End-to-End NFV - vEPC Service Orchestration

End-to-End Service Orchestration of a Virtual EPC Network Function
Virtualization use case on Intel® Architecture®

Audience and Purpose

Network Function Virtualization (NFV) allows the possibility of using standard volume hardware instead of purpose-built hardware and leveraging standard IT virtualization and cloud technologies to reduce total cost of ownership and increase the service innovation and scale, for example in the Evolved Packet Core. This level of automation in provisioning and service delivery can become quite complicated and require sophisticated orchestration software of these virtualized resources for the service operator to truly benefit from the promise. This technical document describes how this can be accomplished with orchestration software from Cyan that builds on Red Hat Linux® and OpenStack® running on Intel® Xeon® processor powered platforms from Dell.

The collaboration has been officially accepted as compliant with the ETSI NFV ISG Proof of Concept framework with operator sponsorship.
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Executive Summary

Today’s networks are overly complex, partly due to an increasing variety of proprietary, fixed-function appliances that are unable to deliver the agility and economics needed to address constantly changing market requirements. This is because network elements have traditionally been optimized for high packet throughput at the expense of flexibility, thus hampering the development and deployment of new services. Another concern is that rapid advances in technology and services are accelerating the obsolescence of installed hardware; and in turn, hardware isn’t keeping up with other modes of feature evolution, which constrains innovation in a more network-centric, connected world. Conventional communications infrastructures that rely on dedicated proprietary hardware to implement each network function not only increases cost and complexity, but also this hardware-centric, siloed infrastructure approach can impede business agility and innovation. Scalability is limited, and deployment is often sluggish, as expensive new servers must be acquired and provisioned. Staffing costs escalate, as increased expertise is needed to design, integrate, operate, and maintain the various network function appliances. All of these issues make it difficult to innovate and compete.

Network function virtualization (NFV) can provide the infrastructure flexibility and agility needed to successfully compete in today’s evolving communications landscape. NFV implements network functions in software running on a pool of shared commodity servers instead of using dedicated proprietary hardware. This virtualized approach decouples the network hardware from the network functions and results in increased infrastructure flexibility and reduced hardware costs. Because the infrastructure is simplified and streamlined, new and expanded services can be created quickly and with less expense. A multi-layer (optical, Ethernet, TDM, SONET, etc.) and multi-vendor Software Defined Networking (SDN) based end-to-end service orchestration and NFV management solution is essential to connecting the NFV running in the data center to the end user and operationalizing it in a service provider network.

Intel, Red Hat, Dell, Cyan, and Connectem are collaborating to demonstrate the technical and business viability of carrier-grade NFV deployment and service orchestration using cloud computing technologies. The collaboration delivers a Proof of Concept (PoC) that demonstrates a novel NFV-based orchestration solution for an operator’s cloud-based mobile Evolved Packet Core (EPC). Any mobile operator wanting to migrate to the cloud and operationalize the solution in their end to end network is a prototype customer for this initiative. With the help of Intel, Red Hat, Dell, Cyan, and Connectem, Intel® Xeon® processor-based servers help save up-front acquisition costs (CapEx) due to the economies of scale associated with Commercial Off-The-Shelf (COTS) hardware, reduce power and cooling requirements (OpEx), and provide a common infrastructure, significantly simplifying maintenance compared with the traditional fixed-form, hardware-based different appliances.

1.1 Partners

This reference architecture demonstrates an open network function virtualization infrastructure (NFVI) ecosystem comprised of multiple vendors with a single orchestrator to provision, deploy, and manage a mobile network-service comprised of a vEPC deployed on COTS hardware infrastructure and a Layer2 mobile backhaul network. This section provides an overview of the various hardware and software vendors that partnered to demonstrate the NFV vEPC use case that as operationalized in a carrier network using end to end service orchestration for ease of integration, deployment, management, scaling and fault detection.
Linux OpenStack® Platform controls the overall foundation solution and provides an interface for a wide variety of network orchestration software tools.

1.1.3 Dell
Dell PowerEdge® C6220 servers harness the capabilities of Intel® Xeon® Processor E5-2600 performance with an excellent combination of compute, memory and I/O (input/output) performance inside Dell’s established shared infrastructure servers to help build the scale-out cloud environment.

1.1.4 Cyan
Blue Planet is Cyan's SDN and NFV orchestration platform, which delivers orchestration, virtualization, and visualization to carrier networks. SDN function in Blue Planet enables the management and orchestration of a multi-layer/multi-vendor carrier networks. Included in this functionality is a path-computation element (PCE) that is used for all service path computation and optimization across multi-layer networks. The Network Function Orchestration (NFVO) component supports the deployment and orchestration of virtualized network functions (VNFs). The Blue Planet NFVO is agnostic to both VNF vendor and function (e.g. vDNS, vEPC). The SDN based service orchestration component enables seamless service delivery across both fixed-network (multi-vendor, multi-layer) and virtualized datacenter resources allowing seamless end-to-end delivery of a service through a single platform. The service orchestration layer orchestrates the end-to-end connectivity of a mobility zone, spanning the vEPC, physical eNodeB, and mobile-backhaul network. Furthermore, Blue Planet is used to control and management both third party and Cyan Z-series packet optical transport switches that are capable of supporting 100G Ethernet connections.

