HPE Helion OpenStack Carrier Grade

Enabling communications service providers to deploy NFV applications on open source software platforms
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NFV—A CSP reality

Network functions virtualization (NFV) introduces revolutionary implementation concepts in deploying telecommunication infrastructure. Communications service providers (CSPs) are looking at NFV as a vehicle to introduce new services, protect topline revenue, minimize OPEX, gain market share through accelerated deployment of new services, and maximize flexibility through adoption of open source solutions.

A core structural change in the way telecommunications infrastructure gets deployed, NFV in turn brings significant changes to the way applications are delivered to service providers. By disaggregating the traditional roles and technology involved in telecommunications applications, NFV enables innovation in the telecommunications industry infrastructure and applications, and creates greater efficiencies and time-to-market improvements.

While implementing NFV, CSPs must also overcome technical challenges such as the integration of service automation and management services with existing operational support system (OSS)/business support system (BSS) infrastructure. In addition, CSPs must address carrier grade performance, service-level agreements (SLAs), and security measures.

OpenStack, NFV, and SDN

The open source project, OpenStack®, has become the de facto open source cloud operating system, enabling enterprise and telecom companies to build private and public clouds by virtualizing compute, storage, and networking. The OpenStack Foundation is backed by all major enterprise IT and telecom vendors, CSPs, and many startup companies, fueling a revolution in cloud infrastructure management.

Software-defined networking (SDN) enables the emerging software-based networks that allow cloud operators to apply business logic directly and dynamically to introduce new services faster, at lower management costs and complexity. SDN also commoditizes network functions, thereby reducing CAPEX. SDN is an enabling technology that challenges current practices by decoupling the control plane from the data forwarding mechanisms.

HPE NFV Reference Architecture

The European Telecommunications Standards Institute (ETSI) has been chosen as the home of the industry specification group (ISG) for NFV. Membership of the ISG for NFV has grown to more than 260 individual companies, including 37 of the world’s major service providers as well as representatives from both telecoms and IT vendors. In context of NFV, ETSI has published a reference architecture (Figure 1) that is regarded as the standard for NFV implementation.
Following the ETSI model, the HPE NFV reference architecture (Figure 2) is based on a layered approach that allows customers to incrementally add new functionality and also gives them the openness and flexibility to work with platforms and solutions from different vendors at each layer.

Figure 1. ETSI reference architecture

Figure 2. HPE NFV Reference Architecture
HPE Helion OpenStack Carrier Grade

One key component of the ETSI NFV Reference Architecture is the virtualization infrastructure manager (VIM), which orchestrates the resources of a virtualized pool of physical infrastructure (servers, storage, and networking) to host virtual network functions (VNFs) on an NFV Infrastructure-as-a-Service (NFVaaS) platform.

An open source project with significant industry support, OpenStack has become the preferred open source cloud management system of CSPs. However, OpenStack is still in its early stages of technology maturity and is primarily focused on enterprise IT and public cloud use cases. Within the OpenStack community, there’s an emerging trend to understand the NFV use cases and develop features and capabilities to meet CSPs’ needs for NFV. The interest in NFV is in its early stage; it will likely take some time before it delivers on a critical mass of capabilities required for NFV deployments.

Deploying a production-ready VIM to manage an NFV platform requires the successful integration of many core technologies that are outside the realm of the OpenStack project. Some key examples include the host operating system (for example, Linux®), server virtualization (KVM), network virtualization (vSwitch and SDN controllers), an installer and cloud lifecycle management framework, fault and performance management, and high-availability framework for the OpenStack control plane and the NFVI layer.

In addition, some of the previously mentioned open source software components beyond OpenStack are not optimized for NFV use cases. For example, standard KVM is not suitable for virtualizing a server running VNFs like a vIMS or a virtualized packet gateway (vPGW) that cannot tolerate jitter or high latency. Similarly, a standard open virtual switch (OVS) does not have the performance to deliver packets of all sizes at a high throughput to VNFs that require handling multiple gigabits per second of bearer traffic.

