Beyond the Data Center: How Network-Function Virtualization Enables New Customer-Premise Services

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This paper describes how network-function virtualization (NFV) and software-defined networking (SDN) will help network operators profit from greater flexibility and the faster rollout of new revenue-generating services. Important building blocks in this transformation are embedded processors optimized for networking and communications. NXP's QorIQ processors are well positioned to meet the requirements of virtualized network services. The Linley Group prepared this paper, which NXP sponsored, but the opinions and analysis are those of the author.

Squeezed by rapidly growing data traffic and customer demand for new services, network operators need to upgrade their network architecture and change their business model to become more efficient, nimble, and profitable. Consequently, everyone is talking about network-function virtualization (NFV) and software-defined networking (SDN) as the most promising solutions. Although the buzz revolves mostly around data centers and cloud servers, NFV and SDN will also change network-edge devices and even customer premise equipment. Small-business and enterprise branch-office routers are prime candidates for these changes, but home gateways will soon evolve, too. NFV and SDN are really end-to-end solutions that can make every network component more efficient, flexible, and cost effective.

In addition to helping operators manage escalating costs, SDN and NFV can generate new revenue by rapidly adding new services. One example is *virtual* customer-premise equipment that can offer new features such as antivirus security, a firewall, a virtual private network (VPN), and unified communications for voice and data. Typically these services are distributed on both the local and the remote equipment. To quickly add new services or to reconfigure existing ones, operators need a flexible cloud.

Migrating Away From Fixed-Function Hardware

SDN makes the network more flexible by replacing dedicated fixed-function hardware with programmable hardware and open software. NFV scales performance by implementing the networking functions in general-purpose virtual machines. Racks of multipurpose systems can perform the same functions as the expensive function-specific equipment that proliferates in today's central offices and Internet points of presence. Network operators want the freedom to easily port the virtual network functions (VNFs) among platforms from different vendors.

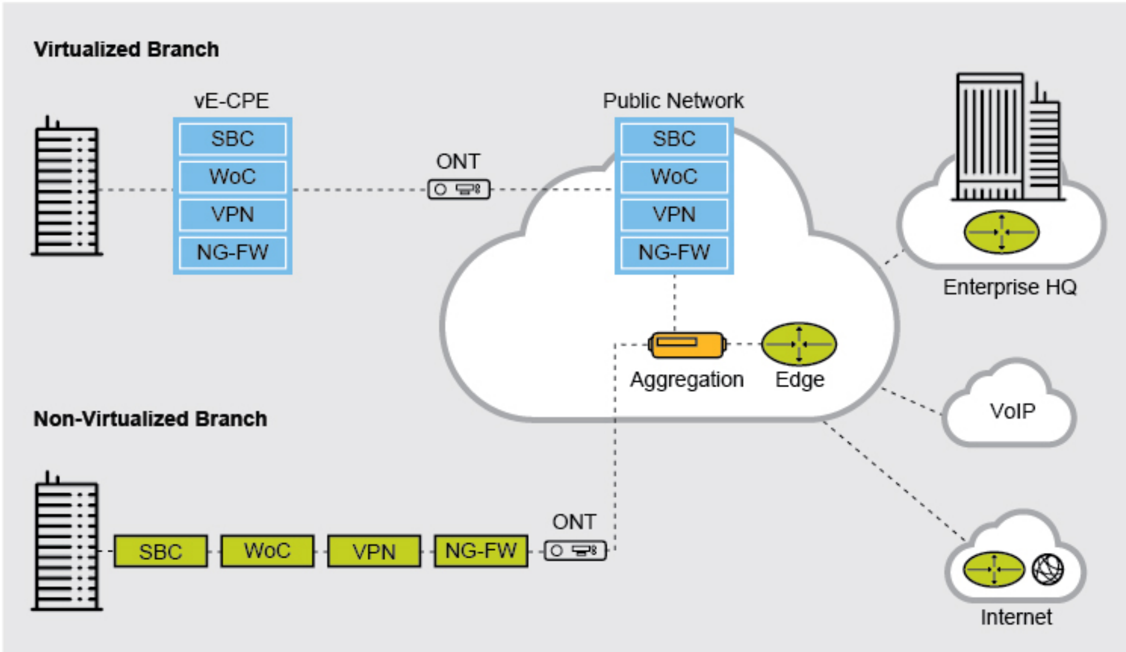

Figure 1. Software-defined networking (SDN) and network-function virtualization (NFV) extend to the premises. Functions implemented in separate systems in a classical nonvirtualized branch can be implemented in virtual enterprise customer-premise equipment, hosted either at the branch or at an aggregation site in the public network.

