different Operators





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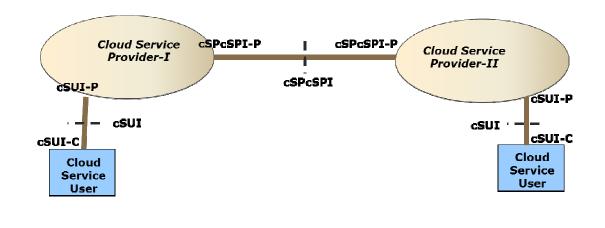
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Figure 4: cSC between two Cloud Provider entities.

174 It is also possible for two or more cSPs to be involved in providing a cloud service to a Cloud 175 Consumer as depicted in Figure 5 where two cSPs interface to each other via a standards inter-



- 176 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 $(cSO)^2$.
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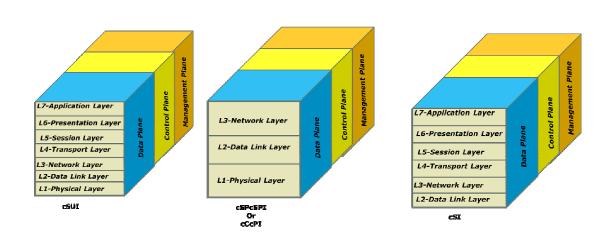
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Figure 5: Two Cloud Service Providers collectively providing Cloud Services

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. The protocol stack at each

interface that can be supported is depicted in Figure 6. Each of the protocol layer may be further decomposed into their data, control and management plane components.

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

 $^{^{2}}$ cSO is a cSP that is not responsible from the end-to-end service. It can be cP or cC or an entity providing cloud applications in addition to cC and cP functionalities. 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.

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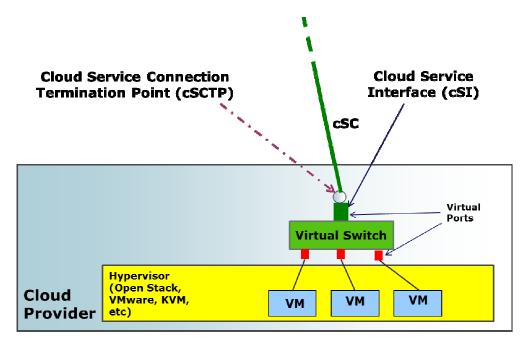
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The cSC provides connectivity between two or more cSCTPs. The cSC could be an EVC, LSPor IP VPN connection.

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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.

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Figure 7: Multiple VM sharing a cSC

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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.



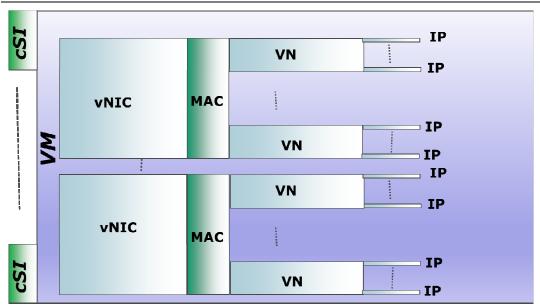
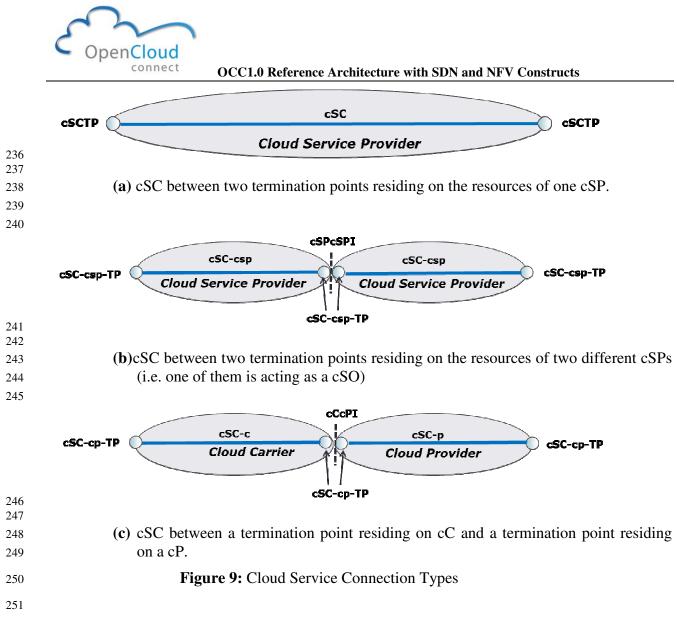


Figure 8: VM supporting multiple cSIs, virtual network interface controllers (vNICs), MACs, virtual networks (VNs) and IP addresses.

Cloud service connection types are depicted in Figure 9. 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)

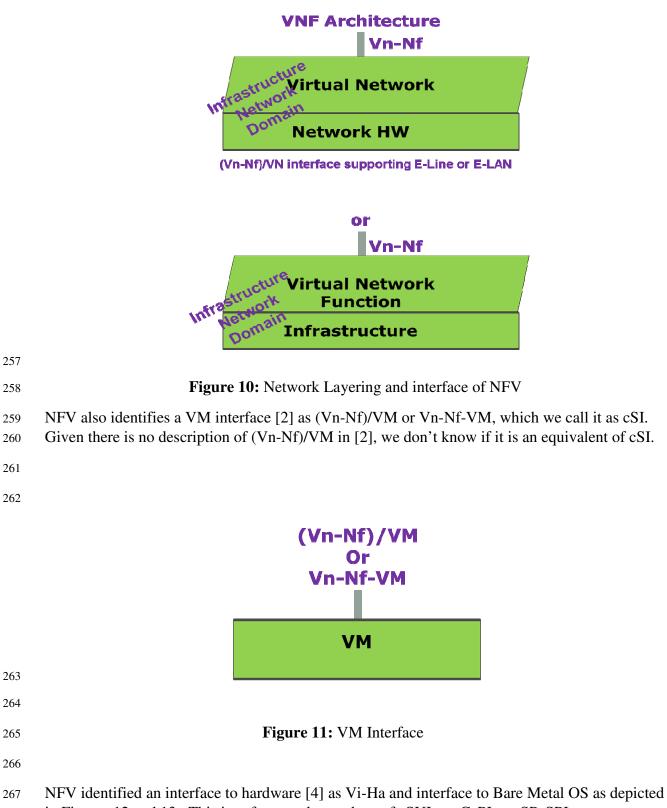
and the connection segment within the cC is called Cloud Carrier Connection (cSC-c).



