Technical white paper

Network functions virtualization

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Introduction

Network Functions Virtualization (NFV) is a core structural change in the way telecommunication infrastructure gets deployed. This in turn will bring significant changes in the way that applications are delivered to service providers. NFV will bring cost efficiencies, time-to-market improvements and innovation to the telecommunication industry infrastructure and applications. NFV will achieve this through disaggregation of the traditional roles and technology involved in telecommunications applications.

This disaggregation will be enabled by changing the industry's traditional approach to delivery of applications from a closed, proprietary, and tightly integrated stack model into an open, layered model, where applications are hosted on a shared, common infrastructure base.

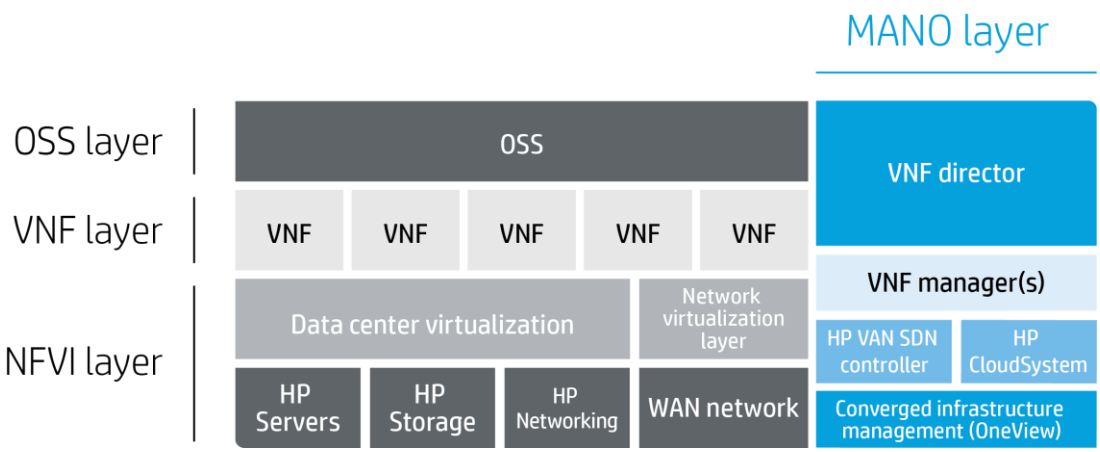
This paper reflects HP's view on how cost will be reduced and how major innovations will be introduced as NFV is adopted. The associated dynamics will be analogous to the dynamics that enterprise IT has undergone over the last decade, and its associated benefits. NFV brings these market dynamics and efficiencies to the core revenue-generating applications of telecommunications.

The requirements and open standards that underpin NFV are being developed by an ETSI Industry Specification Group (ISG). HP has several contributing members in this group.

This paper also outlines HP's view on the "roadmap" to NFV, including the evolution of role(s) of different types of vendors in the market structure. We specifically highlight the architectural principles HP will promote to secure its customers the most value, and therefore competitive edge, in a world of increasing competition.

The open architecture described in this paper has two key modules—the NFV infrastructure, realized with HP Converged Infrastructure, and the hypervisor-independent NFV Orchestrator, based on elements of HP's converged cloud. The architecture delivers a vision for an open solution that ensures our customers can access the best technologies to deploy NFV. The architecture has a deep alignment with Software Defined Networking (SDN) and specifically HP's developments in this area.

HP's NFV architecture is based on a layered approach that allows our customers to incrementally add new functionality and also gives customers the openness and flexibility to work with the tools and vendors they prefer.



For the infrastructure layer, we provide pre-integrated, workload-optimized systems to run virtualized functions on the carrier network, based upon the latest technologies in easy-to-buy, manage, and support models. We support various deployments of hypervisors with SRVIO/DPDK, providing ISVs and CSPs a way to achieve line rate networking performance on HP servers. This allows carriers to run their networks with the same hardware that IT uses.

Our converged infrastructure management solution of OneView provides a single, collaborative management platform built for speed. It allows IT/network teams to work and collaborate in a more natural and automated way. It's a software-based approach to lifecycle management that automates operations to reduce the cost and time to deliver IT services with an open development platform designed to rapidly adapt to business needs. This programmable platform, built on the REST API, allows you to scale beyond your data center walls to the cloud.