Variable workloads are more easily balanced on multipurpose hardware that can adapt to rapidly changing conditions; adding capacity is easier and less expensive when the hardware is standardized and programmable; single points of failure vanish when tasks can quickly migrate to other hosts; software upgrades can quickly offer new services; and equipment maintenance is easier, thus improving reliability and security.

The most-optimized solutions will combine acceleration hardware with general-purpose processors to run the control-plane and high-level data-plane tasks. As Figure 2 shows, new industry standards such as OpenFlow (OF), Open Data Plane (ODP), and Open Platform for NFV (OPNFV) enable developers to write software that's more flexible and more portable to multipurpose "white box" hardware.

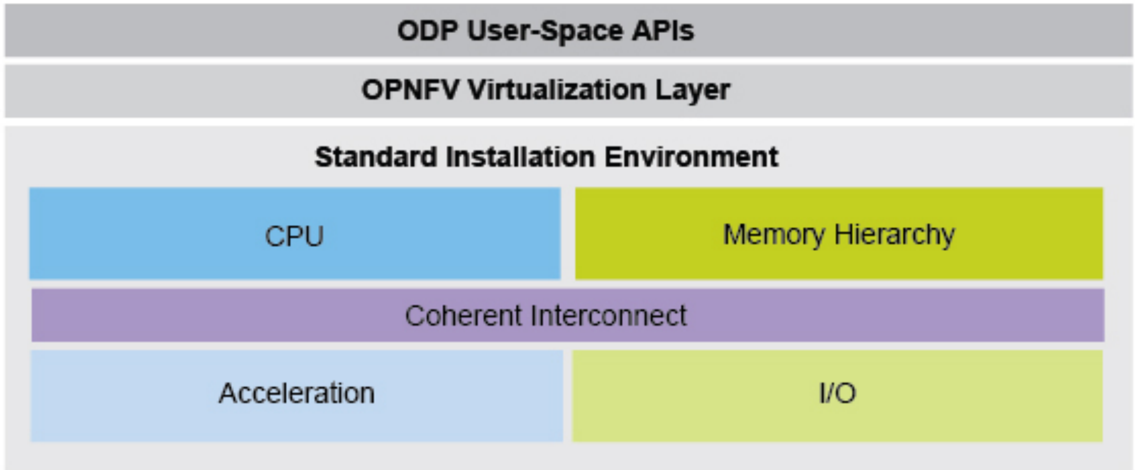

Figure 2. Standard software enables interoperability and portability across multiple vendors. NXP is a co-founder or contributor to several of these industry standards.

Looking beyond data centers, central offices, and the cloud, this evolution must be an end-to-end transformation. It must include not only the network core, but also its edges, its access points, and even the customer premise equipment (CPE). Although virtualized functions such as vRouters in the network are vital links in the chain, virtual CPE (vCPE) completes the link and allows network operators to offer new services.

The vCPE is still a box located on the customer's premises, but the VNFs it supports can run either locally and remotely. Network operators can use them to deliver new services such as those described above. The VNFs may not be co-located but the services are often chained together within the network and the vCPE for a cohesive user experience. Whether the operator implements these services locally or remotely is transparent to the end users.

Standards Create a Multivendor Environment

Most routers already separate the control plane and data plane. SDN and NFV don't alter those basic functions but do change their implementations. SDN enables a reconfigurable data path that software can modify on the fly in response to changing conditions.

NFV enables a customizable network, so operators can add new services more quickly than legacy equipment would allow. Software interfaces created by the industry's new open standards (such as the aforementioned OF, ODP, and OPNFV) help to enable this flexibility by inserting abstraction layers between the application software and the underlying hardware. Programmers can write portable high-level code to application programming interfaces (APIs) without worrying about the underlying hardware—thus enabling software portability across platforms. These standards enable network operators to choose equipment from different OEMs.

Solution: Optimized Embedded Processors

SDN and NFV can be implemented on embedded processors that are optimized for communications, virtualization, programmability, and security. These optimized solutions embed hardware accelerators that are more power efficient for specialized tasks than general-purpose processors. Additionally, they integrate networking and storage interfaces that enable smaller system designs and high density.

NXP's QorIQ processors represent the ideal marriage of processing power and hardware engines for SDN and NFV applications. Depending on the particular chip, these processors may include NXP's Security Engine (SEC), which handles all the popular cryptography algorithms and protocols; the Data Compression Engine (DCE), which accelerates popular compression and decompression algorithms; the Pattern-Matching Engine (PME), which can perform regular-expression (reg-ex) operations for deep packet inspection (DPI); and the Data Path Acceleration Architecture (DPAA), which accelerates many low-level packet-processing functions. Where present, all this optimized hardware works together to accelerate the data plane. Furthermore, it is user programmable and supports standard APIs such as ODP for easy application portability.