To enable CSPs to deploy NFV applications on open source software platforms, Hewlett Packard Enterprise created the VIM plus compute and network virtualization offering for NFV. Known as HPE Helion OpenStack Carrier Grade (HPE Helion Carrier Grade), it’s built on the same foundation as the HPE Helion OpenStack Enterprise Edition, and adds significant enhancements in three key areas, providing carrier grade features for manageability, availability, and performance (Figure 3).

CSP requirements for NFV platforms

- **Availability and reliability**
  - Advanced self-healing
  - No single point of failure

- **Performance**
  - Nearline rate networking throughout
  - Bare metal compute performance

- **Manageability**
  - In-service upgrade capabilities
  - Enhanced security
  - Advanced resource scheduling and orchestration capabilities

Enhancements and defect fixes made in the OpenStack projects included in HPE Helion Carrier Grade will be submitted to the community to include upstream open source. To deliver on the previously mentioned three main areas, HPE Helion Carrier Grade includes other open source and non-open source components as well.

Figure 3. Key enhancements in HPE Helion Carrier Grade

HPE Helion OpenStack Carrier Grade components overview

The main components of HPE Helion Carrier Grade are:

- OpenStack—core services include Horizon, Nova, Neutron, Cinder, Glance, Swift, Keystone, Ceilometer, and Heat. Other services will be added as needed in the future

- Compute node software package including:
  - Carrier grade Linux (host operating system [OS] running on the compute nodes)
  - Carrier grade KVM (for virtualization of the compute node)
  - Carrier grade accelerated virtual switch (AVS), Data Plane Development Kit (DPDK)-enabled high-performance virtual switch
- Management and middleware—composed of high-availability (HA) management; operations, administration, and maintenance (OAM); software image management; and fault and performance management
- Guest software development kit (SDK) for inclusion in the guest OS of the VNF for performance acceleration and improving the HA framework above and beyond standard VIMs
- HPE Helion Lifecycle Manager (HLM)—cloud installer and lifecycle manager (not shown in Figure 4)

**Figure 4.** Key functional components of HPE Helion Carrier Grade

### Carrier grade Linux and OpenStack features

**OpenStack**
HPE Helion OpenStack Carrier Grade services include Keystone, Horizon, Cinder, Glance, Swift, Nova, Neutron, Ceilometer, and Heat; more services will likely be added in the future. These services are based on the Juno community version with enhancements in some of the key services. All enhancements and defect fixes made in these OpenStack components are planned to be submitted to the OpenStack community.

In addition to these enhancements, some of these services provide plug-ins to integrate with third-party software and hardware. For example, HPE Helion Carrier Grade provides Keystone plug-ins for Lightweight Directory Access Protocol (LDAP) and SQL Servers, Cinder plug-ins for HPE 3PAR, and virtual storage appliance (VSA) drivers for storage. HPE Helion Carrier Grade provides embedded Swift service.
Although most services in HPE Helion Carrier Grade are based on the Juno community version, one significant exception is Nova, which is based on the Kilo version. Nova in HPE Helion Carrier Grade has enhancements to provision single-root input/output virtualization (SR-IOV) and PCI-passthrough, as well as enable NUMA node affinity, CPU core pinning, large memory page assignment to virtual machines (VMs, 1 GB/2 MB), vCPU scaling, network performance-based scheduling, CPU type, and NUMA node aware scheduling. These features are all important to ensure a VNF has the resources needed for high performance. In addition to the Nova features that enable performance, HPE Helion Carrier Grade has features that enable high availability of VNFs like live migration and VM evacuation. HPE Helion Carrier Grade’s Nova supports live migration for VNFs using DPDK and only when they’re using external shared storage (not ephemeral or local disk) and when connected to the accelerated virtual switch (AVS, not to an SR-IOV VF or using PCI-passthrough).