1.1.5 Connectem
The Virtual Core for Mobile (VCM) is a vEPC software solution from Connectem that delivers higher network performance during peak usage periods, where millions of customers could be accessing a mobile network via smartphones or tablets. The Connectem VCM software is a part of a key initiative that reduces the time to deploy new services as software applications on general-purpose computing platforms. Connectem VCM architecture and software have been developed to comply with the best practices to meet the strict service requirements expected of the Mobile Broadband carriers.

2 Business Proposition
Communications companies face increased competition as the lines blur between segments (e.g., voice, Internet, cable). Network operators must provide new and differentiated services and offerings, within the confines of tight budgets, to remain competitive. Conventional communications infrastructures are based on dedicated network hardware hold businesses back with slow, expensive, difficult to scale infrastructure with increased costs from complexity and reduced business agility. Today’s infrastructures are composed of many different Network Elements (NEs):

- DSL modems, Fiber transceivers
- SONET/SDH ADMs, OTN switches, ROADMs
- Ethernet switches, IP routers, MPLS LSRs, BRAS, SGSN/GGSN
- NATs, Firewalls, IDS, CDN, WAN acceleration, DPI
- VoIP gateways, IP-PBXes, video streamers, performance monitoring
- Mobile communications systems (Evolved Packet Core)

Network operators are slowed down by the inefficiencies and inflexibilities of the traditional networks and network functions against various challenges in the market place. Over-the-top (OTT) content providers are reaping most of the benefits of the infrastructure and services deployed and invested by carriers. Consumers expect such services to go down in price as the on-demand availability, bandwidth, resiliency, QoS, mobility and speed go up. On the other hand, proprietary, fixed-form hardware based NEs are taking longer to standardize, design, acquire, and learn how to operate, and are becoming more complex and expensive to maintain. Figure 1 illustrates that unless carriers can more efficiently scale their operations and deliver services, the long term viability of the current business model is at risk.

NFV aims to address these problems by evolving standard IT virtualization technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage that can be located in data centers, network PoPs or on customer premises. This involves the implementation of network functions in software, that can run on a range of general purpose hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need for installation of new equipment. VNFs potentially offer many benefits including, but not limited to:

- Reduced equipment diversity and reduced power consumption through consolidating equipment and exploiting the economies of scale of the IT industry.
- The separation of hardware and software provides independent scaling.
- Increased speed of time to market by minimizing the typical network operator cycle of innovation.
• Targeted service introduction based on geography or customer sets is possible. Services can be rapidly scaled up or down as required.
• Ability to deploy systems that elastically support various network functional demands and which allow directing the capacity of a common resource pool against a current mix of demands in a flexible manner.

One of the critical aspects of mobile communications, which is expected to grow at staggering speeds, is the EPC infrastructure that is currently implemented with dedicated and proprietary hardware devices. EPC is an IP-based core network for use by LTE and other access technologies. EPC provides mobile core functionality that, in previous mobile generations such as 2G and 3G, has been realized through two separate methods; circuit-switched (CS) for voice was transmitted through circuit switched technology whereas data was transmitted through packet-switched technology. EPC combines data and voice under one roof and provides a simplified, all-IP core network architecture to efficiently provide advanced real-time and media-rich services, with enhanced QoS.

EPC is defined as consisting of the following components:
• Serving Gateway (S-GW)
• Packet Data Network (PDN) Gateway (P-GW)
• Mobility Management Entity (MME)
• Policy and Charging Rules Function (PCRF)

Virtualizing the EPC as software running on commodity resources that are easily provisioned help provide network services in a manner similar to the elastic compute and storage services provided in cloud computing. To use cloud computing technologies within the
network infrastructure as a more flexible, cost effective approach to support both traditional network services and those delivered to application tenants in a cloud computing environment, allows carriers to reap both the benefits of NFV as well as instantly on, scalable, and ubiquitous cloud computing resources.

However, such a cloud computing-based NFV solution needs to be operationalized and well integrated into the carriers’ infrastructure to deliver these benefits. Integration requires collaboration both on the northbound side facing the OSS/BSS layer as well as the southbound side that touches all the network elements that provide end to end communication, including Network Interface Devices (NIDs), cellular towers (eNodeB), switches, routers, packet optical backhaul, gateways, cloud computing, and NFV resources.

