The Challenge

The transformation of the Telco Cloud data center is rapidly progressing. Proprietary and purpose-build hardware platforms are being replaced with their virtualized counterparts creating an open ecosystem where commodity general-purpose x86-based hardware is deployed at a much lower price. These general-purpose x86 platforms are used to host virtual machines (VMs) and containers for virtualized network functions (VNFs) and containerized network functions (CNFs). With this virtualization infrastructure in place, application deployment related manual operational tasks can now be done automatically with massive scale reducing operational costs and time to affect changes. This revolutionary change left the network a step behind and unable to keep up with the automated application layer of the Telco Cloud as it was still primarily manually configured.

This was why SDN was born to provide the programmable and automated networking framework that can inter-connect these cloud-based workloads with scale. By separating the control plane from the data plane CSPs can now program their network centrally to ensure that the network adapts to the cloud environment. In the data plane this is achieved by creating overlay VPN network tunnels by adding a further layer of encapsulation. However, due to the additional overhead packet processing has dramatically degraded in this new environment and matching previous bare metal native packet performance is extremely difficult.

This weakness is being further exacerbated in the era of 5G and IoT as these technologies sets the stage for faster speeds and other advancements such as reduced latency, increased capacity and improved machine to machine communications. Smart City security, autonomous vehicles, connected machines with vision capabilities, advanced drones with high resolution cameras, tele-medicine and tele-health, sensors on manufacturing equipment will all contribute to the explosion of traffic that the Telco Cloud needs to accommodate. Solutions must provide an improved method to increase packet processing performance and leverage compute resources more efficiently. Acceleration techniques are needed to address this challenge.

Nuage Networks™ and Mellanox Technologies have collaborated to offer an innovative and efficient Software Defined Networking (SDN) solution for data plane acceleration in a Telco Cloud data center environment. The solution combines the agility, elasticity and automation of the Nuage Network’s Virtualized Services Platform (VSP) with the performance, efficiency and scalability of Mellanox smart network adapter technology to accelerate the processing of packets in the data plane.

This joint solution helps communication service providers (CSPs) who offer a Telco Cloud solution realize the vision of offering multi-tenant cloud scale network automation by substantially improving the throughput and packet rate performance. Mellanox’s purpose-built Smart network adapters boost infrastructure efficiency significantly by freeing up CPU resources so CSPs can deploy more applications on top of Telco Cloud infrastructures to achieve a high return on investment (ROI).

About Mellanox

Mellanox Technologies (NASDAQ: MLNX) is a leading supplier of end-to-end Ethernet and InfiniBand intelligent interconnect solutions and services for servers, storage, and hyper-converged infrastructure. Mellanox intelligent interconnect solutions increase datacenter efficiency by providing the highest throughput and lowest latency, delivering data faster to applications and unlocking system performance.

More information is available at: www.mellanox.com or @mellanoxtech on Twitter.
The solution to the packet performance challenge leverages Nuage Network’s from Nokia SDN infrastructure and its various methods that offload the packet processing task from the traditional Linux kernel to make it faster and more efficient.

**Nuage Networks SDN infrastructure**

Nuage Networks Virtualized Services Platform (VSP) is the single platform that provides both SDN and SD-WAN services. For SD-WAN, the VSP enables Virtualized Network Services (VNS) and for SDN it enables Virtualized Cloud Services (VCS). VCS is the framework that enables the Telco Cloud SDN solution that is discussed in this paper.

As part of the VSP, the Virtualized Services Directory (VSD) is a programmable policy and analytics engine. It provides a flexible network policy framework that enables CSPs to define, apply, and enforce business policies across the network service in a user-friendly manner. Another component of the VSP is the Virtualized Services Controller (VSC). The VSC functions as a centralized and robust network control plane for the network services, maintaining a full view of the network and routing topologies.

Virtual Routing and Switching (VRS) and its other variants (xVRS) represent data plane elements within VCS. VRS is a software module that is installed in the hypervisor layer for VMs or in the host OS for containers. It represents the virtual tunnel endpoint (i.e. VXLAN Tunnel Endpoint (VTEP)) used to create virtual connections to connect VMs and containers. These tunnels are created by further encapsulating the original Ethernet frame from designated traffic allowing direct overlay tunnels between VMs or containers. VRS is based on the Open vSwitch (OVS) which is an open-source implementation of a distributed virtual multilayer switch. Through the VRS, changes in the compute environment are immediately detected, triggering instantaneous policy-based responses in network connectivity to ensure application performance. There are two other variants of the VRS. The Accelerated VRS (AVRS) and the Offload VRS (OVRS). The AVRS leverages Data Plane Development Kit (DPDK) technology to help improve packet performance. The OVRS leverages Mellanox SmartNIC technology to completely offload SDN packet processing from the Linux kernel. Please refer to Figure 1 to see how these VSP components are connected.