Neutron, a key service in HPE Helion Carrier Grade, provides virtual network orchestration for VNFs and provides tenant separation using provider virtual local area networks (VLANs), and virtual extensible local area networks (VXLANs), distributed virtual routing (DVR) functionality, security, and quality of service (QoS) policy. Neutron in HPE Helion Carrier Grade provides a modular layer 2 (ML2) plug-in mechanism to control and program the AVS, as well as the ability to send VLAN-tagged packets to and from VNFs. This feature preserves the existing implementation of VNFs where traffic to and from VNFs is expected to be tagged with 802.1Q VLANs.

Heat is an important service in HPE Helion Carrier Grade as it’s used to automate the orchestration of a VNF through its lifecycle, for example, onboarding and auto-scaling.

HPE Helion Carrier Grade includes key additional features, enhancements, and defect fixes to Heat; some of the more notable features and benefits include:

- Lifecycle management of a composite application (“Stack”)
- Ability to define a set of resources (VMs, networks, Cinder volumes, Swift databases, etc.) that make up a larger, more complex application
- File- and template-based definitions
- Support for lifecycle commands such as “start,” “modify,” and “stop”
- VM instance bootstrapping/configuration through cloud-initiative and cloud-formation mechanisms
- Application auto-scaling (with low-scale load balancing)
- Integration of protection groups
- Improved usability of templates
- Improved detection time of failed entities
- Improved usability of Heat’s Horizon dashboards

Ceilometer is a service in HPE Helion Carrier Grade that provides monitoring and statistics gathering for physical and virtual elements on a server. These statistics help in the performance management aspects of HPE Helion Carrier Grade’s middleware. In addition, Ceilometer’s enhanced metrics such as network statistics can be used by the Nova scheduler to make intelligent choices in VNF placement. Other enhancements in Ceilometer enable northbound telco type interfaces in the form of a secure file transfer protocol (SFTP) pull interface of a comma-separated value (CSV) format file with performance metrics.

Horizon dashboard provides the graphical user interface (GUI) for HPE Helion Carrier Grade users. HPE Helion Carrier Grade’s Horizon also provides a detailed dashboard of system-level inventory of the compute nodes in the cloud and also has a dashboard webpage to display the active alarm list (dynamically updated) and a webpage to display the historical alarm list (dynamically updated). In addition to Horizon, command-line interface (CLI) and representational state transfer (REST) application programming interfaces (APIs) are also provided to the OpenStack services.

HPE Helion Carrier Grade also provides integration capabilities through standards-based and open APIs with other layers and components of the ETSI architecture, especially the service orchestration and OSS components of the management and orchestration (MANO) layer, such as the HPE NFV Director (service orchestration and monitoring), HPE Operations Manager i (OMi), Network Node Manager i (NNMi), SiteScope for OSS/BSS, and third-party VNF managers.
**Carrier grade Linux**

Carrier grade Linux is a set of specifications that details standards of availability, scalability, manageability, and service response characteristics that must be met for the Linux kernel-based operating system to be considered “carrier grade” (that is, ready for use within the telecommunications industry). The term is particularly applicable as telecom converges technically with data networks and commercial-off-the-shelf hardware. The latest version of the carrier grade Linux specification is 5.0.

HPE Helion Carrier Grade distribution includes the Wind River carrier grade Linux package as the host operating system to run VNFs, which is itself carrier grade Linux 5.0 registration specifications compliant.

**Carrier grade KVM—open virtualization platform**

High-performance VNFs like vIMS, voice over LTE (VoLTE), vPGW are required to perform at deterministic levels. Deterministic performance is not just about bandwidth but also about latency, and it’s critical that the latency induced by the underlying virtualization layer be very low and consistent.

The HPE Helion Carrier Grade compute node software package also includes a carrier grade KVM with real-time kernel extensions to provide low-latency throughput, resiliency, availability, and security optimized for NFV workloads. It adds kernel preemption support to the industry-standard kernel-based virtual machine (KVM) hypervisor, with a 40X decrease in jitter and 74 percent decrease in average latency, providing deterministic and predictable performance for VNFs.