2.1 ETSI NFV Industry Specification Group Proof-of-Concept
ETSI’s NFV Industry Specification Group (ISG) has created a framework to coordinate and promote multi-vendor Proof of Concepts (PoCs) illustrating key aspects of NFV ISG work. This collaboration demonstrates an open NFVI ecosystem comprised of multiple vendors with a single orchestrator to provision, deploy, and manage a mobile network-service comprised of a vEPC deployed on COTS hardware infrastructure using industry standard IT cloud technologies and a legacy Layer2 optical mobile backhaul network. The collaboration has been officially accepted to comply with the ISG requirements and published on their portal as an operator sponsored PoC.

3 Overview of vEPC Topology in a Carrier Network
This section describes the functional and logical view of the vEPC orchestration topology in a representative carrier network. Figure 3 shows the main logical components: the Connectem-based vEPC in the Intel Xeon processor-based data center running on 6WIND’s packet processing stack, accelerated by the Intel DPDK and the RedHat Enterprise grade Linux and OpenStack software, the wireless backhaul network based on Carrier Ethernet services provided by the Cyan Z-Series P-OTP network elements, the eNodeB for the RAN components, and the Cyan Blue Planet SDN and NFV Orchestration Platform.

3.1 Key Ingredients
3.1.1 Intel
Intel Xeon processors provide the foundation for innovation in NFV by powering the COTS hardware with performance, power efficiencies, virtualization, and manageability features that support automation of the virtualized data centers and clouds and that are flexible, efficient, cost-effective, and can be scaled. Technologies like Intel integrated I/O, that reduces latency, and Intel® Data Direct I/O Technology, that improves I/O performance through direct storage to cache communication, provide fast data movement and accelerate network and storage communications by eliminating network bottlenecks. Advanced Programmable Interrupt Controller virtualization (APICv) reduces virtualization overhead to improve performance and scalability.
10 Gigabit Intel® Ethernet Converged Network Adapters improve performance and lower memory latency, while wide internal data paths eliminate performance bottlenecks by efficiently handling large address and data words.

Intel DPDK
In addition to making continuous improvements in the silicon to enhance packet processing, Intel DPDK libraries and optimized NIC drivers improve packet processing throughput on Intel architecture (from Intel Xeon processors to Intel® Atom™ processors) by using a run-to-completion polling mode driver that delivers the packets directly to the applications in user space and hence provides a framework and the performance for NPU workloads on Intel Architecture cores. It provides a simple API interface using standard tool chains to provide an Environment Abstraction Layer with primarily platform-specific boot guidelines and initialization code that eases application porting effort. The libraries also provide commonly used functions like queue and buffer management, packet flow classification.

• **Memory Manager**: Responsible for allocating pools of objects in memory. It makes use of 2M & 1G hugepages and cache aligned structures called pools and uses a ring to store free objects. It also provides an alignment helper to ensure that objects are padded to spread them equally on all DRAM channels. Basic unit for runtime object allocation is the memory zone and it can contains rings, pools, LPM routing tables, or any other performance-critical structures.

• **Buffer Manager API**: Reduces the time the operating system spends allocating and de-allocating buffers by a significant amount. The Intel DPDK pre-allocates fixed-size buffers which are stored in memory pools. These pools are based on Intel DPDK rings, and as a result are multi-producer and multi-consumer safe, use CAS instructions, provide no locking, and can be used in multi-process environments. The pools are optimized for performance through use of cache alignment and per-core buffer caches so that allocation/freeing can be done without using shared variables. Bulk allocation/freeing support is also provided.

• **Queue Manager API**: Instead of using spinlocks, implements safe lockless queues that allow different software components to process packets, while avoiding unnecessary wait times. Supports bulk enqueue/dequeue for packet-bunching, and implements high and low watermark thresholds for back-pressure/flow control.

• **Flow Classification API**: Provides an efficient mechanism which incorporates Intel® Streaming SIMD Extensions (Intel® SSE) to produce a hash-based on tuple information so that packets can be placed into flows quickly for processing, thus greatly improving throughput. Application examples could be router implementations using "longest-prefix-match" or a security implementation that needs to identify individual flows.

• **Poll Mode Drivers**: The Intel DPDK includes Poll Mode Drivers for 1 GbE and 10 GbE Intel Ethernet* controllers which are designed to work without asynchronous, interrupt-based signaling mechanisms, which greatly speeds up the packet pipeline.
3.1.2 Red Hat

Red Hat provides a complete open source solution that spans to many functional components part of the NFV Infrastructure and NFV Management and Orchestration.