At the network virtualization layer we believe that SDN controllers will increasingly need to support both virtual and physical networks. This is a key design goal consideration, and HP's solution provides automated provisioning of both physical and

virtual networks. In addition to overlay support, physical switches support both layer 2 and layer 3 forwarding plus flows, which will enable bridges between SDN and non-SDN implementations. An all-encompassing management platform such as HP's IMC will be imperative to the successful deployment of an SDN solution in heterogeneous environments, and it is our aim to bring this ease of management to our customers.

HP CloudSystem delivers a simple, proven path to the NFV infrastructure as a service (IaaS). It supports multiple hypervisors and enables consumers to access private clouds and virtual resources. It features:

- Simple infrastructure services provisioned within minutes, leveraging HP's Cloud OS software
- Open APIs—including OpenStack APIs—provided for both administrative and cloud service functions, enabling highly automated cloud delivery.
- New administration console, aligned with HP OneView—an infrastructure management tool designed from the ground up for convergence, and for managing all HP Converged Infrastructure
- Fast and easy installation via software appliance delivery model

HP, with its strong heritage in management software, has rich portfolio offerings to support carriers in their journey to integrate the entire NFV stack into their existing OSS/BSS solutions. Our solutions range from traditional fault management to complex services-based management supporting the complete FCAPS needs for our carriers.

Finally our NFV Director is the HP implementation of the NFV Orchestration (NFVO) functionality from the emerging ETSI model. This NFV Orchestration function is critical to the actual operationalization of NFV. Ensuring the capability to manage NFV in heterogeneous, multi-vendor, and geographically distributed environments is a key differentiator for HP. HP brings our deep experience and expertise in both Telco and IT to ensure HP NFV Director addresses all the key functionality required.

NFV building on key enterprise IT trends and technologies

One lens we can look through to understand the future of NFV is a view on what has happened in enterprise IT. NFV uses traditional IT virtualization techniques on commodity hardware (compute, storage, and networking) to consolidate network applications onto industry high-volume servers and storage and hence allows the industry to gain from both the cost and innovation dynamics of traditional IT. It is possible today to use COTS IT Infrastructure to do complex tasks that have traditionally required custom hardware builds on specialized ASIC or DSP devices (thanks to recent technologies such as the packet processing capabilities found in the latest CPUs).

Within enterprise IT applications, server and storage sprawl and complexity cause most organizations to spend more than 70% of their budget and resources on "maintenance and operations"—and less than 30% of time and money on innovation—on the things that help the business be more competitive. As a result, most IT organizations have seen a widening gap between what the business demands and what IT can deliver. They lack the agility to respond to business requests in a timely manner.

At HP, we believe that the only way for enterprise IT and networks to shift resources from operations to innovation is through infrastructure convergence.

HP Converged Infrastructure is a blueprint for the data center of the future that accelerates the provisioning of IT services and applications by integrating servers, storage, networking, security, power, cooling, and facilities into shared pools of interoperable resources, all managed through a common management platform.

The first step for most organizations has been one of "standardization"—to increase quality and speed of IT service delivery with lower cost of operations and better, more efficient management. This could include moving to a small number of approved standard configurations, based on industry standards with reusable components and implemented in a consistent fashion with consistent management tools. The end result of this step is a more standards-based, modular, and reusable infrastructure.

The second step for IT has been one of "virtualization," moving from physical server, storage and networking environments to virtualizing the entire data center, increasing the quality of the service delivered and making IT more responsive and aligned to the needs of the business.

What virtualization and automation have achieved in the data center is what NFV aims to achieve for the revenue-generating applications run by CSPs. Thus, NFV will build on the journey that enterprise IT has undertaken.

Virtualization is a step on the journey to cloud, and in the world of enterprise IT, applications are evolving to services, and the role of the CIO is evolving to become that of a service broker.