4. Summary of NFV Architecture

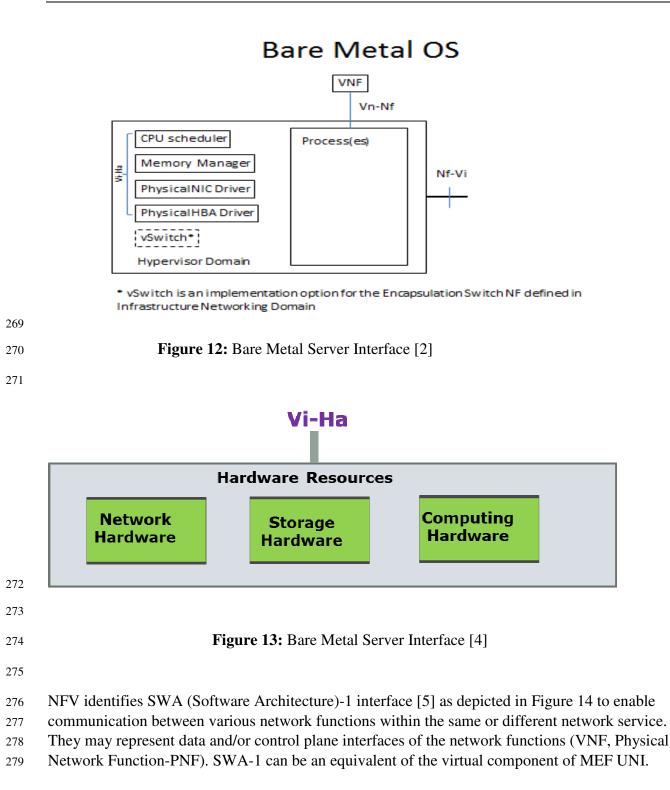
NFV [2, 3] divides the network into two layers, Network Hardware (or Infrastructure) and Virtual Network (or Virtual Network Function) as depicted in Figure 10 below. (Vn-Nf)/VN interface
is identified as the virtual interface for the network. The E-Line and E-LAN services of MEF are
being considered as examples of (Vn-Nf)/VN.

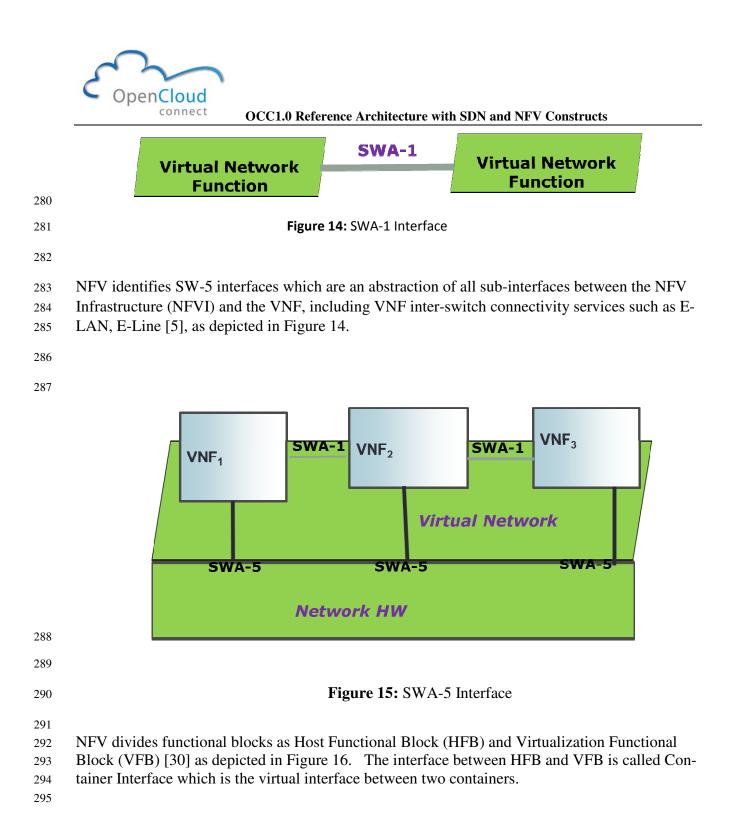




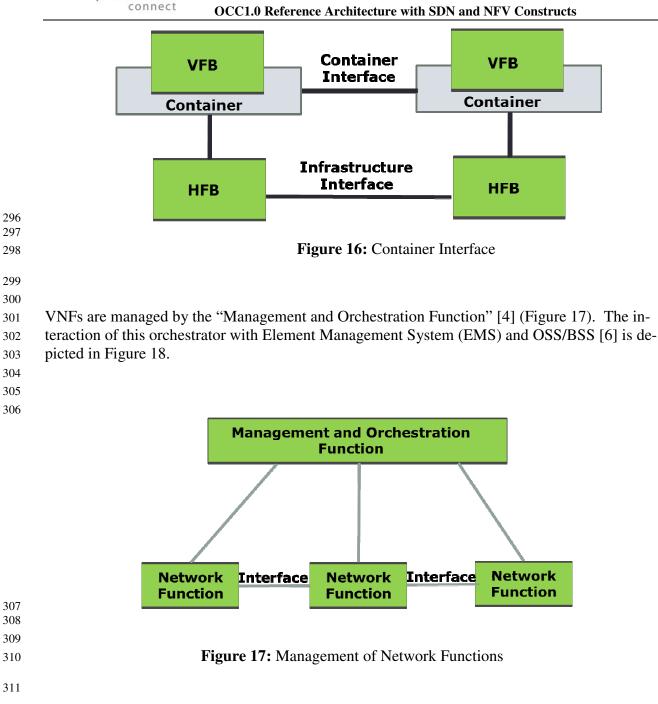
in Figures 12 and 13. This interface can be a subset of cSUI or cCcPI or cSPcSPI.