**Carrier grade virtual switch**

A key component in the data plane of a VNF is the virtual switch (vSwitch). The throughput and efficiency of the vSwitch is critical for many VNFs to handle multiple Gbps of bearer plane traffic. Since the vSwitch is a software element, it also must utilize the CPU resources efficiently.

HPE Helion Carrier Grade compute node software includes the Accelerated vSwitch, a high-performance user space vSwitch based on an enhanced version of the Intel Data Plane Development Kit (Intel DPDK) that enables high-performance VM-to-VM communication without the need to use the Linux kernel OVS, as well as high-performance packet processing from the server network interface card (NIC) to applications in VMs.

The AVS uses only two cores per CPU to provide 20 Gbps, and when compared to the standard Linux kernel-based OVS, is about 6.7X more efficient in its CPU utilization. This efficient utilization of the CPU by the AVS while delivering high bandwidth enables an increase in the density of high-performance VNFs on a CPU, thereby improving the economics of NFV (Figure 5).

What is virtual network interface card (vNIC)?

- Supports VNFs written for OVs and native Linux
- Virtual NIC driver provides 10X better performance than native Linux
- Optimized for Intel DPDK—even better performance for DPDK apps
- Supports multiple guest OSs
- Application not aware that network interfaces are virtual
Figure 5. AVS supportability matrix and performance at different packet sizes

Table 1. AVS efficiency improving VNF density

<table>
<thead>
<tr>
<th>vSwitch analysis</th>
<th>STANDARD OVS</th>
<th>Wind River AVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching bandwidth for first core</td>
<td>0.3 mpps</td>
<td>120 mpps</td>
</tr>
<tr>
<td>Switching bandwidth for subsequent cores</td>
<td>0.3 mpps</td>
<td>120 mpps</td>
</tr>
<tr>
<td>Total switching bandwidth required</td>
<td>6.0 mpps</td>
<td>40.0 mpps</td>
</tr>
<tr>
<td>Number of cores required for vSwitch</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Number of cores available for VMs</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Unused cores</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

VM density improvement 6.7X

Configuration assumptions
Cores: 24
VMs/core: 1
Bandwidth: 2 mpps

Besides higher performance, customers achieve increased capacity, meaning they can have more payloads with fewer servers.
Management and middleware
The management and middleware layer of HPE Helion Carrier Grade provides performance, fault, high availability, and software management features. Performance management in HPE Helion Carrier Grade relies on plug-ins to the Ceilometer service. Performance metrics are collected for both the compute server and VMs. Enhanced statistics beyond basic OpenStack such as per-vNIC bandwidth, aggregate bandwidth, and TX/RX frame, bytes, and errors are collected. HPE Helion Carrier Grade provides access to performance measurement samples in the form of CSV files, which offer the following benefits:

- Offline permanent storage of large sample history
- The use of offline tools for data analysis, accounting, and archiving

The CSV files are expected to be retrieved from the controllers using any suitable file transfer client application such as SFTP or SCP. This can be done manually by the system administrator, or automatically by an operations and support server (OSS/BSS) configured with the appropriate login credentials.

Fault management in HPE Helion Carrier Grade makes available information about faults and other events related to physical and virtual elements in the form of the following alerts:

**SNMPv2c**
- Mandatory management information bases (MIBs)/tables (system, simple network management protocol [SNMP], community)
- Traps
- Notifications MIB (active alarm list and historical alarm list)

**Hypertext transfer protocol (HTTP) to GUI:**
- Horizon dashboard webpage to display active alarm list (dynamically updated)
- Horizon dashboard webpage to display historical alarm list (dynamically updated)

**Secure shell (SSH) to CLI:**
- Command(s) to display active alarm list
- Command(s) to display historical alarm list
- Command(s) to enable streaming of alarms as they occur to CLI session

The high-availability management aspect of HPE Helion Carrier Grade's middleware is responsible for ensuring the high availability of VNFs in the midst of failures or planned outages in the physical or virtual elements of a compute server. Some of the key aspects of this HA manager include:

- Automatic VM recovery on failure of a host compute node (node failure detection in seconds rather than minutes)
- Automatic VM recovery on failure of a VM (VM failure detection 60X faster than standard IT grade)
- Live migration of VMs using Intel DPDK (not available in IT-grade OpenStack)
- Controller node redundancy and automatic failover (not available in IT-based OpenStack)
- VM monitoring tied into application health checks within the guest
- VM protection groups (ensuring VMs of the same group are created on different compute nodes)
Table 2 illustrates how HPE Helion Carrier Grade’s virtualization meets carrier grade requirements compared to standard and enterprise OpenStack.