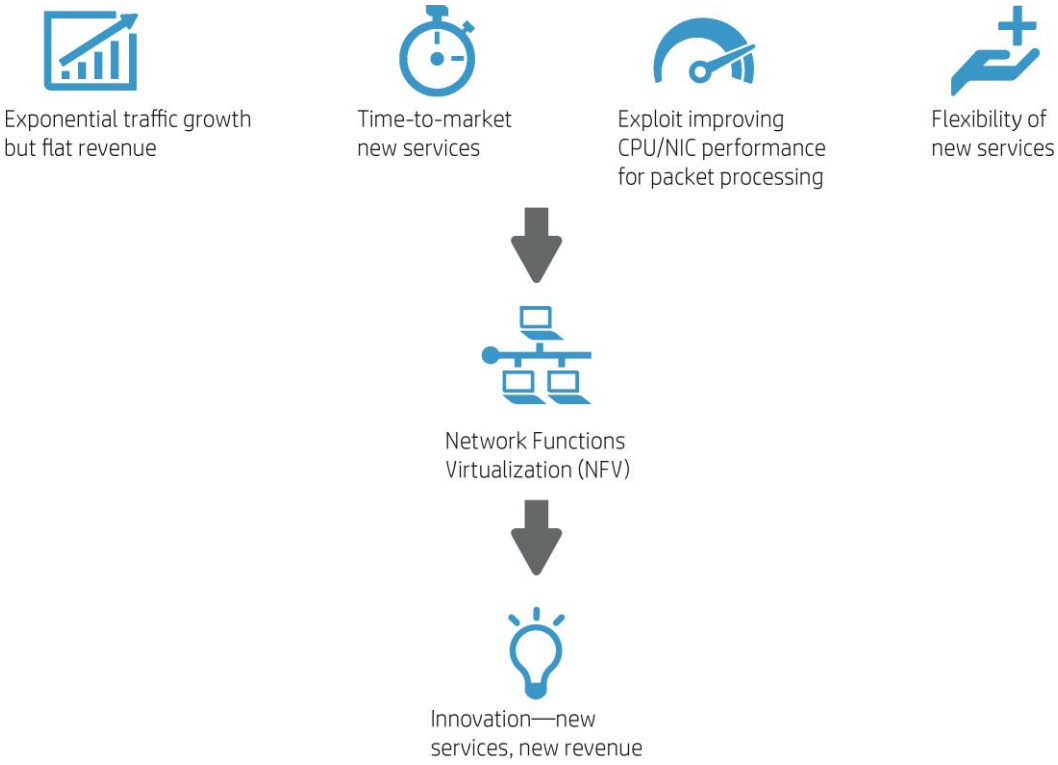
Later in this paper it will be shown how NFV can be enhanced by close coupling (within the HP architecture) with SDN. This is because, just as with the stresses and strains seen within enterprise IT, network resources and operational processes have been stressed and stretched thin for years. SDN inserts both service intelligence and application intelligence into the

infrastructure layer for a more robust network with hardware-independent flexibility. The network can be programmed as if it were a single entity, with features readily added or expanded as needed from a central controller. Data flows can be adjusted dynamically to meet application needs amid changing network conditions. Rules for network switches can be changed on the fly.

NFV is a catalyst for structural market change

With the rapid growth of rich media applications and the decrease in voice revenues, CSPs find themselves in a position of exploding network traffic while their revenues are stagnating. They face competition from over-the-top (OTT) players who are agile, flexible, and able to roll out revenue-generating services much faster than the CSP. CSPs are aware that their network capacity utilization can be poor as they have to engineer their networks for peak traffic rates and have no way of utilizing the spare capacity this creates. Enterprise IT demonstrates a more efficient way to manage the delivery of multiple networked applications through shared virtualized infrastructure. NFV applies virtualization to the telecom core network functions and the associated core and value-added applications of a CSP, enabling the CSP to reduce cost and improve time to market.

Figure 2. NFV drivers and enablers



NFV will transform the way that CSPs architect and design parts of their networks using standard IT virtualization technologies. (To be clear, the part that is standard is the traditional compute side; the networking enhancements such as 40 Gbps/100 Gbps with packet processing capabilities like DPDK, PF_RING is new.) NFV will allow a CSP to consolidate many applications and networking appliances onto industry-standard high-volume servers, switches, routers, and storage. Through NFV, CSPs will automatically benefit from any major advances and disruptions that appear in IT.