VCS exposes its rich API through the VSD to enable integration with 3rd party tools and cloud orchestrators such Kubernetes, Openstack, and VMWare.

**Packet acceleration methods**

As an overlay SDN solution, Nuage Networks VCS uses VXLAN tunneling to encapsulate the original Ethernet frame (e.g. inner frame). For network interface cards (NICs) that do not recognize these new packet header formats, even the most basic packet offloading to the NIC will not work, which means that all packet-manipulating operations need to be done in software running on the Linux kernel. This can cause significant network I/O performance degradation and create large CPU overhead, especially as server I/O speeds increase and packet sizes decrease.

To overcome these inherent performance challenges, packet acceleration techniques based on offloading processing burden from the Linux kernel (i.e. OVS offload) are needed. Nuage Networks offers various OVS offload techniques. Refer to Figure 2 for a comparison of all three OVS offload methods.
To understand these methods more clearly please refer to the following definitions:

**Off Box** – this represents the control and orchestration plane from where data plane and forwarding decisions are made.

**Slow Path** – on this path packets are processed on the OVS kernel itself which is deemed slow.

**Fast Path** – on this path packet processing avoids the OVS kernel and processing is performed in a more dedicated and faster way.

**SR-IOV** - single root input/output virtualization is a specification that allows the efficient sharing of HW switching resources in a virtual environment to support VM networking requirements.

**DPDK** - data plane development kit is a set of data plane libraries and network interface controller drivers for fast packet processing, currently managed as an open-source project under the Linux Foundation.

**User space** – code and virtual memory that runs outside of the Linux OVS kernel.

**PMD** – Poll Mode Driver consists of a set of APIs to configure the device and their

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**Business benefits**

- Drive Telco Cloud application performance with agile, elastic and secure SDN deployment enabling unconstrained, deterministic cloud network performance
- Exceed new Telco Cloud requirements with an integrated and tested solution ready for Software Defined Data Centers (SDDCs), Network Functions Virtualization (NFV), and public, private and hybrid cloud deployments
- Maximize Telco Cloud network resources with enhanced cloud infrastructure efficiency and higher application workload density
In OVRS environments, Mellanox offers Accelerated Switching and Packet Processing (ASAP2). This solution combines the performance and efficiency of Mellanox networking hardware on the SmartNIC with the flexibility of SDN. This approach leverages dedicated silicon on the SmartNIC and is programmed through the open source Linux-based TC-flower control interface.

At the data plane level of the SmartNIC this method follows the Single-Root Input/Output Virtualization (SR-IOV) approach where each physical function (PF) on the NIC is divided into a group of virtual functions (VFs) that are each assigned a VM for direct packet delivery once the packet processing is completed. This approach delivers post-processed packets from the SmartNIC directly to the VM or container fully bypassing the Linux kernel creating a direct fast path (or PCI host passthrough) for data transmission. Each VM must have the appropriate Mellanox SmartNIC driver installed. This approach is ideally suited for the most stringent and demanding applications such as the infrastructure components of the 5G packet core.

ASAP2 offers up to 10 times better performance when compared with non-offloaded OVS solutions, delivering software-defined networks with the highest total infrastructure efficiency, deployment flexibility and operational simplicity. Furthermore, this performance incurs no incremental CPU usage once VXLAN tunnels were established and near zero packet loss.

VRS - OVS offload

In a VRS environments OVS packet processing is done in the Linux OVS kernel assisted by stateless offloading in the NIC for certain functions such as segmentation and checksum offloads. Post processed packets are then sent back through the OVS kernel to the relevant VM through the VirtIO interface. The advantage of this approach is that since nearly all data center NICs support stateless offloads it is hardware independent offering ultimate flexibility. This approach speeds up packet processing and is efficient for larger IO requests and larger packet sizes but is not optimized for smaller IP packets which require much more processing. This approach is well suited for management traffic or enterprise applications that require less stringent processing.