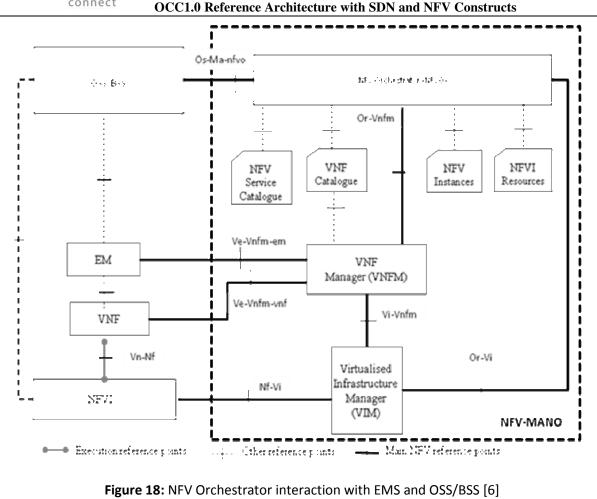












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5. Mapping Between NFV and OCC Reference Architecture Constructs

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

mended mappings between NFV and OCC architectural constructs.

321 322

	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

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User and VM or between VMs	
Connection Termination Point	cSCTP

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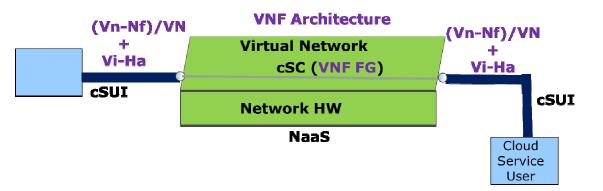
Table 2 : Mapping between OCC and NFV Constructs

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NaaS and Cloud User interfaces to NaaS are depicted in Figure 19 using NFV constructs. Since cSUI represents both physical and logical components of NaaS, we map the cSUI to the combi-

nation of Vi-Ha and (Vn-Nf)/VN.

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Figure 19: Cloud User Interface-NaaS architecture with NFV constructs

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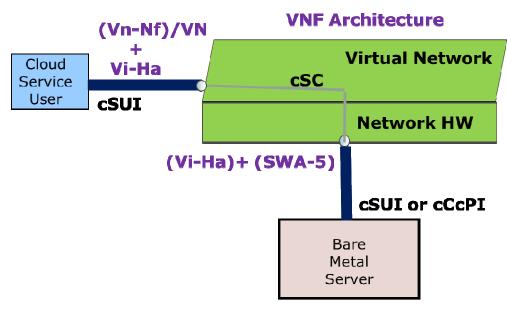
Cloud user access to bare metal servers over NaaS is depicted in Figure 20, using NFV constructs. As described in [1], bare metal servers can interface to NaaS using cSUI or cCcPI. We map this interface to the combination of Vi-Ha and SWA-5 since this interface can support both physical and logical components.

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Figure 20: Bare Metal Server Interface and Naas

346 Cloud user access to VMs over NaaS is depicted in Figure 21, using NFV constructs. The func-

tions of the cSI interface which is an equivalent of (Vn-NF)/VM ride over cCcPI. Although 348

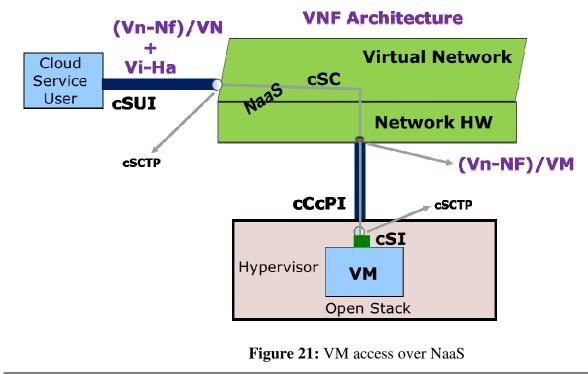
VNF forwarding may map to cSC, there is no concept of connection termination point in VNF. 349

The End Point as depicted in [4] does not correspond to a connection termination point. The End 350

Point is more like a device such as Customer Edge (CE) or an NE. 351

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6. Basic NFV Components of OCC Architecture

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.

364365 6.1. N

6.1. NFV Components of cSUI

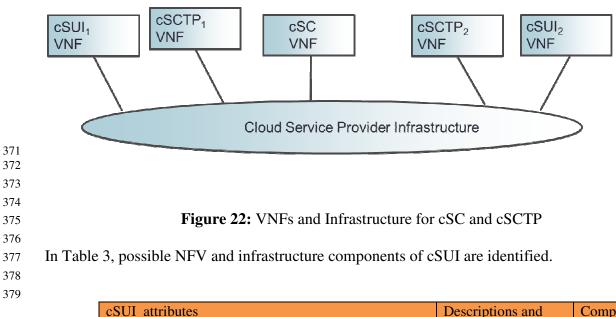
VNF and infrastructure components of a point-to-point cSC and its cSCTPs in support of cloud services between two cSUIs are depicted in Figure 22.



366



VNF Implementation



- cSUI attributes Descriptions and Recommended Values of Attributes COMPONENT OF Infraues of Attributes Both cSUI Id Arbitrary text string to identify cSUI
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	ence Architecture with S		<u> </u>
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) iden- tifier such as VLAN IDs. Multiple VN identifiers can be- long to a tenant [38].	VNF
NaaS Identifier		[50].	VNF
Physical Interface			, 1 11
Ethernet if supported	speed, mode, physi- cal medium		Infrastructure
	MAC Layer		Infrastructure
DOCSIS if supported	speed, mode, physi- cal medium		Infrastructure
EPON if supported	speed, physical me- dium		Infrastructure
GPON if supported	speed, physical me- dium		Infrastructure
WDM if supported	speed, physical medium		Infrastructure
SONET/SDH if supported	speed, physical me- dium		Infrastructure
Optical Transport Network (OTN)	speed, physical me- dium		Infrastructure
Maximum Transmission Unit (M	TU)	\geq 1522 bytes	Both
Connection Multiplexing		Yes or No	Both
Maximum number of Connection Points(or End Points)	n Termination		Both
L2 Ethernet configuration attribu	tes		
MEF UNI Service attributes for Ethernet Private Services in Table 11 of MEF 6.2			VNF
MEF UNI L2CP Service At- tributes for UTA in Table 18 of MEF 45			VNF
MEF UNI Service attributes in Table 4 of MEF 6.2			VNF
MEF UNI L2CP Service At-			VNF
tribute for vNID Case A in			