**Red Hat Enterprise Linux**: Red Hat Enterprise Linux is a Linux distribution developed by Red Hat and targeted toward the commercial market. It is released in server versions with support for 32-bit and 64-bit Intel architecture-based systems and Intel Xeon processor-based systems. All of Red Hat’s official support and training at the Red Hat Certification Program center is around the Red Hat Enterprise Linux platform. Red Hat Linux is the common open standards substrate for hosting the core foundational building blocks enabling an end-to-end NFV architecture.

**Red Hat Enterprise Virtualization**: Red Hat Enterprise Virtualization (RHEV), an enterprise virtualization product produced by Red Hat, is based on the KVM hypervisor. Red Hat Enterprise Virtualization uses SPICE protocol and VDSM (Virtual Desktop Server Manager) with a centralized management server. It can acquire user and group information from an Active Directory service or FreeIPA Active Directory emulator, although it does not support standards-based LDAP servers such as OpenLDAP.

Some of the technologies of Red Hat Enterprise Virtualization came from Red Hat’s acquisition of Qumranet (KVM). Other parts derive from oVirt.

**Red Hat Enterprise OpenStack Platform**: Red Hat Enterprise Linux OpenStack Platform combines all the benefits of Red Hat Enterprise Linux with the fastest-growing cloud infrastructure platform from OpenStack.

Red Hat Enterprise Linux provides OpenStack a stable, reliable, and secure foundation, along with the hardware and application support needed to run in demanding, massive-scale enterprise environments. Combining Red Hat’s OpenStack technology with Red Hat Enterprise Linux provides the performance needed to quickly scale infrastructure to tens of thousands of virtual machines to address customer or end-user demands for services quickly and efficiently.
3.1.3 Cyan

Blue Planet Service Orchestration and NFV Management Software

Cyan’s Blue Planet is the first purpose-built SDN/NFV solution designed for service providers to simplify the development, deployment, and orchestration of scalable services. Blue Planet is a scalable platform with open north/southbound APIs to interface with multi-vendor network hardware, OSS systems and applications.

Cyan’s Blue Planet supports plugins for providing the functionality of NFV management and orchestration (see Figure 1 NFV Reference Architecture). It is responsible for the management and orchestration of all resources of a cloud data center, including computing, networking, storage, and virtual machines (VMs). In addition, it is responsible for the lifecycle of virtual functions running within the NFV infrastructure (NFVI). The Blue Planet orchestrator covers the orchestrator and VNF manager functions as described in the ETSI NFV’s architecture diagram. It also supports FCAPS for the NFVI and the virtual network functions (VNFs), including tracking the relationships and interdependencies between the NFVI resources and the VNFs. Blue Planet orchestrator provides the tools for the operator to conduct root cause analysis and to be able to show impacted service when a fault occurs within the NFVI or with a particular VNF. It also supports different NFVI implementations, including different cloud management software and physical servers such as Red Hat OpenStack, HP OpenStack, VMware, Dell Servers, IBM Servers, etc.

Figure 7: Virtualizing WAN and data center resources for end-to-end service orchestration
Blue Planet supports the ability to reliably deploy virtual NFs, run tests, validate correctness and performance, configure necessary devices on the user-content path for policies inline with the service, monitor the health of the service, preemptively address potential issues, scale the performance of the virtual functions based on the network traffic or user needs, and provide real-time upgrades without need to shut down services.

Architectural Details
Blue Planet SDN/NFV Service Orchestration is focused on multi-domain service orchestration. A domain represents a logical grouping of resources under a single administrative umbrella. A domain can represent:

- Resources managed by different organizations or affiliates within a single service provider
- Resources owned by different service providers
- Resources of an enterprise customer

At the core is a generic service orchestrator engine that can be used to deliver any type of digital service: Network as a Service (NaaS), virtual network functions, cloud services, etc. The goal is to enable service providers or service brokers the ability to offer new types of aggregated services (a service composed of multiple individual services).

The software provides a plugin architecture to support interfacing with multiple domains. For each unique domain type the software supports a "domain plugin." Examples of domain plugins:

- NaaS - Planet Operate managed network
- NaaS - ALU SAM (Service Aware Manager) network
- OpenStack DC – Red Hat OpenStack
- OpenStack DC – Alternative OpenStack distributions
- Enterprise Customer Data Center
- Layer-3 IP Managed Services

Another key feature of Blue Planet SDN/NFV software is the concept of “service templates.” Service templates specify the capabilities, attributes, and policy of a service. Service templates are hierarchical, which allow services to be combined together into an aggregated service.

A service template has the following characteristics:

- Service type
- Resources: physical and virtual
- Rules / policy
- Prerequisites
- Acceptance conditions
- Continuous verification probes

Through the use of service templates, features like service chaining can be achieved. Blue Planet orchestrates the physical network, virtual network, and interconnecting virtual functions (firewall, DPI, etc.) to achieve service chaining. Service templates can be defined for each service component and then combined into an aggregated service template that will define the service chain. A service provider can create, delete, and modify service templates through a GUI interface, thus enabling the service provider to create unique services that would differentiate them in the market. It will also allow them to be more responsive to their customers by quickly making modification to services based on customer need.

