

MEF Standard MEF 68

Cloud Services Architecture

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1 List of Contributing Members

The following members of the MEF participated in the development of this document and have requested to be included in this list.

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- Ciena
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2 Abstract

This document defines the architectural framework for Cloud Services provided by a Cloud Service Provider to a Cloud Subscriber or by a Cloud Operator to a Cloud Service Provider. Actors of Cloud Services, interfaces and connections among the actors, connection termination points, and associated terminologies are defined.



3 Terminology and Abbreviations

This section defines the terms used in this document. In many cases, the normative definitions to terms are found in other documents. In these cases, the third column is used to provide the reference that is controlling, in other MEF or external documents.

| Term | Definition | Reference |
|-------------------------|---|---------------|
| | A component of a Cloud Service such as compute, | |
| Cloud Application | storage or software logic, that does not provide | This document |
| | connectivity. | |
| Cloud Application | The demarcation point between a Cloud Application | This document |
| Interface | and one or more Cloud VC EPs. | |
| Cloud ENNI | Cloud External Network Network Interface | This document |
| Cloud External | A demarcation point representing the boundary of | This document |
| Network Network | responsibility between two Cloud Operators or between | |
| Interface | a Connectivity Operator and a Cloud Operator. | |
| Cloud Operator | An organization that provides Cloud Services to Cloud Service Providers and/or Cloud Super Operators. | This document |
| Cloud Service | A service comprising one or more Cloud Applications | This document |
| | and connectivity among them that may be accessed by | |
| | the user of the service from one or more locations. | |
| Cloud Service | A Protocol Data Unit (PDU) that is exchanged at a | This document |
| PDU | Cloud UNI, a Cloud ENNI, or a Cloud Application | |
| | Interface. | |
| Cloud Service | An organization that provides Cloud Services to Cloud | This document |
| Provider | Subscribers. | |
| Cloud SP | Cloud Service Provider | This document |
| Cloud Subscriber | The end-user (i.e. a person or organization) that | This document |
| | maintains a business relationship with and uses Cloud | |
| | Services from a Cloud Service Provider. | |
| Cloud Super | A Cloud Operator that uses other Operators to provide | This document |
| Operator | Cloud Services to the Cloud SP or another Cloud Super | |
| | Operator. | |
| Cloud UNI | Cloud User Network Interface | This document |
| Cloud User | The demarcation point marking the boundary between | This document |
| Network Interface | the responsibility of the Cloud Subscriber and the Cloud | |
| | Service Provider. | |
| Cloud VC | Cloud Virtual Connection | This document |
| Cloud Virtual | An association of two or more Cloud VC End Points. | This document |
| Connection | | |
| Cloud VC EP | Cloud Virtual Connection End Point | This document |
| Cloud Virtual | A logical construct at a Cloud UNI, Cloud ENNI or | This document |
| Connection End | Cloud Application Interface to which a subset of the | |
| Point | Cloud Service PDUs passing over that interface is | |
| | mapped. | |

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| Term | Definition | Reference |
|-----------------------|--|-----------------|
| Connectivity | The lowest protocol layer that is preserved as a Cloud | This document |
| Laver | Service PDU passes over a Cloud VC | This document |
| Connectivity | An organization that provides connectivity services to a | This document |
| Operator | Cloud Super Operator, Connectivity Super Operator, or | This document |
| Operator | Cloud Super Operator, Connectivity Super Operator, of | |
| Commontivity | A Compositivity Operator that uses other Compositivity | This do sum and |
| | A Connectivity Operator that uses other Connectivity | This document |
| Super Operator | Operators to provide connectivity services. | TT1 (|
| Container | A virtual runtime environment that runs on top of a | This document |
| | single operating system kernel and emulates an | |
| | operating system rather than the underlying hardware. | |
| IaaS | Infrastructure as a Service | NIST 500-291 |
| | | [1] |
| Infrastructure as | A category of Cloud Services where the capability | This document; |
| a Service | provided by the Cloud Service Provider to the Cloud | adapted from |
| | Subscriber is to provision processing, storage, intra- | NIST 500-291 |
| | cloud network connectivity services (e.g. VLAN, | [1] |
| | firewall, load balancer, and application acceleration), | |
| | and other fundamental computing resources of the cloud | |
| | infrastructure where the Cloud Subscriber is able to | |
| | deploy and run arbitrary applications. | |
| Internet VC | Internet Virtual Connection | This document |
| Internet Virtual | An association between one or more Cloud VC End | This document |
| Connection | Points and the Internet. | |
| NFVI | Network Functions Virtualization Infrastructure | ETSI GS NFV- |
| | | INF 001 [3] |
| Network | Totality of all hardware and software components which | ETSI GS NFV- |
| Functions | build up the environment in which VNFs are deployed. | INF 001 [3] |
| Virtualization | | |
| Infrastructure | | |
| Operator | An organization with administrative control over | This document |
| 1 | connectivity and/or applications, and which provides | |
| | Services to other Operators or to Service Providers. In | |
| | this document, "Operator" is to be read as meaning | |
| | "Cloud Operator" or "Connectivity Operator". | |
| Operator Cloud | A Cloud Service provided by a Cloud Operator to a | This document |
| Service | Cloud SP or a Cloud Super Operator. | |
| Operator Cloud | Operator Cloud Virtual Connection | This document |
| VC | | |
| Operator Cloud | A Cloud VC that is part of an Operator Cloud Service | This document |
| Virtual | agreed between an Operator and a Cloud SP or a Cloud | |
| Connection | Super Operator. | |
| Operator Cloud | Operator Cloud Virtual Connection End Point | This document |
| VC EP | | |
| Operator Cloud | A Cloud VC EP that is part of an Operator Cloud | This document |
| VC End Point | Service. | |