NFV enables significant benefits through deployment of virtualized network applications on shared infrastructure, and it brings additional benefits through the IT like layering and purchasing decisions:

- Direct cost savings with improved utilization and wider adoption of standard industry servers for core telecom applications in a shared compute infrastructure.
- Greater flexibility with a cloud fulfillment model where, for example, applications can be readily deployed without delays, speeding time to market.
- NFV also allows for a simplification of the planning and scaling of the network as new hardware can be quickly added to meet demands without long network appliance procurement processes.

- Allowing CSPs to add or delete application or service capacity on demand to meet the elastic needs of the traffic. This will allow the CSPs to run the networks more efficiently and reuse a shared pool of compute resources for various functions, thus reducing operational costs.

Additionally, having a uniform infrastructure produces operational savings by reducing management complexity and its associated cost. This frees up valuable resources to innovate and contribute to CSP differentiation.

NFV is complementary to software-defined networking (SDN) although NFV can be implemented without SDN being required. SDN allows IT to apply business logic directly to emerging software-based networks and dynamically introduce new services faster with lower management costs and with less complexity. SDN unlocks overprovisioned, underutilized, and constrained networks to drive value out of networks. It enables network simplification by abstracting away complexity.

NFV and SDN can be combined to create greater value as SDN extends to the network infrastructure the agility that server virtualization brings to the compute infrastructure. HP foresees that functions being virtualized today eventually become virtualized network services within an SDN architecture.

Demonstrating in-depth integration of the two is a key requirement fulfilled within the HP architecture.

Table 1. NFV and SDN comparison

Network Functions Virtualization (NFV)	Software-Defined Network (SDN)
By leveraging standard IT virtualization technology to consolidate many network equipment types onto industry-standard high-volume servers, switches, and storage, NFV provides a model to meet the challenges around reducing CapEx, improving manageability, decreasing the time-to-market, and encouraging a wider ecosystem.	SDN enables the emerging software-based networks that allow IT to apply business logic directly and dynamically to introduce new services faster, lower management costs with less complexity, and commoditize many network functions, reducing CapEx. SDN is an enabling technology that challenges current practices by decoupling the control plane from the data forwarding mechanisms.

The NFV value delivery system will consist of many vendors, with some vendors taking on several roles to meet CSP needs. This will be the case through a multi-year transition phase while the ecosystem and technology mature to fully deliver on the NFV objectives. To explain HP's point of view and how we see the market maturing, we will highlight four of the core roles and how we believe that they will evolve over time:

- **Network infrastructure providers:** Companies that can deliver the core compute, storage, and network capabilities that are at the core of the NFV infrastructure. These companies will also take on the challenge of how to enable more demanding applications by introducing new types of resources (such as digital signal processing capabilities) into this "elastic" infrastructure.
- **Infrastructure orchestration providers:** Companies that enable the orchestration of the underlying core platform to enable the virtualization and orchestration of the infrastructure. While typical IT cloud capabilities are very well developed, these players will focus on enabling this layer to deliver on the often more stringent requirements of telecommunications.
- **Application providers:** Both the providers of the critical applications that today are delivered in the traditional model and new innovative providers will enter the market. The critical applications are often delivered on standard computer architectures. However, many are still delivered on proprietary hardware to meet performance and quality requirements. The primary challenge of the providers of critical applications will be to evolve existing network functions that have been developed for bespoke appliances as well as standard computer architectures, to more effectively execute in a cloud environment, while also taking advantage of the new infrastructure to migrate more demanding applications onto the infrastructure as it evolves. New innovative application providers should enter the market as the availability of an open infrastructure should boost the strength of this ecosystem, which today is limited by route to market and complexity of deployment of new applications.
- **System integrators (SIs):** Organizations that will take ownership for the end-to-end implementation of systems incorporating applications and NFV infrastructure.

Vendors currently take on a combination of the above roles and will continue to do so as the market transitions to NFV. For example, the traditional NEPs will in some cases continue to play the role of application provider, system integrator, etc. NFV will allow them to deliver applications in more of an ISV model as NFV standardizes on the shared, open infrastructure.

