WHITE PAPER

Developing and Deploying NFV Solutions Efficiently: Nasdaq Transforms Its Network Infrastructure

Achieving Network Agility through Virtualization

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Executive Summary

The adoption of network functions virtualization (NFV) solutions across many industry sectors has generated a tremendous amount of excitement, but also has presented significant challenges to enterprises and telecommunications firms that have elected to virtualize network operations. Along with many enterprises that are transforming network infrastructures using software-defined networking (SDN) principles, Nasdaq faces a number of challenges in moving the organization's IT operations to the cloud. However, through Nasdaq's affiliation with Intel® Network Builders the company is successfully meeting these new architectural challenges and implementing a new set of operational behaviors suitable to a large-scale financial institution with critical security, reliability, and scalability requirements.

As proven commercial implementations have become increasingly common, Nasdaq has been steadily moving toward SDN and NFV solutions, exploring the use of virtualization to enhance agility, use compute resources more efficiently, and reduce IT costs. The research project discussed within these pages examines the feasibility of using open-source software ingredients, virtual machines, and virtual network functions on standard high volume servers (SHVSs) based on Intel® architecture. Brocade contributed key components to this infrastructure, as did other members of the growing ecosystem affiliated with Intel® Network Builders.

This paper examines the approach that Nasdaq took in its adoption of SDN and NFV solutions to transform its network infrastructure and meet the primary requirements of the project. The result of the engagement successfully brought NFV solutions into use on an infrastructure built on Intel architecture-based hardware, replacing traditional network hardware components with virtual appliances.

"SDN and NFV technologies offer great opportunities for us to consolidate and provide agility to our business systems. The technology transition of Nasdaq's existing network infrastructure components from dedicated purpose-built devices to virtualized high performance servers that provide multiple network functions will enable Nasdaq to realize the anticipated benefits of SDN and NFV of agility, reduced time to market, capital and operational savings."

– Kenneth Kirk, Director of the Networking Architecture Group, Nasdaq

Technology Challenge: Transforming the Network for Enhanced Efficiency

At the start of the engagement to develop a proof of concept (PoC) based on SDN and NFV, Nasdaq posed a fundamental question: How do we transform our networks to operate more efficiently? Drawing upon evaluations of available technology and research into solutions, Nasdaq identified a number of key areas in which SDN and NFV might benefit from the organization's IT framework:

- **Improved operational efficiency**. With a single point of control for network, storage, and compute configurations, administration becomes much easier. The SDN/NFV approach supports dynamically adding, deleting, or connecting end-point groups and automating provisioning.
- **Enhanced architectural modularity and scalability**. Quality of Service (QoS) controls provide rapid adjustments to throughput, performance, and service chaining, thereby delivering greater responsiveness to customers.
- **Reduced time-to-market**. With greater configuration flexibility and centralized management, the SDN/NFV platform makes it possible to quickly test new business solutions (without adding new hardware) and launch products rapidly. The availability of cloud-based self-service portals makes adoption easier.
- **Rapid provisioning**. With the capability to configure compute resources, network resources, and storage on demand, provisioning times can be reduced from weeks to minutes.
- **Stronger security**. Security policies can be defined and implemented dynamically, enabling dynamic traffic steering, isolation, and segregation—managed easily from a single control point.
- **Greater cost savings**. With fewer hardware components required, more efficient power use, centralized management features, and a common operational model, the SDN/NFV infrastructure offers opportunities for reduced operational expenses and reduced total cost of ownership.

Overview

The Nasdaq SDN/NFV PoC is based on OpenStack*, the latest Intel® Xeon® processor E5 v3 family, and Intel® network interface cards (Ethernet Controller XL710). The infrastructure also uses Brocade's OpenDaylight*-based NetConf and YANG model-capable controller (Brocade VDX* and MLXe*).

The software ingredients include the Data Plane Development Kit (DPDK), Intel® QuickAssist Technology, and Vyatta* vRouter.