| Term | Definition | Reference |
|------------------|---|----------------|
| PaaS | Platform as a Service | NIST 500-291 |
| | | [1] |
| PDU | Protocol Data Unit | MEF 12.2 [8] |
| Platform as a | A category of Cloud Services where the capability | This document; |
| Service | provided to the Cloud Subscriber is to deploy user- | adapted from |
| | created or acquired applications onto the cloud | NIST 500-291 |
| | infrastructure using platform tools supported by the | [1] |
| | Cloud Service Provider. | |
| PNF | Physical Network Function | ETSI GS NFV |
| | | 002 [4] |
| SaaS | Software as a Service | NIST 500-291 |
| | | [1] |
| SECaaS | Security as a Service | Cloud Security |
| | | Alliance [16] |
| Security as a | A category of Cloud Services where the capability | This document |
| Service | provided to the Cloud Subscriber by the Cloud SP is the | |
| | provision of security functions such as firewalls and | |
| | malware detection. | |
| Software as a | Category of Cloud Services where the capability | This document; |
| Service | provided to the Cloud Subscriber is to use the Cloud | adapted from |
| | SP's applications running on a cloud infrastructure. | NIST 500- |
| | | 291[1] |
| Subscriber Cloud | A Cloud Service provided by a Cloud SP to a Cloud | This document |
| Service | Subscriber. | |
| Subscriber Cloud | Subscriber Cloud Virtual Connection | This document |
| VC | | |
| Subscriber Cloud | A Cloud VC that is part of a Subscriber Cloud Service | This document |
| Virtual | agreed between a Cloud Subscriber and a Cloud SP. | |
| Connection | | |
| Subscriber Cloud | Subscriber Cloud VC End Point | This document |
| VC EP | | |
| Subscriber Cloud | A Cloud VC EP that is part of a Subscriber Cloud | This document |
| VC End Point | Service. | |
| VM | Virtual Machine | ETSI GS NFV |
| | | 002 [4] |
| Virtual Machine | A virtualized computation environment which behaves | ETSI GS NFV- |
| | very much like a physical computer/server. | INF 001 [3] |
| VNF | Virtual Network Function | ETSI GS NFV |
| | | 002 [4] |

Table 1 – Terminology and Abbreviations



4 Introduction

In recent years, Cloud Services have grown rapidly with little standardization. This MEF Standard defines an architecture for Cloud Services. The architecture is intended to be a framework within which standard definitions for Cloud Services can be specified. With the common framework, availability of off-the-shelf vendor products for Cloud Services and interoperability among them are facilitated. Furthermore, defined architectural constructs allow the Lifecycle Service Orchestration (LSO) architecture to be expanded and Application Programming Interfaces (APIs) to support Cloud Services to be developed, as in MEF 55.1 [10].

The US National Institute of Standards and Technology (NIST) defined in NIST 500-291 [1] a generic high-level conceptual model for the development of cloud computing architectures and a companion taxonomy. The NIST architecture primarily focuses on the application component of Cloud Service. It does not expand on the connectivity components of the service and their implications on the end-to-end service.

Later, the Open Cloud Connect (OCC) organization defined a reference architecture for Cloud Services in OCC 1.0 [2] consisting of connectivity and applications. This MEF Standard enhances the OCC reference architecture with additional details regarding the use of the Internet for Cloud Services, and aligns terminology with other MEF Standards such as MEF 10.4 [7] and MEF 26.2 [9].

The key objectives of the Cloud Services architecture defined in this MEF Standard are:

- To define formally the terminology and roles of actors for Cloud Services; and
- To define interfaces, connections, and connection end points among actors involved in Cloud Services to support interoperability; and
- To define the Cloud Services architecture independently of how the Cloud Services are implemented.