Other Blue Planet Platform Components
In addition to the NFV Management and Service Orchestration features, Blue Planet is comprised of multiple individual components. The Cyan Blue Planet Platform includes the Blue Planet core infrastructure and network services.

- **Planet Design**: Rapid design and planning of new networks and services
- **Planet Operate**: Service provisioning and multi-layer management system, with 3D visualization.
- **Planet View**: Verification of service and network performance with historical and real-time analytics
3.1.4 Connectem

Connectem Virtual Core for Mobile (VCM) is a self-contained virtual packet core that provides all the functionalities of an Evolved Packet Core (EPC). As a self-contained packet core, it defines the boundary of the system around packet core functions with standard interfaces to the RAN and the PDN via Iu/S1 and (S)Gi interfaces. All the functions and interfaces inside the packet core are internalized.

This section briefly outlines the Connectem vEPC software components that are being orchestrated for the deployment of vEPC by Cyan orchestration platform. Figure 9 shows the distribution of the Connectem components on four Intel Xeon processor-based servers.

The standard EPC functionality as per the 3GPP standards which contained in the S-Gw, P-Gw and the MME has been decomposed into a set of proprietary components that essentially preserve the 3GPP interfaces and functionality, but are distributed into software components that enable virtualization, scalability, and elasticity. It consists of the following components that are deployed in 1+1 redundant configuration for reliability:

- Data Processing Engine (DPE)
- Radio Interface Function (RIF)
- Configuration (CPE)
- SDB – the database Engine
- EMS – Element Management System
- NMS – Network Management System
Connectem has taken the opportunity to collapse the functions and re-define the functions for maximum optimization of data center tools, technologies, and economics. In effect, Connectem has taken a holistic approach to functional virtualization to achieve maximum efficiency as compared to the incumbent technology providers who are simply replicating existing nodes as a software asset.

For instance, Figure 10 shows node-based virtualization where each node is virtualized. With this approach, purpose-built hardware is not needed and although some efficiency may be achieved inside the node, the node boundaries are still intact and the fundamental problems of inefficiency and complexity are not solved. There are still multiple unnecessary processes across nodes for any single service. For example, all the nodes are involved to perform one attach procedure. With the node boundaries intact, the encoding and decoding at each interface between the nodes still needs to be performed, resulting in inefficiencies. Furthermore, all the nodes need replication for high availability which results in complexity and inefficiency even though it is software based.

Connectem VCM takes the entire EPC as a module to provide services to the users. It dismantles the node boundary and removes the need for encoding and decoding at multiple interfaces. VCM has defined “services” to perform critical functions for the subscribers which can run on virtual machines. With this approach each service can scale independently and elastically according to the load factor at any given time. As a result VCM provides a robust, high performance, scalable, and fault tolerant solution that is optimized for the task of processing sessions. The benefits of the VCM architecture include the following:

- Simplification and abstraction of complex interactions between packet core elements, instead delivering a set of common services
- Implementation of these services using stateless functional components to allow maximum parallelization and fault tolerance
- Distribution and tiering of these stateless components to achieve unlimited scalability, resilience, and separation of concerns
- Virtualization of the software to provide on-demand elasticity for the services

The ability to elastically adjust the resource requirements for “just-in-time” increases and decreases in capacity of control plane, data plane, and session database is critical in managing cost efficiency in core networking. Connectem’s VCM leverages years of innovation and investment from computing and data networking entities such as Cyan, Dell, Intel, and Red Hat other independent Software Vendors as well as the Open Source community to bring an elastic, scalable, and robust platform optimized for operational simplicity.
4 Architecture
This section provides an overview of the network architecture that spans operator’s legacy optical mobile backhaul network elements that connect the eNodeB to the service provider data center where industry standard COTS hardware and cloud management technologies are used. It gives an overview of the orchestration stack and architecture as it relates to the NFV end-to-end architecture elements and shows the mapping to its architectural blocks provided by different vendors and how they come together to provide an multi-vendor NFV solution.

4.1 Network Architecture
A simplified view of the underlying network architecture is shown in Figure 11. E-Line services are built from the eNodeB to the Layer-2 gateway inside the NFV data center. The L2 gateway maps the E-Line service to GRE tunnels connecting to the appropriate OVS on each compute node.

In this particular setup an E-Line (Ethernet point to point connection that a carrier provisions) service is created from the eNodeB device to the Layer-2 gateway residing inside the data center. The (Network Interface Device) NID provides demarcation, in addition to a number of other functions. The packet optical transport platforms form a mobile backhaul network, which is how wireless data services are carried over long distances. In many cases the various network devices that reside between the eNodeB (or a more traditional cellular tower) and the data center may belong to different vendors. Furthermore, various services such as E-Line or the fiber as well as the packet optical transport platforms may be leased from different service providers. Regardless, the demonstrated solution is multi-vendor and multi-layer (operating on layers 1, 2 and 3).