QorIQ processors also support virtualization in hardware, and they are fully programmable. NXP offers some off-the-shelf software under its VortiQa brand, such as the Open Network Switch Software and the Open Network Director Software. Both are commercial-grade products for switches, routers, and gateways in enterprises, data centers, and customer premises. Both of these VortiQa products also comply with the Open Networking Foundation's OpenFlow 1.3 protocol. Third-party software suppliers offer additional ready-made solutions, and developers can fine-tune their own networking software. This programmability includes the hardware accelerators as well as the general-purpose CPU cores.

In addition, some newer QorIQ processors have a significantly enhanced version of DPAA. This second-generation DPAA2 is available in the QorIQ LS2085A and LS1088A, a pair of ARM-based eight-core processors. It is also being designed into NXP's future ARM chips.

Figure 3 shows how a QorIQ LS1043A processor can enable vCPE in a router using industry standards such as OpenFlow and Open Data Plane. This 64-bit processor has four ARM Cortex-A53 cores, providing ample general-purpose processing muscle for this application. For packet acceleration, it has DPAA and a SEC engine. Network interfaces include a 10 Gigabit Ethernet (10GbE) port and five Gigabit Ethernet (GbE) ports. For additional I/O, it has three PCI Express (PCIe) controllers and a SATA III controller. A 32-bit DRAM controller supports low-power DDR3L or higher-performance DDR4 external memory.

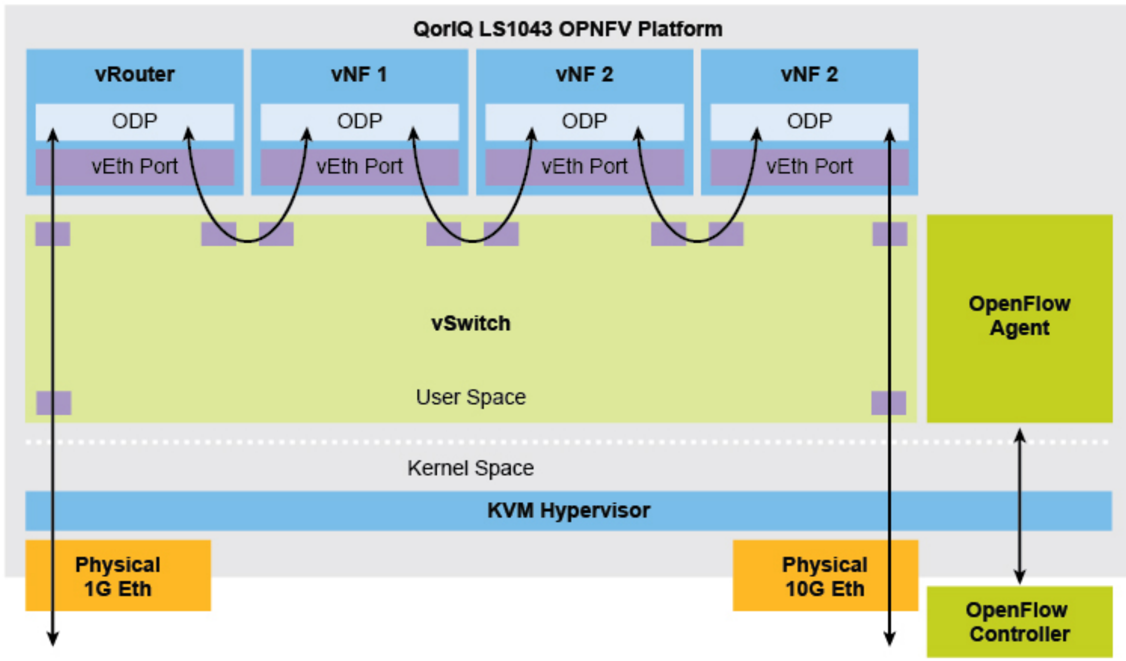

Figure 3. The basic building block of this virtual customer-premise equipment is a QorIQ LS1043A quad-core ARM processor with packet acceleration, a cryptography engine, hardware support for virtualization, and fast I/O and network interfaces.

Using this building block and industry-standard open APIs, designers can implement a vCPE router. It runs a hypervisor in the kernel space and a virtual multiport Ethernet switch in the user space. VNFs running on the Open Data Plane layer can share the physical Ethernet ports through their virtual Ethernet (vEth) ports. This design implements multiport switching in hardware-accelerated Open vSwitch software instead of using a dedicated hardware switch that's either on or off the chip. The virtual switch is fast enough for this vCPE application and is more flexible than a dedicated Ethernet switch because it's programmable. Also, by eliminating a hardware switch, this router is a lower-power and lower-cost solution.