The orchestration of Cloud Services is supported by the MEF LSO architecture MEF 55.1 [10]. However, LSO for Cloud Services is outside the scope of this MEF Standard.



5 Actors of Cloud Services

A Cloud Service is a service comprising one or more Cloud Applications and connectivity among them that may be accessed by the user of the service from one or more locations. A Cloud Application is defined as a component of a Cloud Service such as compute, storage or software logic, that does not provide connectivity.

A Subscriber Cloud Service is a Cloud Service provided by a Cloud Service Provider (Cloud SP) to a Cloud Subscriber. An Operator Cloud Service is a Cloud Service provided by a Cloud Operator or a Cloud Super Operator to a Cloud SP or a Cloud Super Operator.

The key actors of Cloud Services are defined as:

- Cloud Subscriber: The end-user (i.e., a person or organization) that maintains a business relationship with and uses Cloud Services from a Cloud Service Provider.
- Cloud SP: An organization that provides Cloud Services to Cloud Subscribers.
- Operator: An organization with administrative control over connectivity and/or applications, and which provides Services to other Operators or to Service Providers. In this document, "Operator" is to be read as meaning "Cloud Operator" or "Connectivity Operator".
- Cloud Operator: An organization that provides Cloud Services to Cloud Service Providers and/or Cloud Super Operators.
- Cloud Super Operator: A Cloud Operator that uses other Operators to provide Cloud Services to the Cloud SP or another Cloud Super Operator.
- Connectivity Operator: An organization that provides connectivity services to a Cloud Super Operator, Connectivity Super Operator, or Cloud SP.
- Connectivity Super Operator: A Connectivity Operator that uses other Connectivity Operators to provide connectivity services.

Figure 1 shows an example with a Cloud Subscriber, a Cloud SP, and several Operators. The Cloud Subscriber buys a Cloud Service from the Cloud SP. The Cloud SP implements the service by subcontracting with two Connectivity Operators (Connectivity Operator-A and Connectivity Operator-B) and two Cloud Operators (Cloud Operator-A and Cloud Operator-B) to buy two connectivity services and two Cloud Services. The Cloud SP is responsible for stitching these four services together so as to provide the Cloud Service requested by the Cloud Subscriber.



Figure 1 – Example of Actors of Cloud Services with Operators

A Cloud SP is responsible for providing the Cloud Service to a Cloud Subscriber using their own resources and/or those of Connectivity Operator(s) and Cloud Operator(s). Figure 2 shows an example with a Cloud Subscriber, a Cloud SP, Operators, and Super Operators. The Cloud Service provided to the Cloud Subscriber is implemented by the Cloud SP by subcontracting with three Operators (i.e., the Connectivity Super Operator, Cloud Operator-A, and the Cloud Super Operator). The Connectivity Super Operator implements the connectivity service provided to the Cloud SP by subcontracting with two further Connectivity Operators, Connectivity Operator-A and Connectivity Operator-B. Note that as these are roles, it is possible that one of the Connectivity Operators is in fact the same organization as the Connectivity Super Operator. Similarly, the Cloud Super Operator implements the Cloud Service that they are providing to the Cloud SP by subcontracting with Cloud Operator-B and Connectivity Operator-C.

Note that in this example, the Cloud SP does not have a direct business relationship with Connectivity Operators A, B or C, or with Cloud Operator-B, and may not even be aware that the services they have bought from the Super Operators have been subcontracted to other Operators.



Figure 2 – Example of Actors of Cloud Services with Super Operators

The Cloud SP is responsible for delivering Cloud Services that can be accessed from the Cloud Subscriber locations. The Cloud Subscriber connects to the Cloud SP directly via a private network, or indirectly via the Internet (see Section 7.5.1). In the latter case, the Cloud Subscriber and Cloud SP are each responsible for their own connectivity to the Internet. The Cloud SP, in turn, either selects and contracts with one or more Connectivity Operators or Cloud Operators to deliver the Cloud Services at the requested locations, or directly delivers them. Typically, the Cloud SP is the single point of contact for the Cloud Subscriber; the Cloud Subscriber does not have a direct business relationship with the Cloud Operators or Connectivity Operators; and might not even be aware that the Cloud SP has subcontracted part or all of the service implementation to them.

There is no constraint on the type of organization that can act as the Cloud SP. For example, a system integrator, a mobile Operator, an Internet Service Provider, or a Cloud Operator can be a Cloud SP. When a Cloud Operator or Connectivity Operator acts as the Cloud SP, this means that the Cloud Service provided to the Cloud Subscriber is implemented partly using the Cloud SP's network and infrastructure, and partly using services purchased from other Operators. Furthermore, Cloud Subscribers can act as their own Cloud SP in which case they will contract with various Cloud Operators and Connectivity Operators.