OCC1.0 Reference Architecture with SDN and NFV Constructs

Table 23 of MEF 45			
MEF UNI L2CP Service At-		VNF	
tribute for vNID Case B in			
Table 26 of MEF 45			
MEF UNI Service attributes		VNF	
for EPL in Table 7 of MEF		VINI	
6.2			
MEF UNI Service attributes		VNF	
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			
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			
MEF UNI Service attributes			
for EVP-LAN in Table 16 of			
MEF 6.2			
		VNE	
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			
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		
IPv4 Address	Status		VNF
DSCP Marking IPv6 Address			VNF VNF
IPv4 VPN[31]			VNF VNF
IPv6 VPN [32]			Both
L4 attributes if L4 protocols			Doui
such as Transmission Con-			
trol Protocol (TCP), User			
Datagram Protocol (UDP)			
and Stream Control Trans-			
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			
WWW browsers, NFS, SNMP,			
Telnet, HTTP, FTP are sup-			
ported.			
Operational State		Enabled or Disa-	VNF
-		bled	
Admin State		Enabled or Disa-	VNF
		bled	
Interface Level Security			
ACL (Access Control List) att	ributes		VNF
Packet Encryption	IPSec Encapsulat-		Both
	ing Security Pay-		
	load (ESP) attrib-		
	utes		
	SSL VPN (Secure		Both
			Dom
	Sockets Layer Virtual Private		
Connection A (1)	Network)		
Connection Authentication			

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	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.	
	Keys for API	
Billing		
	Recurring Charges	VNF
	Non-recurring	VNF
	Charges	

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

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6.2.NFV Components of cSC and cSCTPs

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

cSCTP attributes		Descriptions and Recommended Val- ues of Attributes	Component of VNF or Infra- structure or Both
cSCTP Id		Arbitrary text string to identify the cSCTP	VNF
cSUI Ids and cSI Ids ³		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			Both

³ cSUI Id and cSI Ids are included to identify cSUI and cSI that cSCTP is related to. The cSUI-cSCTP and cSIcSCTP relationships maybe represented via association in the information model instead of an attribute of the cSCTP object.

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OCC1.0 Reference Architecture with SDN and NFV Constructs

6.2	1	
6.2		Ded
MEF EVC per UNI Service attributes		Both
for EP-LAN Service in Table 14 of		
MEF 6.2		
MEF EVC per UNI Service attributes		Both
for EVP-LAN Service in Table 18 of		
MEF 6.2		
MEF EVC per UNI Service attributes		Both
for EP-Tree Service in Table 20 of		
MEF 6.2		
MEF EVC per UNI Service attributes		Both
for EVP-Tree Service in Table 23 of		
MEF 6.2		
MEF EPL Option 2 L2CP Processing		Both
Requirements in Table 8 of MEF 45		
MEF EPL Option 2 L2CP Processing		Both
Recommendations in Table 9 of MEF		
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 INI
Maintenance End Point (MEP)		VNF
Id		VINI
MEP Level		VNF
L3 attributes if interface is L3		VINF
		VNF
IPv4 Subnet Address		
IPv6 Subnet Address		VNF
DSCP Mapping		VNF
Bandwidth Profile	CIR	Both
	CBS	Both
	EIR	Both
	EBS	Both
Protection (via redundant	1:1or 1+1	Both
cSCTP on a different port		
of the		
same CE or different CE		
providing		
1 0		
the cSUI, and on a different		
VM of		
the application entity		
providing cSI)		
LSP Label		VNF

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EXP Mapping			VNF
Operational State		Enabled or Disabled	Infrastructure
Administrative State		Enabled or Disabled	VNF
cSCTP Level Security			
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		
Service Level Security	Rate limiting of		Infrastructure
	DoS attacks and		
	excessive resource		
	consumption		

³⁸⁷

cSC attributes		Descriptions and recom-	Component of VNF or
		mended values of attributes	Infrastructure or Both
cSC Id		Arbitrary text string to iden- tify the cSC	VNF
List of associated cSCTP Ids ⁴			VNF
Overlay Network Attributes	VNI ID	•	VNF
Туре	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 attrib	utes [71,47]		
MEF EVC Service attributes in Table 6 of MEF 6.2			Both
MEF EVC Service attributes of EPL in Table 9 of MEF 6.2			Both
MEF EVC Service attributes of EVPL in Table 12 of			Both

⁴ 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.

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OCC1.0 Reference Architecture with SDN and NFV Constructs

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			
MEF 6.2			
MEF EVC Service attributes			Both
of EP-Tree in Table 21 of			
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			
per CoS in Table 25 of MEF			
6.2			
L3 connection attributes (if	Service Level	Delay, jitter, loss	Both
supported)	Objectives		
	(SLOs)		
	MTU		Both
	Туре	Point-to-Point, Multipoint-	VNF
		to-Multipoint, Rooted Mul-	
		tipoint	
Connection Start Time		Specified in seconds in Co-	VNF
		ordinated Universal Time	
		(UTC).	
Connection Start Interval (Sta		Specified in seconds in	VNF
rameter to indicate the accepta		UTC	
the Start Time during which the			
modifications can be made.) [80]		
Connection Duration		Specified in days, minutes	VNF
~		or seconds.	
Connection Period		Specified in daily, weekly	VNF
		or monthly	
Operational State		Enabled or Disabled	Infrastructure
Administrative State		Enabled or Disabled	VNF
Billing Options	Monthly,		VNF
	Hourly		
L		1	1

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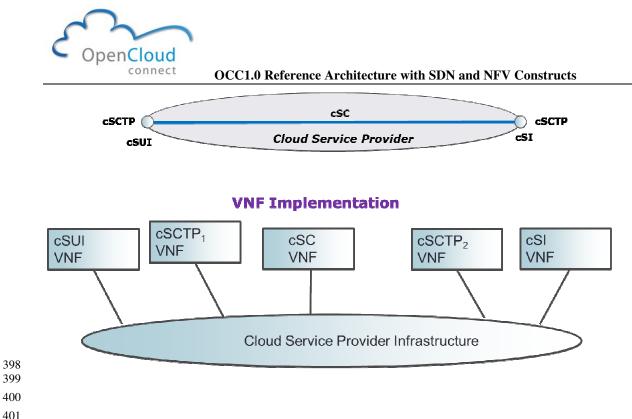
392

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

393 6.3. NFV Components of cSI

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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 23.