Core Components Used in the Nasdaq Proof of Concept

The core components used in the Nasdaq PoC include:

- OpenStack*
- OpenDaylight (ODL)
- DPDK
- Open vSwitch* (OVS)

Contributions by Intel and members of Intel Network Builders to these projects have helped advance the technologies that underpin SDN and NFV. Ongoing collaboration among leaders in this space enhances the interoperability of solutions and establishes a framework of building blocks, components that have been shown to work well together, making it easier to design and develop virtualized network components.

Descriptions of Core Components

OpenStack

OpenStack, the open-source cloud operating environment, manages and orchestrates applications running on network elements. By exposing hardware and infrastructure attributes, deeper operational insights are available, leading to improved decision making, faster network performance, and balanced workloads. Contributions by Intel and others to Enhanced Platform Awareness (EPA) have enabled accurate matching of workload demands to platform capabilities and improved access by virtual machines to advanced hardware capabilities. All of these factors make it possible for customers to effectively comply with service-level agreements.

OpenDaylight

ODL performs the role of SDN controller in a virtualized environment, featuring the major common components required to build an SDN solution in a variety of production network environments. As a Platinum member of the ODL Project, Intel works collaboratively with a number of network vendors in the community, to refine and improve software-defined infrastructure (SDI) capabilities and integration with OpenStack.

DPDK

Originally developed by Intel and then released to the open-source community, DPDK consists of a set of software libraries and drivers to accelerate packet processing on Intel® architecture. Performance improvements of up to 10 times have been recorded[1] and throughput can be boosted to 80 Mpps on a single Intel® Xeon® processor, as well as double this value in a dual-processor configuration. Intel continues to work closely with the DPKD project community to further advance the capabilities.

Open vSwitch

OVS, an open source virtual multilayer network switch, can be integrated into NFV deployments. OVS with DPDK-netdev, available in OVS 2.3, provides an implementation that enables better performance of the data plane when using DPDK libraries.

Details and Status of the Engagement

Nasdaq envisioned applying the NFV infrastructure (NFVI), co-developed in this engagement with Intel, to its traditional financial services offering, including those offerings demanding ultra-low latency response times. The competitive nature of the electronic trading industry requires Nasdaq to operate trading platforms that keep latency and jitter to a minimum. Another key consideration is software and hardware interoperability, ensuring that services can be delivered reliably and consistently regardless of vendor components used in the ecosystem.

Nasdaq expects that following deployment the NFVI will make it possible to dynamically provision network resources and improve time-to-market for new customer products and services. Because of the nature of its customer base, Nasdaq also places a high premium on a seamless user experience.

During the course of the engagement, Intel provided the platform—based on the Intel Xeon processor E5 v3 family (formerly code-named Haswell)—and also provided Intel staff to test the NFV functionality and to optimize the software for the platform.

Research Insights

During the research stage of this engagement, Nasdaq set out to confirm the feasibility of SDN- and NFV-based solutions for improving the operational efficiency and modularity of its commercial offerings while substantially reducing the time-to-market needed to introduce new products. Nasdaq is actively working with a range of partners, evaluating components and determining the most promising SDN and NFV technologies, while exploring ways to maximize the benefits derived from an SDI.

To date, the first stage of the research confirmed that the basic concept—virtualizing the network with SDN and NFV—is possible. For a successful implementation, at a minimum Nasdaq needs to deliver performance comparable to the current platform profile. An operational model of the virtualized environment must conform to or exceed the current performance envelope.

Product initiatives based on the SDN and NFV framework considered for launch on the platform under discussion include:

- Customer connectivity to the Nasdaq exchange(s)
- Security controls associated with customer access to Nasdaq's trading platforms

The traditional connectivity method that Nasdaq offers to its customers involves co-location, with the customers connecting their server and networking infrastructure—within Nasdaq data centers—to Nasdaq's trading platform infrastructure. This provisioning process, which involves personnel from multiple teams on both the Nasdaq and customer sides, requires physical and logical changes typically carried out over a period of time, sometimes for weeks.

By moving to an SDI, relying on virtual appliances to replace physical hardware and managing resources dynamically in an automated fashion, provisioning is streamlined, hardware cost is reduced, and operational efficiencies are gained.