Note that Cloud SP, Cloud Operator, and Connectivity Operator are roles that an organization may play with respect to a given Cloud Service. The same organization may be a Cloud SP for some services, a Cloud Operator for some services, and a Connectivity Operator for other services.



In order to provide a connectivity service to a Cloud SP, a Connectivity Operator may act as a Connectivity Super Operator by contracting with one or more Connectivity Operators. Similarly, in order to provide a Cloud Service to a Cloud SP, a Cloud Operator may act as a Cloud Super Operator by contracting one or more Connectivity and/or Cloud Operators. An example configuration for Connectivity Super Operator and Cloud Super Operator is given in Figure 2.



6 Characteristics of Cloud Services

Cloud Services include connectivity and application functionalities with operational flexibility in service ordering, provisioning, monitoring, and billing. In Cloud Services, networking, compute, storage, and applications are treated together in providing a service to a Cloud Subscriber.

Capabilities provided by virtualized functions and virtualized infrastructure such as Virtual Network Functions (VNFs) and Network Function Virtualization Infrastructure (NFVI) as defined by ETSI GS NFV002 [4] are frequently utilized in implementing Cloud Services. For operational flexibility, virtualized components are widely used. For example, a cloud security service implemented using a virtual firewall can be placed by the Cloud SP at the Cloud Subscriber's premises, in a data center in the core of the network, or anywhere in between, based on the Cloud Subscriber's requirements in terms of security, performance, etc. The firewall can be instantiated dynamically and charged based on its usage.

Figure 3 depicts an example of a security gateway service provided by a Cloud SP to a Cloud Subscriber for communication between its headquarters and branches, and for accessing the Internet. In this example the service is implemented using a virtual firewall and a virtual router in the Cloud SP's data center, along with storage and compute resources required to support the security gateway function. The service also includes connectivity between the enterprise sites and the security gateway, and connectivity from the security gateway to the Internet.



Figure 3 – Example of the Cloud Subscriber View of a Security Gateway Service



Some of the characteristics of Cloud Services are listed below. A Cloud Service may expose some or all of these characteristics:

- combining connectivity and applications with compute, storage and networking resources;
- consisting of network functions implemented using just non-virtualized components (e.g., PNFs) or both virtualized components (e.g., VNFs) and non-virtualized components (e.g., PNFs) that may or may not be fully exposed to Cloud Subscriber;
- consisting of applications implemented using virtualized components such as VMs, Containers, and VNFs that may or may not be fully exposed to Cloud Subscriber;
- consisting of connections provided by one or more Cloud Operator(s) and Connectivity Operator(s);
- providing the ability for the Cloud Subscriber to modify the Cloud Service dynamically within pre-agreed limits;
- supporting service monitoring and usage-tracking by Cloud Subscribers;
- collaboration among Connectivity and Cloud Operators in providing resources;
- supporting dynamic scalability of resources;
- supporting various high availability options from physical layer to application layer; and
- supporting "pay as you use" (i.e. usage based billing).

Services described by NIST 500-291 [1] such as Infrastructure as a Service (IaaS) and Platform as a Services (PaaS) focus primarily on the application component of Cloud Service. They do not expand on the connectivity components of the service and its implications on the service. The description of Cloud Services Architecture in this document expands upon how connectivity is used to reach the application components.

The connectivity component can be provided as part of the Cloud Service or over the Internet as provided by one or more Internet Service Provider(s) (ISPs). Internet connectivity for Cloud Services is described in Section 7.5.1. Private network connectivity using Carrier Ethernet Services is described in MEF 47.1 [6].

A Cloud Service may be delivered by the resources of multiple Cloud Operators (e.g. network, compute and storage) within the domains of these operators. For example, the Security Gateway Service depicted in Figure 3 can be provided by multiple Operators as illustrated in Figure 4 where the Security Gateway is provided by a Cloud Operator while connectivity to the Gateway is provided jointly by the Connectivity Operator and the Cloud Operator. The Connectivity Operator and the Cloud Operator shown in Figure 4 are not visible to the Cloud Subscriber, but are visible to the Cloud SP.



Figure 4 – Example of the Cloud SP View of a Security Gateway Service

In addition, resources at Cloud Subscriber locations may be fully or partially owned and maintained by one of the Operators involved in delivering the service. For example, customer premises hardware could be provided by the Operator while software is provided by the Cloud Subscriber.