It is also important to recognize that end-to-end application guarantees are delivered to CSPs at a cost by today's vendors. NFV enables CSPs to selectively choose the SI for specific applications in the case where such guarantees are needed. However, to achieve the maximum economic benefit from NFV, it is also clear that, similar to the IT industry, CSPs will increasingly have to evaluate where such SLAs are strictly necessary from the vendors, and where the CSP can more cost-effectively carry the risk.

HP's leadership role in NFV

As the world's largest IT vendor, HP is naturally positioned to leverage our strength from the IT enterprise market and bring this strength, scale, and experience to bear for NFV. This is demonstrated by:

- HP's commitment to NFV through the introduction of a commercial virtual services router (VSR) based on commercially deployed Comware software.
- Proven experience and product offerings that address quality of service (QoS) requirements, meeting stringent latency, scalability, high availability, and real-time performance specifications. These include our home location register (HLR), core router, and switches that are deployed in core network applications.
- HP leadership in SDN with the largest portfolio of OpenFlow switching products and, most recently, the development of a commercial SDN controller.

Through our broad participation in the infrastructure layer, as well as HP's historic, specific activity in the HLR/HSS domain, HP has developed a structure of product and market experience that allows us to support this emerging NFV trend from the wide variety of angles required to fully enable this trend in a comprehensive way.

As with HP's role in enterprise IT, HP will rely on an ecosystem of partners in delivering this value.

As a **network virtualization platform provider,** HP will build on our existing position as the largest provider of standards-based computer platforms deployed in telecommunications environments. HP has established this position through leverage of our IT product base into the IT market. This is the basis for a significantly improved cost curve for many telecommunications services.

HP will, through its platform evolutions, enable the transition to NFV in several ways:

- HP supports the standardization of the core platforms and their evolution to support more demanding networking specific applications (including bearer plane applications).
- HP supports NEPs (as well as other application vendors) in moving to a standardized platform (server, storage, and networking), as well as continuing to support these vendors in their role as the trusted SIs for the industry.
- HP has recently introduced a new range of servers (MoonShot) that will enable significant operational cost savings as well as integration of more specialized technology (for example, DSP pools, specialized processing cards, virtual switches, virtual routers) to be managed as a general purpose infrastructure.
- HP Software portfolio includes industry-leading fault and event management, performance management, configuration and compliance and security tools to monitor, visualize, manage, secure, and configure the NFV infrastructure.

In addition, HP as an **infrastructure orchestration provider,** offers an Open Middleware platform, the NFV Orchestrator, to deliver the NFV functions defined by ETSI. HP delivers the key components that enable the orchestration of the world's cloud infrastructures. HP is also a leading contributor to many industry organizations such as OpenStack.

HP recognizes the need for openness at this orchestration level of NFV. We work with many providers of orchestration capabilities in a vendor-neutral fashion. HP leverages our experience in telecommunications, our existing middleware ecosystem, and a number of existing HP products to secure for the industry a sufficiently rich set of choices of carrier-grade orchestration capabilities for NFV. Our core platform enables a choice of infrastructure orchestration solutions.

HP's approach to NFV infrastructure relies on a sound architecture and on the breadth of the HP portfolio including Converged Infrastructure, Converged Cloud, and SDN. HP provides a coherent portfolio of open technologies and services that support the deployment of NFV applications developed by our NEP and ISV partners, as well as by HP.