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Table 6 identifies possible NFV and infrastructure components of cSI.

404 405

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 attrib- utes in Table 4 of MEF 6.2		Both
MEF UNI Service attrib-		Both

Figure 23: VNF and Infrastructure Components of cSC between cSUI and cSI

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OCC1.0 Reference Architecture with SDN and NFV Constructs

utes for EPL in Table 7		
of MEF 6.2		
MEF UNI Service attrib-		Both
utes in Table 4 of MEF		
6.2		
0.2		
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		
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		
0.2		
MEF UNI Service attrib-		
utes for EP-Tree in Table		
19 of MEF 6.2		
MEF UNI Service attrib-		Both
		Dom
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		D - 41-
VM Protection (if support-	This would be redun-	Both
ed)	dant VM or redundant	
	server or redundant	
	resource offering the	
	service	
L		



OCC1.0 Reference Architecture with	n SDN and NFV Constructs
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[49] if MPLS is support- ed Ingress B Profile, E width Pro Link Dow	PW ID, MTU, andwidth Egress Band- file, MPLS /n, MPLS AIS, RDI, us ansmission Protocol n Protocol	Yes or No	VNF Both VNF VNF VNF VNF VNF VNF VNF VNF VNF VNF
supportedMPLS UNI attributesLSP ID, F[49] if MPLS is support-Ingress BedProfile, Ewidth ProLink DowLink Up,Lock StatIPv4 AddressIngress BDSCP MarkingIngress BIPv6 AddressIngress BIPv6 VPNIngress BNATIAL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (TPCoIP (PC over IP) Ports50002(Te)P1002 (TC)1172 (TC)PCoIP (PC over IP) Ports3389 (TC)Protocol) Ports3389 (TC)	PW ID, MTU, andwidth Egress Band- file, MPLS /n, MPLS AIS, RDI, us ansmission Protocol n Protocol		VNF Infrastructure VNF VNF VNF VNF VNF VNF VNF VNF
MPLS UNI attributesLSP ID, F[49] if MPLS is supportedIngress BedProfile, Ewidth ProLink DowLink Up,Lock StatIPv4 AddressIngress BDSCP MarkingIngress BIPv6 AddressIngress BIPv6 VPNIngress BNATIAL4 attributes if L4 protocols such as TraControl Protocol (TCP), User Datagram(UDP) and Stream Control Transmission(SCTP) are supportedGeneral Ports32111 (T9427 (TCPCoIP (PC over IP) Ports50002(Te)Attributes IP (Remote Desktop3389 (TC)Protocol) Ports3389 (TC)	andwidth Egress Band- file, MPLS /n, MPLS AIS, RDI, us ansmission Protocol n Protocol		VNF Infrastructure VNF VNF VNF VNF VNF VNF VNF VNF
[49] if MPLS is supportedIngress Barrofile, E Profile, E width Pro Link Dow Link Up, Lock StatIPv4 AddressIngress Barrofile, E width Pro Link Dow Link Up, Lock StatIPv4 AddressIngress Barrofile, E width Pro Lock StatIPv4 AddressIngress Barrofile, E width Pro Lock StatIPv6 AddressIngress Barrofile, E width Pro Lock StatIPv6 VPNIngress Barrofile, E width Pro Lock StatIPv6 VPNIngress Barrofile, E Lock StatIPv6 VPNIngress Barrofile, E Lock StatIA attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T 9427 (TC)PCoIP (PC over IP) Ports50002(Te) 4172 (TC)RDP (Remote Desktop Protocol) Ports3389 (TC)	andwidth Egress Band- file, MPLS /n, MPLS AIS, RDI, us ansmission Protocol n Protocol		Infrastructure VNF
edProfile, E width Pro Link Dow Link Up, Lock StatIPv4 AddressIDSCP MarkingIIPv6 AddressIIPv6 VPNINATIL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(Te) 4172 (TC)RDP (Remote Desktop Protocol) Ports3389 (TC)	file, MPLS (n, MPLS AIS, RDI, us ansmission Protocol n Protocol 'CP)		Infrastructure VNF
width Pro Link Dow Link Up, Lock StatIPv4 AddressDSCP MarkingIPv6 AddressIPv4 VPNIPv6 VPNNATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(Te) 4172 (TC)RDP (Remote Desktop Protocol) Ports3389 (TC)	n, MPLS AIS, RDI, us ansmission Protocol n Protocol CCP)		Infrastructure VNF
Link Up, Lock StatIPv4 AddressDSCP MarkingIPv6 AddressIPv4 VPNIPv6 VPNNATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(Te) 4172 (TC)RDP (Remote Desktop Protocol) Ports3389 (TC)	AIS, RDI, us unsmission Protocol n Protocol 'CP)		Infrastructure VNF
Lock StatIPv4 AddressDSCP MarkingIPv6 AddressIPv6 VPNIPv6 VPNNATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(To)RDP (Remote Desktop Protocol) Ports3389 (TC)	us ansmission Protocol n Protocol CCP)		Infrastructure VNF
IPv4 AddressDSCP MarkingIPv6 AddressIPv4 VPNIPv6 VPNNATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(Te) 4172 (TC)RDP (Remote Desktop Protocol) Ports3389 (TC)	ansmission Protocol n Protocol CCP)		Infrastructure VNF
DSCP MarkingIPv6 AddressIPv4 VPNIPv6 VPNNATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(Te) 4172 (TC)RDP (Remote Desktop Protocol) Ports3389 (TC)	Protocol n Protocol CCP)		Infrastructure VNF
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IPv4 VPNIPv6 VPNNATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(Te)PCoIP (Remote Desktop Protocol) Ports3389 (TC)	Protocol n Protocol CCP)		VNF VNF VNF VNF VNF
IPv6 VPNNATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(Te) 4172 (TC)RDP (Remote Desktop Protocol) Ports3389 (TC)	Protocol n Protocol CCP)		VNF VNF VNF VNF
NATL4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TCPCoIP (PC over IP) Ports50002(TC)PCoIP (Remote Desktop Protocol) Ports3389 (TC)	Protocol n Protocol CCP)		VNF VNF VNF
L4 attributes if L4 protocols such as Tra Control Protocol (TCP), User Datagram (UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(TC)PCoIP (Remote Desktop Protocol) Ports3389 (TC)	Protocol n Protocol CCP)		VNF VNF
Control Protocol (TCP), User Datagram(UDP) and Stream Control Transmission(SCTP) are supportedGeneral Ports32111 (T9427 (TCPCoIP (PC over IP) Ports50002(Te4172 (TCRDP (Remote Desktop3389 (TCProtocol) Ports1000000000000000000000000000000000000	Protocol n Protocol CCP)		VNF
(UDP) and Stream Control Transmission (SCTP) are supportedGeneral Ports32111 (T9427 (TCPCoIP (PC over IP) Ports50002(TcPCoIP (Remote Desktop Protocol) Ports3389 (TC	n Protocol TCP)		
(SCTP) are supportedGeneral Ports32111 (T9427 (TC9427 (TCPCoIP (PC over IP) Ports50002(TC4172 (TCRDP (Remote DesktopProtocol) Ports	CP)		
General Ports32111 (T9427 (TC)PCoIP (PC over IP) Ports50002(TC)4172 (TC)RDP (Remote DesktopProtocol) Ports	,		
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PCoIP (PC over IP) Ports50002(To 4172 (TCRDP (Remote Desktop Protocol) Ports3389 (TC	CP)		VNF
PCoIP (PC over IP) Ports50002(To 4172 (TCRDP (Remote Desktop Protocol) Ports3389 (TC	CP)		VNF
Aligned4172 (TCRDP (Remote Desktop Protocol) Ports3389 (TC			
RDP (Remote Desktop Protocol) Ports4172 (TC 3389 (TC			VNF
RDP (Remote Desktop3389 (TOProtocol) Ports3389 (TO			VNF
Protocol) Ports	/		VNF
	_P)		VINF
Connection server Ports 4001 (TC			
Connection server rous 4001 (10	חי)		VNF
	, 		VINI
L5 attributes if L5 protocols such as	NFS. Net-		VNF
Bios names, RPC and SQL are suppo	orted.		
L6 attributes if L6 protocols such as	ASCIL		VNF
EBCDIC, TIFF, GIF, PICT, JPEG, N			
MIDI are supported	n 20,		
L7 attributes if L7 protocols/applicat	tions such		VNF
as WWW browsers, NFS, SNMP, Te			
FTP are supported.	met, 111 11 ,		
Operational State		Enabled or Disabled	I Infrastructure
Admin State		Enabled or Disabled	
Security		Enabled of Disubled	