7 Architectural Components of Cloud Services

The architectural components of Cloud Services are as follows:

- Cloud Application,
- Cloud User Network Interface (Cloud UNI),
- Cloud Application Interface,
- Cloud External Network Network Interface (Cloud ENNI),
- Cloud Virtual Connection (Cloud VC),
- Cloud Virtual Connection End Point (Cloud VC EP), and
- Internet Virtual Connection (Internet VC).

These architectural components are defined and described in the following subsections.

7.1 Cloud Application

A Cloud Application is a component of a Cloud Service such as compute, storage, software logic that does not provide connectivity. Figure 5 illustrates an example of a Cloud Voice over IP (Cloud VoIP) Service for a Cloud Subscriber consisting of a headquarters (HQ) and two branches. The Cloud Service is formed of

- two Cloud Applications, a Virtual Session Border Controller (vSBC) and a Virtual Firewall (vFW) supporting VoIP,
- the interfaces between the Cloud Subscriber and the Cloud SP, and
- the connectivity to the application where blue lines represent connections as described in Section 7.4.

The vSBC and vFW Cloud Applications could consist of software, compute and storage resources. They represent the components of the Cloud Service excluding the connectivity.



Figure 5 – Example of a Cloud VoIP Service

7.2 Interfaces

The subsections below describe the three different interfaces used in Cloud Services (i.e., Cloud UNIs, Cloud ENNIs, and Cloud Application Interfaces).

7.2.1 Cloud UNI

A Cloud UNI is the demarcation point marking the boundary between the responsibility of the Cloud Subscriber and the Cloud Service Provider. It enables a Cloud Subscriber to connect to and run applications provided by a Cloud SP. The Cloud UNI is depicted in Figure 6.



Figure 6 – Cloud UNI

The Cloud UNI demarcates domains under the responsibility of the Cloud SP and domains under the responsibility of the Cloud Subscriber. Multiple services can be multiplexed over this interface using logical connections.

The Cloud Subscriber in Figure 6 can be an enterprise with multiple employees sharing the same Cloud UNI.

7.2.2 Cloud ENNI

A Cloud ENNI is a demarcation point representing the boundary of responsibility between two Cloud Operators or between a Connectivity Operator and a Cloud Operator¹. A Cloud SP can implement the Cloud Service that it provides to the Cloud Subscriber by subcontracting with one or more Connectivity Operators and/or Cloud Operators.

Two Operators connect to each other via a Cloud ENNI as depicted in Figure 7.

¹ Note that the interface between two Connectivity Operators is out-of-scope for this MEF Standard.



(b) Cloud ENNI between Connectivity Operator and Cloud Operator Figure 7 – Cloud ENNI Variations

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7.2.3 Cloud Application Interface

A Cloud Application Interface is the demarcation point between a Cloud Application and one or more Cloud VC EPs as described in Section 7.4. Unlike a Cloud UNI or Cloud ENNI, a Cloud Application Interface does not represent the demarcation of responsibility between two organizations as the Cloud SP or Cloud Operator providing a Cloud Service is responsible for the functionality on both sides of the Cloud Application Interface. Instead, the Cloud Application Interface marks the boundary between Cloud Applications and elements of connectivity for the Cloud Service, so that connectivity between Cloud UNIs or Cloud ENNIs and Cloud Applications, or between Cloud Applications in the same Cloud Service, can be specified. A Cloud Application may have one or more Cloud Application Interfaces, but each Cloud Application Interface is for a specific Cloud Application in a specific Cloud Service.

For example, if the Cloud Application is implemented using a VNF in a VM or Container, the Cloud Application Interface would be the virtual interface to the VNF, as shown in Figure 8. The same applies if the Cloud Application is the VM or Container (as in an IaaS service), as shown in Figure 9.



Figure 8 – Cloud Application Interface for VNF



Figure 9 – Cloud Application Interface for VM and Container

7.3 Cloud Service PDU

A Protocol Data Unit (PDU) that is exchanged at a Cloud UNI, a Cloud ENNI, or a Cloud Application Interface is called a Cloud Service PDU.

The Connectivity Layer for a Cloud Service is defined as the lowest protocol layer that is preserved as a Cloud Service PDU passes over a Cloud VC. For example, if the lowest layer preserved is the IP layer, the Cloud Service PDU is an IP packet that carries all the information related to the IP layer and the layers above. For many Cloud Services, the Connectivity Layer is the IP layer, although Cloud Services based on Carrier Ethernet or Optical transport are also possible. Protocol layers below the Connectivity Layer for the Cloud Service are only relevant at a particular UNI, ENNI or Cloud Application Interface, and are not carried over the Cloud VC.