The eNodeB, packet optical backhaul, NIDs, and the Layer-2 gateway are provisioned to create a private E-Line service that guarantees bandwidth, manageability, high availability, and fault tolerance to overlay IP based mobile communication between the eNodeB and the vEPC running in the data center.

4.2 NFV Orchestration for the vEPC
Figure 12 illustrates the NFV orchestration stack for vEPC hardware vendors like Dell, providing Intel Xeon processor-based standard COTS servers and software vendors like Red Hat with their enterprise operating system, virtualization offering, and OpenStack-based cloud management systems. In addition, ingredients like Intel DPDK provide the accelerated data path for achieving line rate performance required by telco service providers for implementing typical network functions like EPC. These form the basic NFV Infrastructure as a service (NFVIaaS) platform. Operators can then deploy VNFs like Connectem’s VCM (that is a virtual EPC) on the described NFVIaaS. Cyan’s Blue Planet orchestrator provides the glue that allows the operators to be able to deploy, monitor, and manage their diverse equipment and software that encompasses legacy network elements alongside the newer cloud based infrastructure.

Cyan has developed a platform that supports the deployment and orchestration of virtualized network functions (VNFs). Cyan’s Blue Planet NFVO is agnostic to both VNF vendor and function (e.g. vDNS, vEPC). The Blue Planet NFVO is responsible for interfacing to the OpenStack Virtual Infrastructure Manager along with each VNF (Connectem’s vEPC, ng4T’s vTester, PowerDNS’s vDNS). In addition, Cyan’s Blue Planet is also responsible for orchestrating the overarching service delivery. Blue Planet
Figure 12: vEPC Stack
Service Orchestration is responsible for multi-domain service orchestration. Mobility Zone is the overarching service that is comprised of the following service components.

- **NFV Applications**
  - vEPC – Connectem
  - vTester – ng4T
  - vDNS – PowerDNS

- **Network as a Service (NaaS)**
  - L2VPN Service

The Mobility Zone service is shown in Figure 13. The service and VNF descriptors are built using OpenStack Heat templates. The service and VNF descriptors specify attributes such as:

- Service/VNF type
- Resources: physical and virtual
- Rules / policy
- Prerequisites
- Acceptance conditions
- Continuous verification probes

### Figure 13: Mobility Zone Service

#### 5 Equipment and Software

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<th>Vendor</th>
<th>Component Description</th>
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6 Testing
ng4T develops and delivers active test solutions for verification and deployment of mobile telecommunications networks. ng4T network emulators, load, and stress testers pave the way for the development and the rollout process of network elements. The NG40* test platform is fully scalable and runs on VMs as well as standalone high performance servers. ng4T’s software-based approach makes the NG40 tester the perfect companion in complex NFV orchestration environments.

The NG40 test software can be used as core or RAN network element emulator. In the present virtualization environment, the NG40 eUTRAN test software is used to test a started EPC instance prior going into productive operation.

By combining the UEs and the eNBs in a single RAN entity, NG40 eUTRAN platform emulates the behavior of millions of mobile subscribers accessing the network via thousands of eNBs. System critical parameters that typically are stored on the Subscriber Identity Module (SIM) and databases are read from configuration files and stay in memory for fast access and modification during test execution. The architecture makes RF obsolete for most of the test purposes. This allows us to run the eUTRAN Subsystem without expensive hardware on a virtual machine.
7 Orchestration Process
This section describes each step of the orchestration process that is executed to instantiate a Mobility Zone service:

1. Start the Mobility Zone service
2. Instantiate vEPC
3. Bind/map virtual and physical networks
4. Instantiate vDNS
5. Configure Mobile Backhaul Network
6. Instantiate vTester
7. Mobility Zone service orchestration complete

NOTE: The Blue Planet and OpenStack services are already up and running. Also, pre-built VM images are stored in a local repository for faster launch of the VMs.

7.1 Start Mobility Zone Service
A user can create a new Mobility Zone service either through the Blue Planet GUI, CLI, or RESTful API. The Mobility Zone service consists of a descriptor that defines and chains a number of services to provision a complete end-to-end solution. In this particular case, the Mobility Zone descriptor defines a vEPC to provide the mobile backend services, a virtual domain name server (vDNS) to resolve addresses and direct traffic, a RESTful API call to Blue Planet Operate to provision the physical A to Z NID devices to deliver an E-Line service, and a vTester to emulate an eNodeB and test the setup before operationalizing the service in a carrier network.