Table 2. Meeting CSP requirements

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>HPE Helion OpenStack Carrier Grade</th>
<th>Standard OpenStack and Enterprise Linux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection of failed VM</td>
<td>500 ms</td>
<td>&gt; 1 minute</td>
</tr>
<tr>
<td>Compute node failure detection</td>
<td>Sub-second</td>
<td>1 minute or longer</td>
</tr>
<tr>
<td>Controller node failure recovery</td>
<td>Sub 10 seconds</td>
<td>Requires custom development to enable</td>
</tr>
<tr>
<td>Live migrate DPDK apps</td>
<td>Fully supported</td>
<td>Not possible</td>
</tr>
<tr>
<td>Network failure detection for compute notes</td>
<td>50 ms</td>
<td>Depends on Linux distribution</td>
</tr>
</tbody>
</table>

VNF guest SDK

On top of HPE Helion Carrier Grade, any VNF running on any industry-standard Linux guest operating system can utilize either the standard Virtio-based Linux drivers or it can use a special AVP vNIC driver to experience higher throughput (6X to 10X better performance than Virtio), and the ability to do queuing per vNIC basis. This enhanced networking capability can be achieved simply by loading a kernel loadable module on the guest VM without the complication of any code compilation.

The guest VMs can also take advantage of an SDK to participate in application health checks (as part of HPE Helion Carrier Grade’s high availability management) to enable VM and application health monitoring. VM protection groups enable grouping of similar VMs on different nodes to exchange state information so they can benefit from state change information of their peer VMs. This guest SDK also provides the ability to listen to shutdown request messages from HPE Helion Carrier Grade’s HA manager so that a VM can be gracefully shut down before evacuation or to accelerate a VM live migration when experiencing high bearer traffic loads. See table 3 for guest SDK information.

Table 3. Benefits that require SDK inclusion in VNFs

<table>
<thead>
<tr>
<th>FUNCTIONALITY</th>
<th>SDK MODULE</th>
<th>BENEFITS</th>
<th>MODULE INCLUSION METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-performance I/O (AVP)*</td>
<td>AVP-KMOD</td>
<td>7X I/O performance</td>
<td>Compiled with kernel distribution</td>
</tr>
<tr>
<td>High-performance DPDK driver (PMD)</td>
<td>AVP-PMD</td>
<td>40X I/O performance</td>
<td>Compiled as a component of Intel DPDK driver with application</td>
</tr>
<tr>
<td>vCPU scaling</td>
<td>guest-scale server-group</td>
<td>Allows guest to add or remove vCPUs</td>
<td>Requires the modules to be compiled in the guest OS instance</td>
</tr>
<tr>
<td>Guest application control</td>
<td>heartbeat</td>
<td>Allows HCG control plane to monitor health and send messages to VMs to shut down, quicken live migration, and enable auto-evacuation to be more graceful**</td>
<td>Application requires recompilation to take full advantage of this feature</td>
</tr>
<tr>
<td>Server group messaging</td>
<td>server-group</td>
<td>Provides a group of peer VMs a simple messaging channel to exchange state change information, etc.</td>
<td>Application requires recompilation to take full advantage of this feature</td>
</tr>
</tbody>
</table>

* If VNFs do not include AVP, they can use standard Linux Virtio—allow performance I/O option. SR-IOV has no dependency upon inclusion of this driver.