The Cloud Service PDUs transmitted across the Cloud UNI toward the Cloud SP are considered ingress Cloud Service PDUs. The Cloud Service PDUs transmitted across the Cloud UNI toward the Cloud Subscriber are considered egress Cloud Service PDUs. Similarly, the Cloud Service PDUs exchanged across a Cloud ENNI from another Operator are considered ingress Cloud Service PDUs by the receiving Operator and egress Cloud Service PDUs by the transmitting Cloud Operator.



7.4 Cloud Virtual Connection (Cloud VC) and Cloud VC End Points (Cloud VC EPs)

A Cloud VC is an association of two or more Cloud VC End Points (Cloud VC EPs). A Cloud VC EP is a logical construct at a Cloud UNI, Cloud ENNI or Cloud Application Interface to which a subset of the Cloud Service PDUs passing over that interface is mapped. A Cloud VC provided by a Connectivity Operator could be, for example, an L1VC as in MEF 63 [12] and MEF 64 [13], an EVC in MEF 10.4 [7], an OVC as in MEF 26.2 [9], an IPVC as in MEF 61.1 [11], or an SD-WAN Virtual Connection as in MEF 70 [15]. A Cloud VC provided by a Cloud Operator or Cloud SP is similar to these but may terminate at a Cloud Application Interface as well as at a UNI or ENNI.

A Subscriber Cloud Virtual Connection (Subscriber Cloud VC) is defined as a Cloud VC that is part of a Subscriber Cloud Service agreed between a Cloud Subscriber and a Cloud SP. A Cloud VC EP that is part of a Subscriber Cloud Service is called a Subscriber Cloud VC EP. A simple example is shown in Figure 10. A Subscriber Cloud VC associates two or more Subscriber Cloud VC EPs where the Cloud VC EPs are located at Cloud UNIs or Cloud Application Interfaces. Section 7.4.1 below describes the Cloud VC EP in detail.



Figure 10 – Example of a Subscriber Cloud VC

A Cloud VC that is part of an Operator Cloud Service agreed between an Operator and a Cloud SP or a Cloud Super Operator is called an Operator Cloud VC. A Cloud VC EP that is part of an Operator Cloud Service is called an Operator Cloud VC EP. A Subscriber Cloud VC may be



implemented using a number of Operator Cloud VCs. Figure 11 shows two examples of Operator Cloud VCs, one provided by a Connectivity Operator and another provided by a Cloud Operator, that together could be used to implement the Subscriber Cloud VC shown in Figure 10. An Operator Cloud VC associates two or more Operator Cloud VC EPs where each Operator Cloud VC EP is located at a Cloud UNI, a Cloud ENNI or a Cloud Application Interface.



Figure 11 – Example of Operator Cloud Virtual Connections

7.4.1 Cloud Virtual Connection End Point (Cloud VC EP)

As defined above, a Cloud VC EP is a logical construct at a Cloud UNI, Cloud ENNI, or Cloud Application Interface to which a subset of the Cloud Service PDUs passing over that interface is mapped. As an example, the particular set could be identified by an application identifier, a source and/or destination IP address, a C-Tag VLAN ID, etc., depending on the content of the Cloud Service PDU.

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At a given Cloud UNI, Cloud ENNI, or Cloud Application Interface, there can be multiple Cloud VC EPs for different Cloud VCs. At a Cloud UNI or Cloud ENNI, these Cloud VCs can be part of the same or different Cloud Services. However, at a Cloud Application Interface, if there are multiple Cloud VC EPs, they are all for Cloud VCs that are part of the same Cloud Service.

Cloud Service PDUs are mapped to Cloud VC EPs using fields at or above the Connectivity Layer. If the Connectivity Layer for the Cloud Service is the IP layer, then the set of Cloud Service PDUs for the Cloud VC EP can be identified with fields in the IP packet header or payload; for example:

- IP Source Address
- IP Destination Address
- Version
- Differentiated Services (DS)
- Protocol for IPv4 and Next Header for IPv6
- TCP port numbers

If the Connectivity Layer for the Cloud Service is the Ethernet Layer, then a set of Cloud Service PDUs for the Cloud VC EP can be identified with fields in the Ethernet frame header (e.g., VLAN IDs, etc.).

Note that several Cloud UNIs at one Connectivity Layer can share an interface at a lower layer; for example, if the Connectivity Layer is IP, several Cloud UNIs can be multiplexed over the same physical Ethernet interface using VLANs.

7.4.2 Internet VC

An Internet VC is an association between one or more Cloud VC EPs and the Internet. Figure 12 shows an example of an Internet VC with a Cloud VC EP at a UNI. An Internet VC where all the Cloud VC EPs are at UNIs or ENNIs could be, for example, an IPVC as in MEF 61.1 [11]. An Internet VC that has a Cloud VC EP at a Cloud Application Interface is similar to this, but connects a Cloud Application to the Internet rather than connecting a Cloud Subscriber or another Operator, as depicted in Figure 13.