The following parameters are needed at the time of instantiation:

- Mobility Zone Name: mzone
- vEPC Parameters
  - Maximum group EPC size: 1 or 2 EPCs for auto-scaling
  - Maximum and minimum utilization thresholds (used only for the maximum group EPC size of 2)
  - High availability
  - checked = 14 VMs get deployed
  - not checked = 8 VMs get deployed
- Networking
  - Internal Network: select private
  - External Network: select public
  - UTRAN Network: select utran
- vDNS
  - DNS Domain: example.com
  - DNS Domain Records: host1.example.com: 1.2.3.4
  - Upstream DNS Server: 8.8.8.8
  - Database Root Password: pdns
- Metro Network
  - A-End NID: NID/NID-1
  - Z-End NID: NID/NID-2

Once all the parameters are entered the user then can select to launch the Mobility Zone service. At this point Blue Planet reads the Mobility Zone descriptor files and executes the actions described in the service descriptor file. The top level service descriptor and subordinate VNF descriptor files are all based on OpenStack Heat templates. The top level service descriptor contains the forwarding graph.

The screenshots illustrate how to launch the Mobility Zone service from the Blue Planet Web GUI.

Figure 15 illustrates the available and instantiated resources in the vEPC demo. The logos on the top indicate various services. Each service consists of a descriptor that follows a hierarchical structure of sub services.
Such a nested structure allows the creation of complex services based on aggregating basic services such as E-Line creation or provisioning a VM. In Figure 16 the user drags and drops the MZ service from the top menu.

The user drags the Mobility Zone icon from the list of various pre-defined services to the middle circle that represents the data center. The smaller circles connected to the data center (orbiting around) represent services that are deployed in the data center. The drag and drop action brings up a dialog box that allows the user to configure the vEPC, vEND, E-Line and vTester subservices that are under the Mobility Zone service descriptor that the user intends to deploy within the data center.

Figure 17 illustrates the dialog box for the Mobility Zone. Mobility Zone is a service description with the Mobility Zone icon representing a service descriptor that describes a number of resources that are lined up in a forwarding graph (please refer to the ETSI NFV whitepaper for details) descriptor. This dialog box provides a number of tabs for the user to configure each of the services that are defined by the Mobility Zone service.

1. General: Administrative settings
2. vEPC scaling: Set rules on when the scale up or down
3. Networking: Mapping/binding of various virtual and physical networks
4. vDNS: Setup virtual DNS for lookup
5. Metro: Mobile backhaul (E-Line) setup

In the “General” tab, the “Template Directory” refers to the VNF descriptor depository and “Keypair” is an ssh keyword to provide secure access.

Figure 16: Launch Mobility Zone
7.2 Instantiate vEPC service

As illustrated in Figure 18, Blue Planet provides the user with setting to configure the conditions for automatically scaling VNF services (up or down) as needed. The scaling can be done by creating extra instances of the VNFs or by allocating more resources to an existing VNF. By default only one VNF (vEPC in this case) is deployed but when the Key Performance Indicators (KPIs) from the first instance are higher than the threshold set with the “Maximum Utilization Threshold,” the orchestrator will automatically instantiate a second vEPC. Various resources such as the available bandwidth to the data center and availability of the compute resources, may limit the number of VNFs that can be created. A similar setting “Minimum Utilization Threshold” allows the user to configure when the vEPC should be scaled down because of reduced demand. The Cyan Blue Planet orchestrator continuously monitors the health of the service and the KPIs to gracefully scale up and down services with no interruption.

OpenStack NOVA API calls are made to launch the multiple vEPC VM images, which are stored in qcow2 format. Based on the parameters entered by the user the EPC config files are created and copied onto the appropriate vEPC VMs. After the config files are copied to the appropriate vEPC VMs the services are started. At this point the vEPC is ready for use.

The Mobility Zone service descriptor file references the VNF descriptor file for the ng4T vTester. An OpenStack Heat plug-in was developed to interface to the ng4T vTester. The VNF descriptor specifies that a test be run against the vEPC, and the Heat plug-in contains the necessary ng4T API calls to run the EPC test. The test consists of connecting the ng4Ts emulated eNodeB UE to the vEPC. When this connection is validated the vEPC is ready to be connected to the physical eNodeB.
7.3 Bind Virtual and Physical Networks

In Figure 19, internal network refers to the service network within this data center. In a more complex system that Blue Planet supports, there can be multiple data centers (distributed data centers involved in delivering the service) in which an application is spread over various resources and networks.

External network refers to publicly accessible networks. Blue Planet binds the virtual network defined with a VNF descriptor with the actual networks available in a data center that can be publicly accessed. UTRAN refers to the datapath from vEPC to the eNodeB.