Collaboration with Intel

In the course of building a virtualized environment on an x86-based infrastructure, for both the compute and networking platforms, Nasdaq is working closely with Intel to ensure that the latency profile can be maintained at previous levels. Nasdaq is also relying on guidance from Intel to oversee the DPDK work and for help with low-level customization. This includes the validation of software libraries, performing OS-level tuning, verifying that applications are efficiently deployed on multi-core processors, and carrying out network functions that provide the level of performance and determinism expected of a network component.

Intel has also introduced Nasdaq to experienced companies involved in the SDN and NFV ecosystem, who have offered guidance in the deployment of SDI based on the Intel® Open Network Platform (Intel® ONP) framework. This guidance has helped Nasdaq to work with and evaluate promising vendors and accelerate the testing process.

Solution Opportunities

In the future, once an SDN/NFV platform is established in a production environment, Nasdaq looks to simplify configuration management. Using SDN and NFV components—while maintaining the same compute and network profile—Nasdaq aims to efficiently provide enhanced functionality to its customers.

From the point of view of Nasdaq's customers the Nasdaq ecosystem will remain unchanged, including the look and feel of existing interfaces. From Nasdaq's perspective, entitlement of services (the time required to turn up the services) can be performed much more rapidly. Automation takes the place of the manual processes, so the workflow no longer includes different groups and staff members. Additionally, capacity requirements can be managed automatically, with dynamic adjustments to compute resources to contend with changing customer demands.

"From the perspective of customer interaction with Nasdaq, customers should not see any difference. If customers need to find a new way to interact with us, we feel that this is potentially a broken model. We don't want to ask customers to change how they interact with us. On our side, we are going to ensure that the ecosystem has proper security and isolation capabilities so that the integrity of customer data and customer process is maintained while conforming to the agreed-upon SLAs for performance and service times. That is a primary concern for us."

- Sandeep Rao, Systems and Performance Engineering Team, Nasdaq

Deterministic performance is another important consideration for Nasdaq in the test and evaluation process. Delivering consistent, predictable responsiveness and QoS to customers is essential. By providing a centralized view of network operations, SDN and NFV offer the capability to dynamically measure, adjust, and reconfigure components to meet service requirements and balance workloads across the network.

Figure 1 shows the components under consideration for the solution.