AVRS - OVS offload using DPDK

AVRS leverages DPDK technology developed by Intel® to accelerate the processing of VXLAN encapsulated packets by bypassing the Linux OVS kernel completely resulting in a fast path for packet processing. Performance is improved dramatically as a fixed number of dedicated cores running in user space are programmed to focus only on packet processing. In addition, DPDK changes the packet IO operation from push mode to poll mode, eliminating a number of interrupts, context switches and buffer copies in the Linux network stack. This approach is also hardware independent provided the NIC it will use has a DPDK PMD driver installed.

The disadvantage of this approach is that dedicated CPU cores can only be used for the packet processing. During periods of inactivity, these expensive CPU cores can spin in loops, while waiting for packets to arrive. This approach is well suited for applications with more stringent processing requirements with smaller packet sizes.

OVRS - OVS offload using DPDK

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OVRS - OVS offload using DPDK

In this case packets destined to the VM avoid the hypervisor and xVRS completely and are terminated on an external HW VTEP such as the Nuage 210 WBX or any other third party HW VTEP. This approach also uses SRIOV to leverage the HW VTEP resources to provide packet processing and VM communication. This method provides high performance processing at the cost of control. Figure 3 summarizes the various offload methods to accelerate packet processing.
**FIGURE 3. Summary of the various methods of OVS offload for packet acceleration**

<table>
<thead>
<tr>
<th>Description</th>
<th>VRS</th>
<th>AVRS</th>
<th>OVRS w/SR IOV</th>
<th>WBX w/SR-IOV</th>
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<tbody>
<tr>
<td>A module in the hypervisor performing OVS switching and VTEP</td>
<td>Accelerates packet processing using a DPDK-based ‘fast path’ process running in the Linux user space</td>
<td>Offloads packet processing to the eSwitch on SmartNIC</td>
<td>VM traffic bypasses the hypervisor and VRS and is terminated at the WBX</td>
<td></td>
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<tr>
<td>Management traffic, large packets</td>
<td>Packet flows with smaller packet sizes and VNFs with moderate processing requirements</td>
<td>Processing intensive VNFs like 5G/LTE Data Path, BNG data path, 5G xHaul data path</td>
<td>Processing intensive VNFs like 5G/LTE Data Path, BNG data path, 5G xHaul data path</td>
<td></td>
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<tr>
<td>Flexible as it is HW independent, deployed in any environment</td>
<td>DPDK accelerates packet processing over VRS with little HW dependance</td>
<td>High performance</td>
<td>Processing intensive VNFs like 5G/LTE Data Path, BNG data path, 5G xHaul data path</td>
<td></td>
</tr>
<tr>
<td>Performance for intensive VNFs and packet processing required</td>
<td>Compute cycles could be stranded</td>
<td>HW dependency but hardware e-switch is accessible via Linux Open APIs (TC/Flower)</td>
<td>Least control over traffic</td>
<td></td>
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**Conclusion**

Nuage Networks SDN solution provides a flexible set of OVS offload capabilities tailored for specific Telco Cloud applications. For stringent applications like 5G infrastructure deployments, Mellanox ASAP2 technology embedded in ConnectX-5 SmartNICs enhance the total infrastructure efficiency of Nuage Networks SDN deployments substantially by offloading computationally intensive packet processing operations, freeing costly compute resources to achieve higher application workload density. By offloading virtual overlay network processing from the CPU to the SmartNIC, CPU overhead is significantly reduced. Similarly, NFV packet throughput, latency, and jitter are improved, enabling the infrastructure to support more application workloads, thus improving cloud infrastructure efficiency.

**About Nuage Networks**

Nuage Networks strikes at the heart of the cloud networking challenge: Orchestrating datacenter and wide-area networks to maximize responsiveness, utilization and visibility. Nuage Networks delivers a highly programmable infrastructure that bridges the gap between the application-centric view and the equally important network-centric view, realizing the full power of SDN. The Nuage Networks solution combines ground breaking SDN and virtualization techniques with unmatched networking expertise to deliver a massively scalable solution that consistently spans datacenters and remote locations. Nuage Networks enables enterprise IT to respond instantly and securely to the demands of users and applications anywhere.

Discover more at [www.nuagenetworks.net](http://www.nuagenetworks.net) and follow us @nuagenetworks on Twitter.