Figure 12 – Example Internet VC with a Cloud VC EP at a UNI



Figure 13 – Example Internet VC with a Cloud VC EP at a Cloud Application Interface

From a Cloud Subscriber's perspective, an Internet VC provides general access between the location of the Cloud VC EP (i.e., a UNI, an ENNI or a Cloud Application Interface) and a range of content on the Internet. The location of the content is typically unknown to the Cloud Subscriber, and in particular could be served from within the Cloud SP's domain or from outside it. This means



that, as shown in Figure 12 and Figure 13, there is no clear boundary between the Internet VC and the Internet itself, and hence there is no Cloud VC EP connecting the Cloud VC to the Internet. A key characteristic of an Internet VC is that from the Cloud Subscriber's perspective, it does not provide any special treatment for traffic to or from a particular location or resource.

7.5 Subscriber View, SP View, and Operator View of Cloud Services

The Cloud Subscriber view, SP view, and Operator view of a Cloud Service are depicted from Figure 14 through Figure 24. Cloud Subscribers are concerned only about the Cloud Service and not about the service implementation while Cloud SPs and Operators are concerned about the Cloud Service implementations.

7.5.1 Cloud Subscriber Views of Cloud Services

Examples of the Cloud Subscriber view of a Cloud Service provided by a Cloud SP are depicted in Figure 14. The Cloud Subscriber view consists of the Cloud UNI where they connect to the Cloud SP, along with the Subscriber Cloud VCs, Subscriber Cloud VC EPs and Cloud Applications that form the Cloud Service.





The case where a Cloud Subscriber connects to a Cloud SP over the Internet is depicted in Figure 15. The physical connectivity to the Internet and the connection to the Cloud SP applications and services are visible to the Cloud Subscriber.

The responsibility for connectivity between the Cloud Subscriber and the Cloud SP is distributed between the Cloud Subscriber, the Cloud SP, and the involved Internet Service Providers (ISPs), as described below.

In this scenario, the Cloud Subscriber uses an Internet Access Service (see MEF 69 [14]) from their ISP to connect to the Cloud SP, and hence to the Cloud Applications that are part of the Cloud Service purchased from the Cloud SP. The Cloud SP is responsible for their own access to the Internet, and might use the same or different ISPs than the Cloud Subscriber.



Figure 15 – Example of the Subscriber View of Cloud Services Accessed via the Internet

The examples above show cases where the Cloud Service is accessed via a single Cloud UNI, includes a single Subscriber Cloud VC, and where each Cloud Application has a single Cloud Application Interface. Figure 16 illustrates a case where the Cloud Application has two Cloud Application Interfaces where one connects the Cloud Subscriber via a Subscriber Cloud VC and another connects to the Internet via an Internet Virtual Connection (Internet VC). This configuration could be useful, for example, for a firewall service where the Cloud Subscriber wants all traffic to or from the Internet to pass through the firewall.



Figure 16 – Example of Subscriber View of a Cloud Service which Includes Internet Access

Note that the case shown in Figure 16 differs from that shown in Figure 15. In Figure 15, the Cloud Subscriber can access the Cloud Application over the Internet, for example using an IP-Sec tunnel, but the Cloud Application itself does not have general access to, and cannot be generally accessed from, the Internet. However, in Figure 16, the Cloud Application can access and be accessed from the Internet.

Figure 17 shows a more complex case where the Cloud Service comprises two Cloud UNIs, three Cloud Applications, two Cloud VCs, and an Internet VC. One Cloud VC is a multipoint Cloud VC, connecting the two Cloud UNIs with the two Cloud Applications, and another is a point-to-point Cloud VC connecting two Cloud Applications. The Internet VC provides one of the Cloud Applications access to the Internet.



Figure 17 – Example of Subscriber View of a Complex Cloud Service

7.5.2 Cloud SP View of Cloud Services

The Cloud SP view includes the Cloud Subscriber view, for example as shown in Figure 14, and the details of the service implementations which may use one or more Cloud Operators.

Figure 18 depicts an example of the internals of the Cloud Service shown in Figure 14 (a) that is provided to a Cloud Subscriber by a Cloud SP. Cloud Applications are provided by a Cloud Operator (Operator-B) and the connectivity to the Cloud Operator-B is provided by a Connectivity Operator (Operator-A). The coordination between Operator-A and Operator-B is provided by the Cloud SP. Operator-A, Operator-B, or a third party can be the Cloud SP acting as the single point of contact for the Cloud Subscriber.