7.4 Instantiate vDNS

A virtual DNS (vDNS) is setup to direct traffic appropriately. If a lookup does not match the default entry (provided in the "DNS Domain Records" box) then it will be directed to the upstream DNS server. In this particular case the address of Google’s DNS server is entered. When a user does a lookup (searching the internet) they will be using the services of the virtual DNS that is deployed.

Blue Planet utilizes OpenStack Heat to parse the vDNS VNF descriptor file and starts the launch of the vDNS. OpenStack NOVA API calls are made to launch the vDNS VM image, which is stored in qcow2 format. Based on the parameters entered by the user the DNS config files are created and copied onto the vDNS VM. After the config files are copied to the vDNS VM the service is started. The DNS application reads the config files when it starts to set its initial conditions.
7.5 Configure Mobile Backhaul

At this stage, the A-END (eNodeB) and Z-END (Data center) NIDS are configured. The “Planet Operate URI” refers to the API address of the Blue Planet Operate software to is used to provision E-Line services. The “Bandwidth Profile” is used to setup the size of the data traffic allocated on the E-Line for the mobile communication. Blue Planet Operate uses RESTful APIs to discover topology and setup Layer-2 services.

Planet Operate provisions the E-Line service from the Accedian NID across the Cyan Z-Series hardware. In addition the Heat plug-in also provisions the L2 Gateway by making OpenStack Neutron API calls. The provisioning of the vEPC VM automatically instantiates the vTester. Once the vTester has performed its operation and determined that the vEPC has passed the tests Mobility Zone is ready for use. A user can attach to the mobile network and surf the internet.

- Power on UE (Mobile device).
- Stream content to mobile device from http://www.youtube.com.

![Figure 21: Metro network parameters and setting up the E-Line service](image-url)
# 8 Appendix

This section gives the glossary of abbreviations and terms used in the document.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>CLI</td>
<td>Command Line Interface</td>
</tr>
<tr>
<td>CSO</td>
<td>Corporate Security Office (An AT&amp;T Org)</td>
</tr>
<tr>
<td>DC</td>
<td>Data Center</td>
</tr>
<tr>
<td>DNS</td>
<td>Domain Name System</td>
</tr>
<tr>
<td>DPI</td>
<td>Deep Packet Inspection</td>
</tr>
<tr>
<td>EPC</td>
<td>Enhanced Packet Core</td>
</tr>
<tr>
<td>FCAPS</td>
<td>Fault, Configuration, Accounting, Performance, Security</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>LTE</td>
<td>Long Term Evolution (4G Standard)</td>
</tr>
<tr>
<td>MME</td>
<td>Mobility Management Entity</td>
</tr>
<tr>
<td>MNC</td>
<td>Mobile Network Code</td>
</tr>
<tr>
<td>NFV</td>
<td>Network Function Virtualization</td>
</tr>
<tr>
<td>NG4T</td>
<td>A testing tool (eNodeB simulator)</td>
</tr>
<tr>
<td>nic</td>
<td>Network Interface Card</td>
</tr>
<tr>
<td>NID</td>
<td>Network Interface Device</td>
</tr>
<tr>
<td>PDN</td>
<td>Packet Data Network</td>
</tr>
<tr>
<td>P-GW</td>
<td>Packet Gateway</td>
</tr>
<tr>
<td>PLMN</td>
<td>Public Land Mobile Network</td>
</tr>
<tr>
<td>PoC</td>
<td>Proof Of Concept</td>
</tr>
<tr>
<td>RAN</td>
<td>Radio Access Network</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RHEV</td>
<td>Red Hat Enterprise Virtualization</td>
</tr>
<tr>
<td>S-Gw</td>
<td>Signaling Gateway</td>
</tr>
<tr>
<td>UE</td>
<td>User Endpoint (A 3GPP term for mobile device)</td>
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</table>

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunications System</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
<tr>
<td>UTRAN</td>
<td>UMTS Terrestrial Radio Access Network</td>
</tr>
<tr>
<td>VCM</td>
<td>Virtual Core for Mobile</td>
</tr>
<tr>
<td>vDNS</td>
<td>Virtual Domain Name System</td>
</tr>
<tr>
<td>vEPC</td>
<td>Virtual Enhanced Packet Core</td>
</tr>
<tr>
<td>VLAN</td>
<td>Virtual LAN</td>
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<tr>
<td>VM</td>
<td>Virtual Machine</td>
</tr>
<tr>
<td>VNF</td>
<td>Virtual Network Function</td>
</tr>
<tr>
<td>vRR</td>
<td>virtual Route Reflector</td>
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<tr>
<td>WAN</td>
<td>Wide Area Network</td>
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## 9 References

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
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<tr>
<td>NFV E2E Arch</td>
<td>Network Function Virtualization Reference Architecture</td>
<td><a href="http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.01.01_60/gs_NFV002v010101p.pdf">http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.01.01_60/gs_NFV002v010101p.pdf</a></td>
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