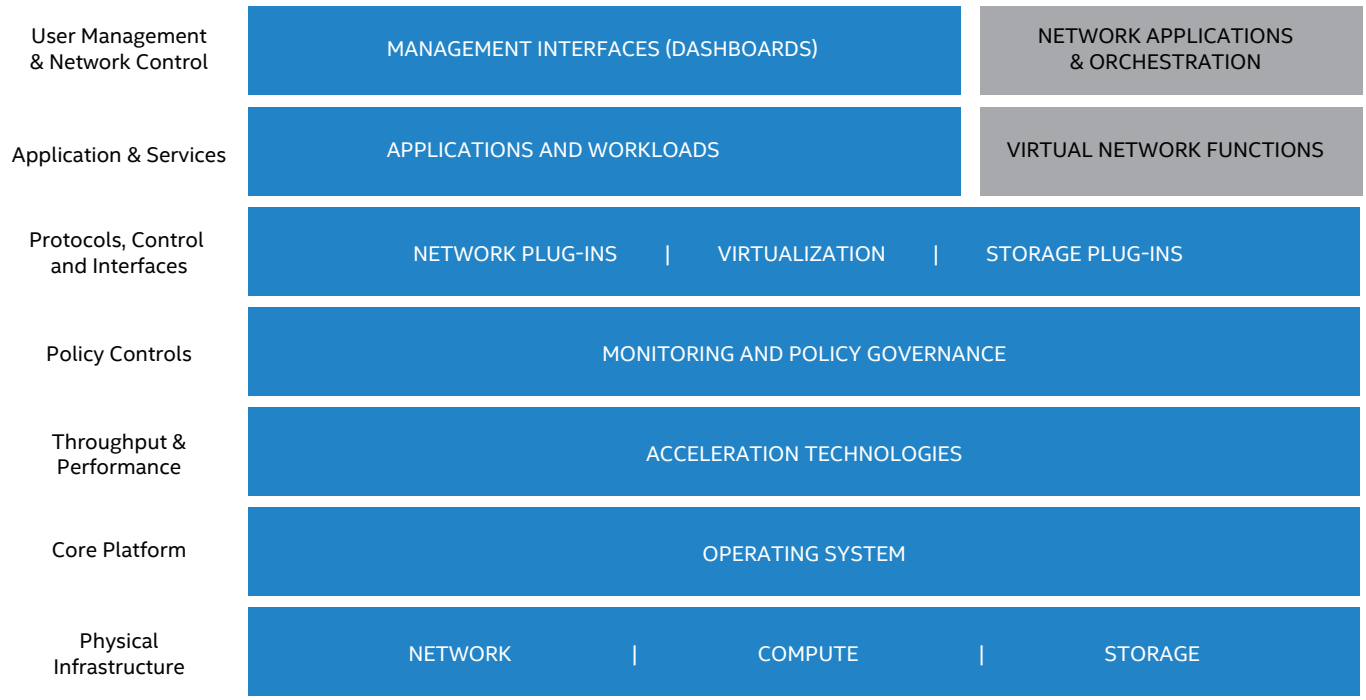

Figure 1. The components of the Nasdaq NFV platform.

Next Steps

Nasdaq will continue to test and evaluate components from third-party vendors, addressing interoperability questions and seeking best-of-breed solutions that will work well within the SDN/NFV environment. Performance benchmarking is also proceeding concurrently. Nasdaq is optimistic that the results of this testing will confirm the original expectations for the SDN/NFV environment.

Although financial services systems have somewhat different requirements than telecommunication systems, both types of systems require a high degree of responsiveness coupled with a need for dynamic resource allocation to meet customer expectations and deliver consistent QoS. Working with other partners, Intel has demonstrated that performance can be maintained in highly demanding NFV architectures for carrier-grade deployments. One example is documented in this white paper: Transforming Networks with NFVI, HP Carrier-Grade Servers, and Intel® ONP.

Creating an Ecosystem for Software-Defined Infrastructure

The Intel® Infrastructure Builders program helps to align the efforts and technology resources surrounding the transformation of data centers across the computer industry and to guide the creation of commercial solutions in this area.

SDN and NFV are important components within Intel's larger vision that seeks to increase the opportunities for data center modernization through SDI. This vision is built around three technology pillars, represented by three Intel groups:

- **Intel® Network Builders**. An ecosystem formed to accelerate the adoption of NFV and SDN solutions in telecommunications networks, public, private enterprise, and hybrid clouds.
- **Intel® Fabric Builders**. An ecosystem that collaborates with industry participants to build world-class solutions based on Intel® Omni-Path Architecture.
- **Intel® Cloud Builders**. An ecosystem that provides tools, techniques, and reference architectures for planning and deploying cloud-computing infrastructures.

Furthering the Adoption of SDN and NFV: Intel® Open Network Platform

Many of the Intel® ONP reference architecture ingredients were included in the PoC. Intel ONP has been a stabilizing force for bringing together the diverse variety of components required at multiple levels to create a stable, reliable SDI suitable for support commercial operations (see Figure 3).

The Intel ONP reference architecture provides a blueprint for enabling commercial adoption of validated hardware and software in key industry sectors. Telecommunication carrier networks, enterprise environments, and cloud data centers can more easily build solutions using an open-source software stack running on SHVSs, as defined by the reference architecture. An ecosystem has been established around the Intel ONP framework with collaboration, contributions, and the support of industry consortiums, telecommunications and cloud providers, Intel® Network Builders, and leading companies involved in open-source projects.