⁵ 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).

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Terminating SSL		VNF
such as load balancer		
		VNF
IPSec ESP (Encapsu-		Both
<i>e i i</i>		
		VNF
		VNF
TCP-AO		VNF
Rate limiting of		Both
DoS attacks and ex-		
cessive resource		
consumption		
Prevent tenants from		VNF
eavesdropping on		
each other via logi-		
cal separation		
REST API (Repre-		VNF
sentational State		
Transfer Application		
face) over SSL (Se-		
•		
· •		
API keys		VNF
Recurring Charges		VNF
Non-recurring		VNF
Charges		
	traffic for services such as load balancer IPSec ESP (Encapsu- lating Security Pay- load) SSL VPN IPSec AH TCP-AO Rate limiting of DoS attacks and ex- cessive resource consumption Prevent tenants from eavesdropping on each other via logi- cal separation REST API (Repre- sentational State Transfer Application Programming Inter- face) over SSL (Se- cure Sockets Layer) /TLS (Transport Layer Security) API keys Recurring Charges	traffic for services such as load balancer IPSec ESP (Encapsu- lating Security Pay- load) SSL VPN IPSec AH TCP-AO Rate limiting of DoS attacks and ex- cessive resource consumption Prevent tenants from eavesdropping on each other via logi- cal separation REST API (Repre- sentational State Transfer Application Programming Inter- face) over SSL (Se- cure Sockets Layer) /TLS (Transport Layer Security) API keys Recurring Charges Non-recurring

406 407

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

408

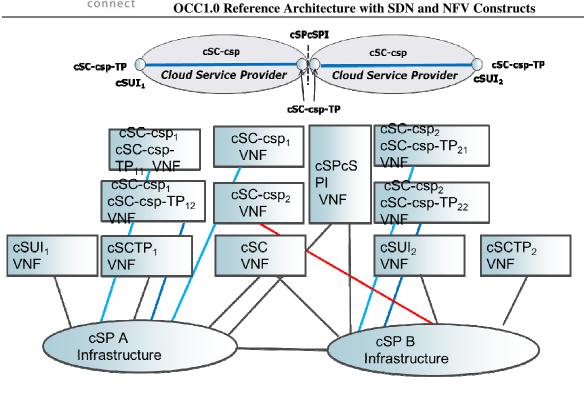
409

6.4.NFV Components of cSC Crossing two cSPs

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 24.

414





- 418
- 419 420

Figure 24: VNFs for cSC-csp and cSC-csp-TP

Table 7 identifies possible NFV and infrastructure components of cSPcSPI.

422

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



	Tence Arcintecture with		
WDM if supported	speed, physical me- dium		Infrastructure
SONET/SDH if supported	speed, physical me- dium		Infrastructure
Optical Transport Network (OTN)			Infrastructure
MTU		≥ 1522 bytes	Both
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			Both
of MEF 26.1			D 1
MEF ENNI L2CP Service Attributes for			Both
Access EPL in Table 17 of MEF 45			D 1
MEF ENNI L2CP Service Attributes for			Both
UTA in Table 20 of MEF 45			D 1
MEF ENNI L2CP Service Attributes for			Both
vNID Case A in Table 25 of MEF 45			D 1
MEF ENNI L2CP Service Attributes for			Both
vNID Case B in Table 28 of MEF 45			
L2 Ethernet SOAM attributes [25]	T		10 F
Maintenance Entity			VNF
Group (MEG) Id			VAL
Maintenance End Point			VNF
(MEP) Id			VNE
MEP Level Maintenance Intermedi-			VNF
			VNF
ate Doint (MID) Id			
Point (MIP) Id LAG MEG			Both
LAG MEG			VNF
Operator MEG			VNF
Other L2 Protocols such as Point-to-Po	cint Ducto col (DDD)		Both
			DOUI
and Point-to-Point Tunneling Protocol	(PPTP) II support-		
ed			
L3 attributes if L3 protocol such as IP	and MPLS are sup-		
ported			
MPLS UNI attributes if MPLS is su-	LSP ID, PW ID,		Both
ported	MTU, Ingress		
	Bandwidth Pro-		
	file, Egress		
	Bandwidth Pro-		
	file, MPLS Link		
	Down, MPLS		
	Link Up, AIS,		