The Cloud ENNI between two Operators is visible to each Operator. However, the service (including connectivity and/or applications) provided by each Operator to the Cloud SP is not visible to the other Operator unless the other Operator is the Cloud SP. Furthermore, the Cloud UNI is visible to the Cloud Operator-A.

In Figure 18, a Connectivity Operator (Operator-A) provides the connectivity required for the Cloud Subscriber to reach the Cloud Operator (Operator-B), and therefore the service provided by Operator-A to the Cloud SP can be considered as a Network as a Service (NaaS). The Cloud Operator (Operator-B) provides Cloud Application(s) such as Software as Service (SaaS), Platform as a Service (PaaS), or Infrastructure as a Service (IaaS) to the Cloud SP.



Figure 18 – Example of Cloud SP View of Cloud Services Provided by Two Operators

In the Cloud Service example shown in Figure 18, the Cloud Subscriber can have the role of the Cloud SP. In this case, the Cloud Subscriber needs to arrange separate services with each Operator in order to obtain the desired overall service.

Figure 19 depicts an example of the internals of the Cloud Service shown in Figure 14 (b) that is provided to a Cloud Subscriber by a Cloud SP. In this example, Cloud Services are provided by a Connectivity Operator (Operator-A) and two Cloud Operators (Operator-B and Operator-C) to the Cloud SP. The Operator-A connects a Cloud Subscriber to Operator-B while Operator-B and Operator-C provide applications and connectivity via agreement between each of the three Operators and the Cloud SP.



Figure 19 – Example of Cloud SP View of Cloud Services Provided by Three Operators

Various types of Subscriber Cloud Services can be supported in this configuration. For an example implementation of a VoIP service, Operator-B supports a session border controller (SBC) application with a virtual SBC (vSBC) VNF while Operator-C supports a firewall (FW) application with a virtual FW (vFW) VNF.

In this configuration, the Cloud Subscriber can use both applications simultaneously or one at a time.

Figure 20 depicts another example of the internals of the Cloud Service shown in Figure 14 (a) that is provided to a Cloud Subscriber by a Cloud SP. In this example, two applications (e.g., vSBC and vFW) form a Service Function Chain (SFC) as defined in IETF RFC7498 [5], which is an ordered set of abstract service functions and ordering constraints that are applied to packets and/or frames and/or flows selected as a result of classification. The Cloud Subscriber uses both applications simultaneously.



Figure 20 – Example of a Service Function Chaining

Figure 21 (a) depicts the Subscriber view of another case where Cloud SP provides SaaS to a Cloud Subscriber. In Figure 21 (b), the SaaS application implemented by Cloud SP uses the IaaS service provided by the Cloud Operator to the Cloud SP. The SaaS application is nested within the IaaS application in providing the SaaS to the Cloud Subscriber.



(b) Example Cloud SP view of SaaS nested within IaaS

Figure 21 – Subscriber View and Cloud SP View of a Nested Service Implementation



The Subscriber Cloud Service depicted in Figure 14 (a) could be decomposed and delivered as in Figure 22. In this example, Cloud Operator-B provides a Cloud Application to the Cloud Service Provider (Cloud Operator-A) which is providing another Cloud Application. The two Cloud Applications are connected to each other over the Internet, for example using an IP-Sec tunnel.



Figure 22 – Example Cloud SP View with Cloud Operators Connected over the Internet

7.5.3 Operator View of Cloud Services

In a Subscriber Cloud Service supported by multiple Operators, an Operator has visibility of the Cloud ENNI with an adjacent Operator but typically does not have visibility of another Operator's internals. A Cloud SP coordinates the implementation activities among Operators to provide the Cloud Service to the Cloud Subscriber as illustrated in Figure 18 through Figure 22. Some examples are shown in Figure 23 and Figure 24.

The Operator view of a Cloud Service differs for a Connectivity Operator and a Cloud Operator. The Cloud Operator view of a Cloud Service consists of Operator Cloud VCs, Operator Cloud VC EPs, Cloud Application Interfaces, and Cloud Applications, as well as Cloud ENNIs with any adjacent Operators, for example, as depicted in Figure 23 (a), or Cloud UNIs and Cloud ENNIs if the Cloud Operator interfaces to both Cloud Subscribers and Operators, for example, as depicted in Figure 23 (b).





(b)

The Operator view of a Cloud Service for the Connectivity Operator consists of Operator Cloud VCs, Operator Cloud VC EPs; and Cloud ENNIs with adjacent Operators, for example, as depicted in Figure 24 (a), or the Cloud UNIs and the Cloud ENNIs if the Connectivity Operator interfaces to both Cloud Subscribers and Operators, for example, as depicted in Figure 24 (b).



Figure 24 – Examples of a Connectivity Operator View of a Cloud Service



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