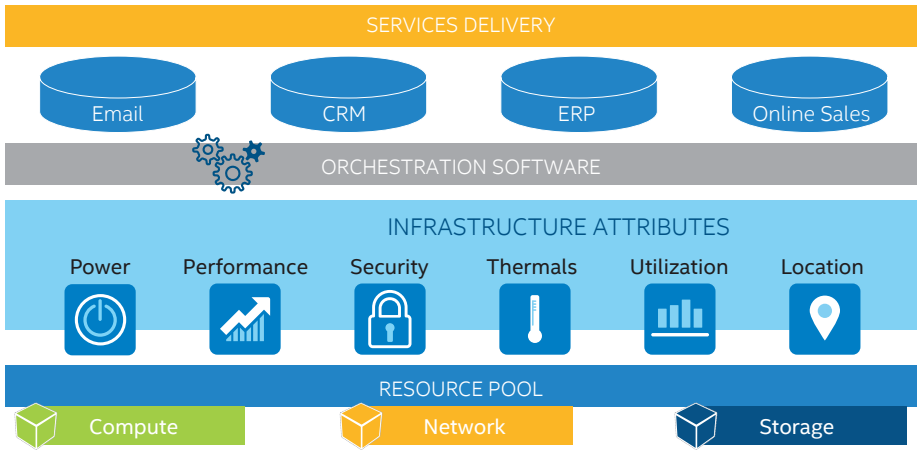

Figure 2. Re-architecting the data center with software-defined infrastructure.

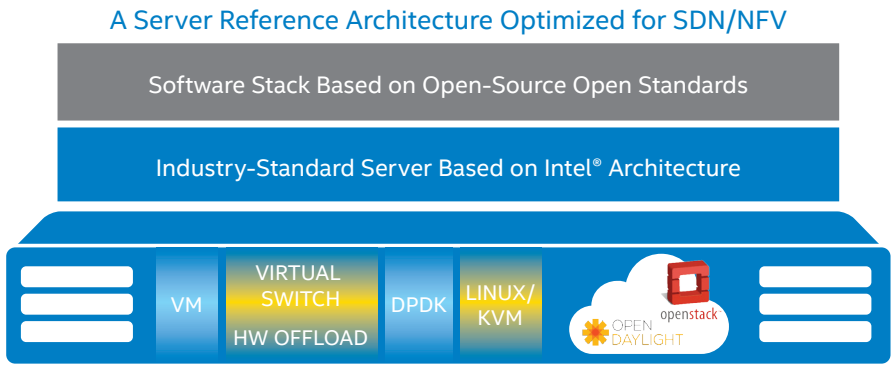

Figure 3. Intel® Open Network Platform reference architecture enables efficient SDN/NFV development.

Enabling Network Transformation: From the Theoretical to the Practical

SDN and NFV solutions have advanced from theoretical constructs and loosely defined architectures to practical implementations based on a selection of validated components built by hardware and software companies, many of them members of Intel® Network Builders. These events have occurred much more quickly than predicted by industry observers, leading to large segments of the industry moving toward adoption and contributing to the collaborative efforts. These efforts center around strengthening the open-source projects that supply the basic building blocks for solutions, participating in standards bodies and consortia that are providing the guidelines for solution operation, and expanding the working knowledge in the field by developing and deploying solutions that showcase particular use cases.

Nasdaq's work with Intel to develop and confirm commercial solutions using SDN and NFV is ongoing and promises to establish new landmarks in the quest to transform data centers. Networking environments incorporating NFV benefit from exceptional agility and great manageability, as well as a heightened capability to create unique services for customers more cost efficiently than ever before.

"This move to software-defined infrastructure we believe is both critical and inevitable."

- Diane Bryant, Senior VP & General Manager of the Data Center Group, Intel

To learn more about the the technologies that Nasdaq uses to power the world's market operators, visit the Differentiate with Technology page: **http://business.nasdaq.com/tech**

Learn more about the Intel® Open Network Platform: **www.intel.com/ONP**

Download the Intel Open Network Platform Server Reference Architecture for NFV and SDN: **www.01.org**

Learn more about Intel Network Builders: **https://networkbuilders.intel.com/**

[1] http://www.intel.com/content/www/us/en/intelligent-systems/intel-technology/packet-processing-is-enhanced-with-software-from-intel-dpdk.html

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