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	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	

424 425

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

426

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

428

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- vice Attributes in Table 17 of MEF 26.1			Both
MEF OVC End Point per UNI Service Attrib-utes in Table 18 of MEF 26.1			Both
MEF OVC L2CP Service Attributes for Access EVPL in Table 13 of MEF 45			Both
MEF OVC L2CP Service Attributes for Access EPL in Table 16 of MEF 45			Both

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OCC1.0 Reference Architecture with SDN and NFV Constructs

MEF OVC L2CP Service Attributes for UTA in Table 19 of MEF 45			Both
MEF OVC L2CP Service Attributes			Both
for vNID Case A in Table 24 of MEF 45			
OVC L2CP Service Attributes for			Both
vNID Case B in Table 27 of MEF 45			
Protection (via redundant cSC-	1:1or 1+1		Both
csp-TP on a different port of the			
same cSPcSPI Gateway			
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			
L2 Ethernet SOAM attributes [25]	I		VNF
Maintenance Entity Group (MEG) Id			VNF
Maintenance End Point (MEP) Id			
MEP Level			
Maximum Number of MEPs			VNF
Maintenance Intermediate			VNF
Point (MIP) Id			
L3 attributes if interface is L3			
IPv4 Subnet Address			VNF
IPv6 Subnet Address			VNF
DSCP Mapping			Both
Bandwidth Profile	CIR		Both
	CBS		Both
	EIR		Both
	EBS		Both
Protection (via redundant	1:1or 1+1		Both
cSCTP on a different port of the			
same cSPcSPI Gateway			
LSP Label			
EXP Mapping			
Operational State		Enabled or Disabled	
Administrative State		Enabled or Disabled	VNF
cSC-csp-TP Level Security			
Packet encryption	IPSec ESP		VNF
	SSL VPN		VNF
Connection Authentication	IPSec AH		VNF
	TCP-AO		VNF
Service Level Security			VNF
Service Level Security	Rate limiting of DoS attacks and		A TAT.
	•	· ·	<u>.</u>



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

429

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

- 430 431
- 432

433 434 7. Summary of Software-Defined Networking (SDN) Architecture

Software-Defined Networking (SDN) is defined by ONF as an emerging architecture that is dy namic, manageable, cost-effective, and adaptable [10]. This architecture decouples the network
 control and forwarding functions (Figure 25) enabling the network control to become directly
 programmable and the underlying infrastructure to be abstracted for applications and network
 services.

440

Abstracting the control plane from the network elements allows network-platform-specific char acteristics 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.

443 re

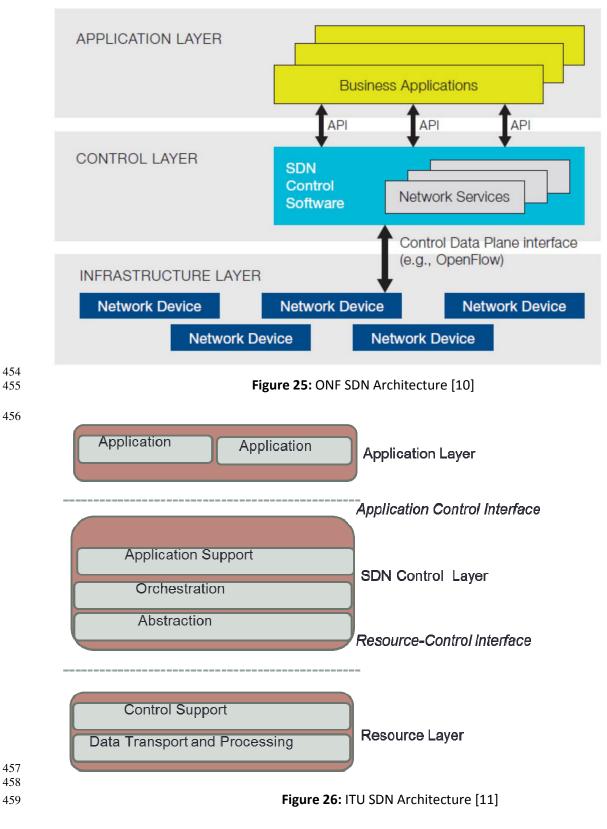
ITU keeps the ONF layer separation and adds orchestration between application layer and con trol layer as depicted in Figure 26 to provide automated control and management of network re sources and coordination of requests from the application layer [11].

448

IETF also keeps the ONF layer separation (Figure 27) and adds a management plane which is

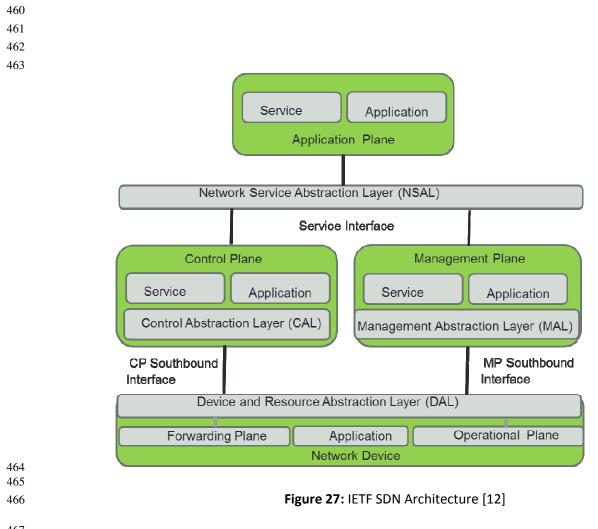
- responsible for monitoring, configuring, and maintaining network devices, in parallel to control
- 451 plane.
- 452 453