What's more, this basic design is highly scalable, because NXP offers larger (and smaller) QorIQ processors that have similar features. For example, a higher-end design could replace the quad-core LS1043A with the LS1088A, which has eight Cortex-A53 cores, second-generation DPAA2 acceleration, two 10GbE ports, eight GbE ports, and a 64-bit DRAM interface. This processor delivers twice the CPU performance and four times the packet throughput of the LS1043A for about twice the power consumption (10W typical). Thus an OEM could offer a broad product line that scales from home gateways to small-business access points to enterprise branch-office routers—all running essentially the same portable software. And ODP helps developers port VMs and VNFs from different vendors, thereby avoiding vendor lock-in.

Figure 4 shows how SDN and NFV enable virtualization throughout the whole network. Almost any network function can be virtualized; the main limitation is performance and power. If the network functions were implemented using general-purpose embedded processors, throughput would indeed suffer—so badly, in some cases, that virtualization would be impractical. Also, power consumption would be higher.

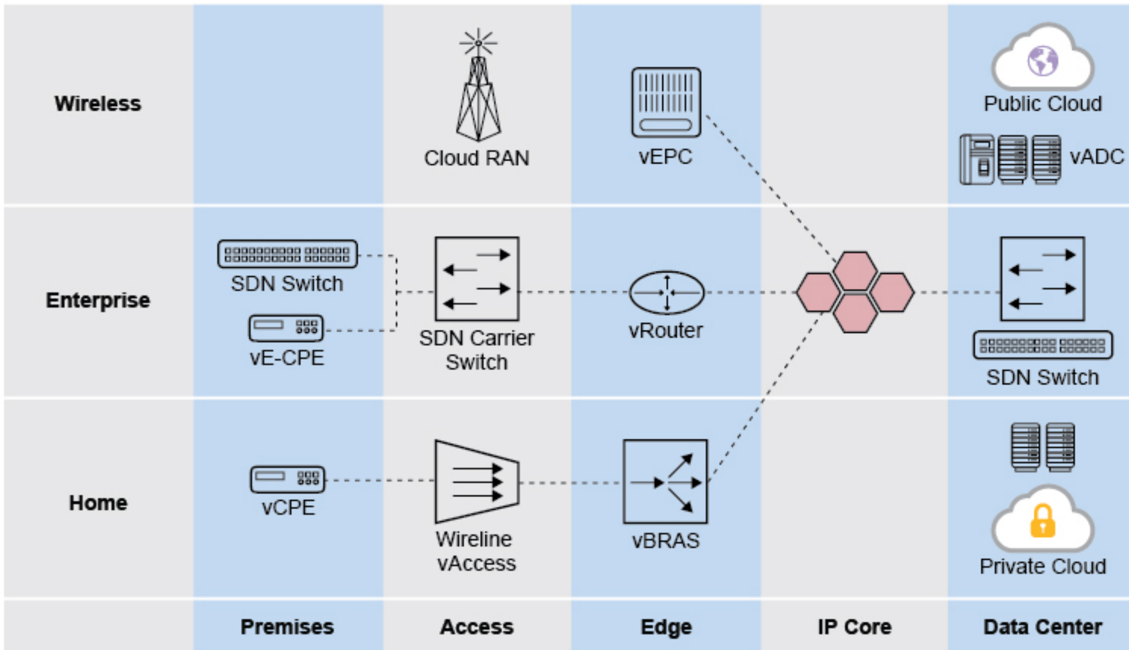

Figure 4. SDN and NFV are overhauling the whole network architecture, not just the hardware in data centers and central offices.

Performing low-level tasks in hardware is generally more power efficient than doing everything in software. By offloading those tasks from the CPUs to the acceleration engines, SDN and NFV can compete with special-purpose networking hardware.

Because multipurpose hardware is programmable using industry-standard software-development tools and open APIs, operators can more easily customize their software, deliver new services, and thoroughly test their code on VMs under real-world conditions before deployment.

Designing for Tomorrow

The simple fact is that networks must become more configurable and scalable to keep pace with the rapid growth of network traffic and the pressure on operator revenues. They must embrace open standards to ease software development and achieve compatibility on hardware from multiple vendors. They must enable the rapid rollout of new services to stay competitive and generate new revenue streams. And they must become more secure to be reliable platforms for e-commerce and business communications.

Hardware designers and OEMs must look at software-programmable SoCs that can scale to the huge volume deployments of network operators while remaining cost- and power efficient. Optimized SoCs that integrate the right combination of CPU performance and hardware engines can achieve this scale.

Tom R. Halfhill is a senior analyst at The Linley Group and a senior editor of Microprocessor Report. *The Linley Group offers the most comprehensive analysis of the microprocessor industry. We analyze not only the business strategy but also the internal technology. Our in-depth reports cover topics including embedded processors, mobile processors, network processors, base-station processors, and Ethernet chips. For more information, see our web site at www.linleygroup.com.*