** VMs have the ability to reject shutdown requests. Live migration and auto-evacuation will be supported without inclusion of this SDK.
To include these SDKs in a VNF, the guest OS has to be of a certain version. See table 4 for supported guest OS versions.

### Table 4. HPE Helion Carrier Grade guest OS support matrix

<table>
<thead>
<tr>
<th>DISTRIBUTION</th>
<th>OS (KERNEL) VERSION</th>
<th>SDK SUPPORT DATE</th>
<th>SUPPORTED SDK COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fedora</td>
<td>19 (3.9)</td>
<td>15 June 2015</td>
<td>All</td>
</tr>
<tr>
<td>openSUSE</td>
<td>12.3 (3.7)</td>
<td>Under investigation</td>
<td>All</td>
</tr>
<tr>
<td>Wind River</td>
<td>6.0 (3.10)</td>
<td>29 May 2015</td>
<td>All</td>
</tr>
<tr>
<td>Wind River</td>
<td>5.0 (3.4)</td>
<td>29 May 2015</td>
<td>All</td>
</tr>
<tr>
<td>Red Hat® Enterprise Linux (RHEL)</td>
<td>6.5 (2.6)</td>
<td>Under investigation</td>
<td>Guest-scale, server-group, heartbeat, heat-template</td>
</tr>
<tr>
<td>CentOS</td>
<td>6.4 (2.6)</td>
<td>Under investigation</td>
<td>Guest-scale, server-group, heartbeat, heat-template</td>
</tr>
<tr>
<td>RHEL</td>
<td>7.0 (3.10)***</td>
<td>Under investigation</td>
<td>All</td>
</tr>
<tr>
<td>RHEL</td>
<td>6.4 (2.6)***</td>
<td>Under investigation</td>
<td>Guest-scale, server-group, heartbeat, heat-template</td>
</tr>
</tbody>
</table>

*** These operating systems are still being tested, and full support is not yet verified.

### HPE Helion Lifecycle Management

HPE Helion Lifecycle Management (HLM) is responsible for the software management in OpenStack and other components within HPE Helion Carrier Grade using a model-based runbook automation approach to cloud lifecycle management. This method enables the software to be installed as packages and python virtual environments. Lifecycle operations are implemented as Ansible runbooks (install/reconfigure/scale up/upgrade) using a pluggable OpenStack installation layer. It also provides default service configuration, but doesn’t constrain the customer to it. It updates and upgrades via selective software (re)installation and reboots the system only for kernel changes. It doesn’t need a dedicated deployment node or transient deployer (doesn’t need to be running after deployment). The network is defined by user and instantiated during installation only. HLM also ensures that the HPE Helion Carrier Grade control plane is deployed in such a fashion that there is no single point of failure that can bring down the cloud operations.

Simplified installation and management in HPE Helion Carrier Grade takes care of the redundancy and fast recovery of failure in the control plane in a highly efficient manner. The dual redundant control node architecture design in HPE Helion Carrier Grade ensures the high availability of the components. With automatic control and compute node failure detection and recovery, the state of the OpenStack controllers is stored, without any loss and without any effect on the VMs. During maintenance, only the individual OpenStack services are restarted, which is a more granular fashion than in non-carrier grade OpenStack versions.

### Hardware support

HPE Helion Carrier Grade control plane can be installed on HPE ProLiant DL360 Gen9 Servers and the compute nodes can be ProLiant DL360 Gen9 or HPE c7000 BladeSystem Gen9 with 6125XLG switches and FlexFabric VC modules. HPE Helion Carrier Grade supports the HPE StoreVirtual VSA and HPE 3PAR StoreServ Storage system as shared storage for the OpenStack Cinder volume service.
Conclusion
As an NFV-ready cloud management system, HPE Helion OpenStack Carrier Grade addresses carrier grade requirements for management, performance, and reliability. Built on top of open source components by a leading contributor to OpenStack, the solution enables greater innovation in the telecom industry infrastructure and applications, leading to efficiencies and time-to-market improvements that can ultimately create a competitive edge.

Learn more at
hpe.com/csp/nfv