457





SDN building blocks are summarized in Figure 28. The application layer sits on top of services 468 layers. The services layer interacts with an orchestrator which can interact with multiple control-469 lers via a north bound API. The north bound interface between applications/services allows the 470 applications to authenticate and learn of which objects they have authorization to manipulate, or 471 to interact with objects belonging to controlling software. The SDN Orchestrator requests object 472 models from each of the controlling software which is responsible for managing and manipulat-473 ing them. The Southbound API provides abstraction for the controller to manage the devices in 474 its domain. 475 476

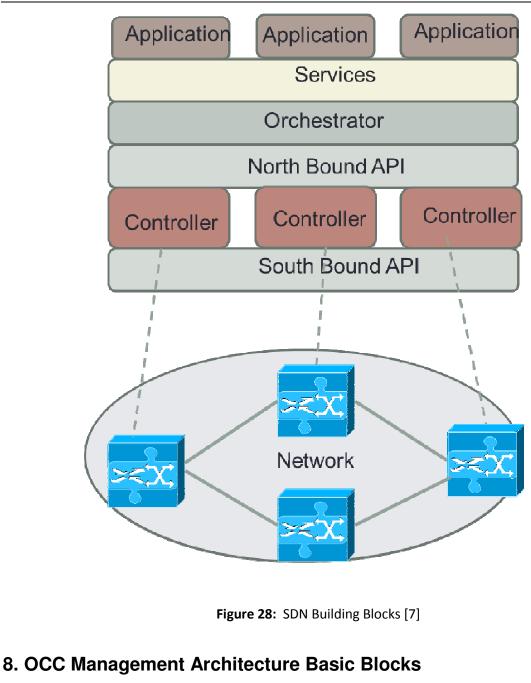
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482

483 484 OCC1.0 Reference Architecture with SDN and NFV Constructs



A high level management architecture is depicted in Figure 29 and Figure 30. 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]. Cloud Orchestrator configures the EVPL between two users by translating this request to appropriate commands to NFV Orchestrator and Controllers via "North Bound API". The NFV Orchestrator is expected to perform service chaining of VNFs and infrastructure components associated with virtualized Network Elements (NEs) while Controllers automate provision-



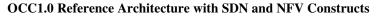
ing of non-virtualized components of the network. It is possible to have non-SDN NEs in the 492 network. They will be managed by Element Management Systems (EMSs). 493 494 The Cloud Orchestrator may perform Life Cycle Service Orchestration (LSO) as described in [9] 495 for each service ordered and provisioned via User Portal and Operation Support System/Billing 496 Support System (OSS/BSS). Some of the LSO functionalities are as depicted in Figure 31: 497 Market Analysis and Product Strategy 498 •Service and Resource Design 499 •Launch products 500 •Marketing Fulfillment Response 501 •Sale Proposal and Feasibility 502 •Capture Customer Order 503 •Service Configuration & Activation 504 •End-to-End Service Testing 505 •Service Problem Management 506 •Service Quality Management 507 •Billing and Revenue Management 508 •Terminate Customer Relationship 509 510 In Figure 29, a Cloud Orchestrator performs Life Cycle Orchestration for Cloud services by a 511 Cloud Service Operator. On the other hand, in Figure 30 where multiple operators are involved 512 in providing cloud services, multiple Cloud Orchestrators might perform Life Cycle Orchestra-513 tion. In this case, a Cloud Orchestrator of the Cloud Service Provider which is responsible from 514

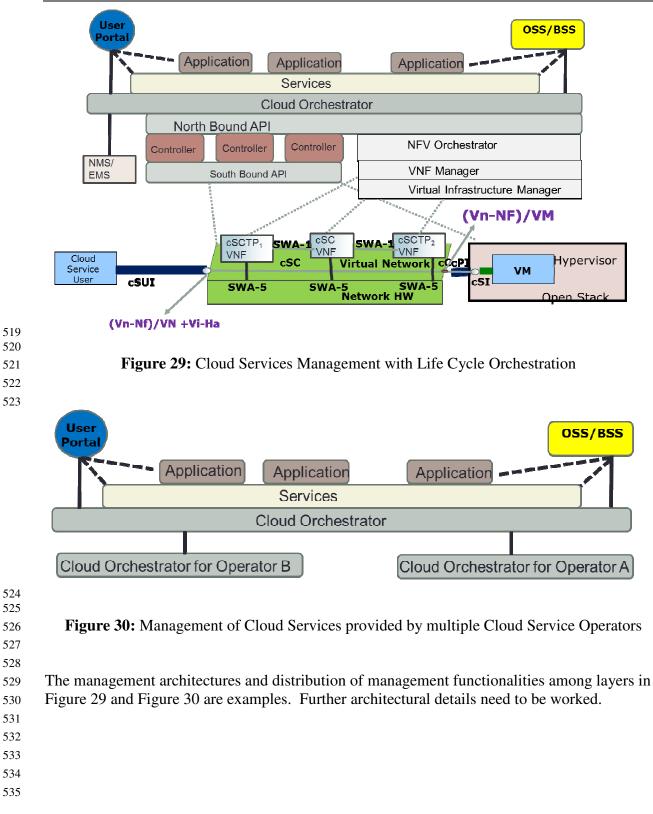
the end-to-end service [1] is expected to perform Life Cycle Orchestration end-to-end.

516

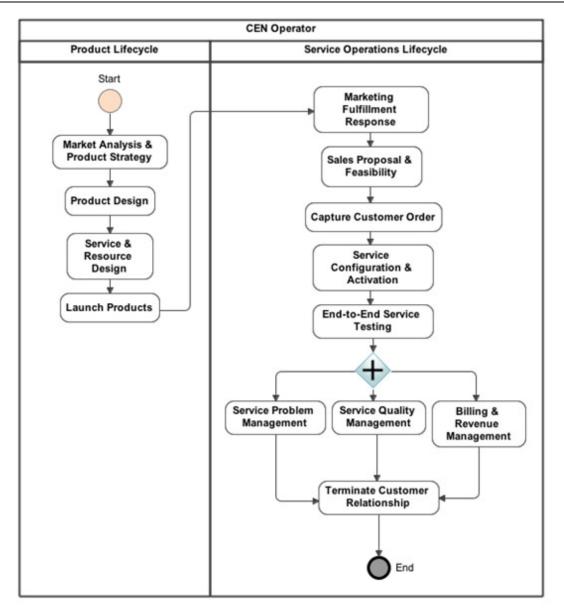
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Figure 31: Product and Service Operations Lifecycle Stages [9]



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