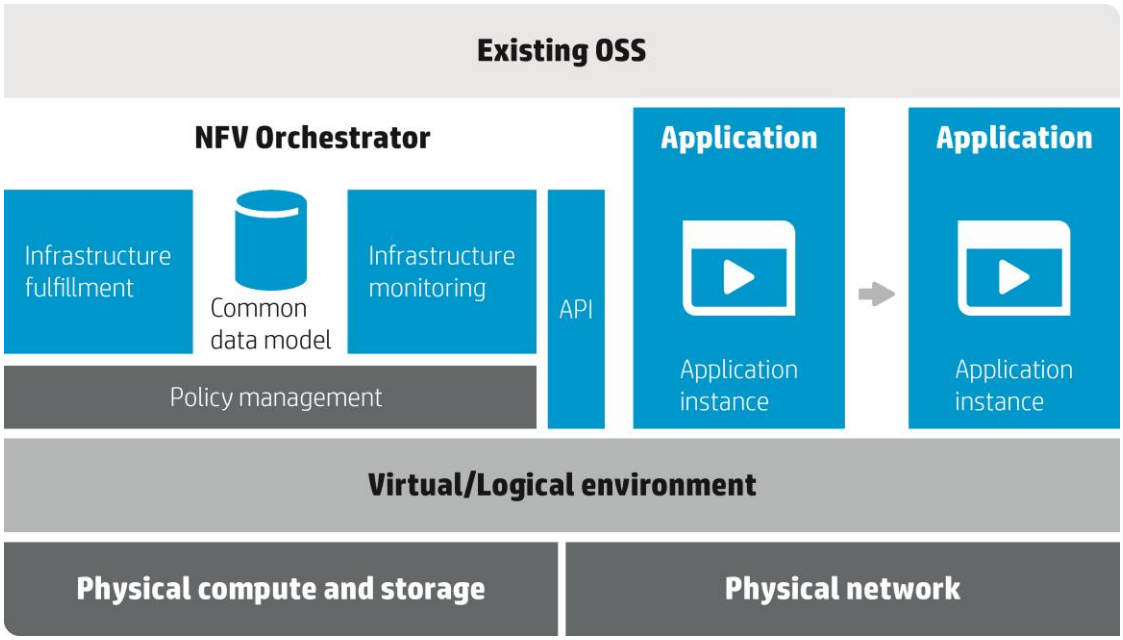
HP's primary role in NFV will be to bring the strength and volume of IT to NFV through infrastructure offerings. We also have a role to play as an NFV application provider. HP is already delivering a set of telecommunications-based applications on industry-standard computer systems and will continue to offer them as part of the NFV ecosystem. In addition, HP has a rich set of networking and security products that will be delivered as NFV applications. For CSPs, and potentially NEPs, HP has a range of virtualized network applications available now, including Home Subscriber Server (HSS), Network Interactive Voice Response (NIVR), Virtual Customer Premise Equipment (VCPE), Virtual Service Router (VSR), virtual switches, CDN, and Virtual Firewall (VFW).

The HP NFV Infrastructure Architecture and portfolio supports all the core roles operating within the NFV ecosystem. HP recognizes the immense strength of the existing vendors and that their roadmap to NFV requires close collaboration to fully realize the value that the new technology can bring to the CSP community. HP aims to be the provider of choice to our customers, whichever role they choose to play (an NEP choosing to implement and deliver network applications, NEPs or ISVs choosing to be pure NFV application providers, CSPs who choose to buy and integrate their NFV solutions themselves).

HP's architectural point of view

The HP architecture underpinning NFV is driven by the way we see the industry evolving and the needs of the different ecosystem participants, including availability and openness.

Figure 3. HP NFV functional architecture



The HP NFV functional architecture is based on the requirements derived from industry drivers, the HP vision, and the industry standards organization, ETSI.

The functionality includes:

NFV Applications provided by NEPs, ISVs, and HP.

The **NFV Orchestrator** is a set of portfolio offerings that can be deployed to realize the ETSI NFV Orchestrator. These offerings are integrated by design and can be deployed either as standalone modules or as a layered solution as NFV deployment grows. The modules are:

- **Fulfillment** that configures the virtualized compute infrastructure, and essential networking for the compute elements to communicate with the physical network for an NFV application.
- **A common data model** that keeps a consistent view of the requested services and the current state of the deployments. It shows how the network connects together the compute elements to create each end-to-end service.
- **Service management** that uses the common data model and status information from the virtualized infrastructure to construct a view on the current state of the services and also the underlying resources. This block creates the data for integration with the legacy OSS, requiring minimal modifications of the OSS.
- **Policy management** that informs both fulfillment and service management block on static/configuration and dynamic/operational policies. As the functions of this block are realized in the fulfillment and service management blocks, its deployment is distributed.

Virtualized NFV infrastructure that includes compute, storage, and networking and their element managers which themselves may embed automated processes. Strictly this is a logical infrastructure as it can support physical resources as well as virtualized resources.

The HP NFV architecture is instantiated by a complete hardware and software solution providing industry standard and hyperscale servers, storage and networking alongside the CloudSystems software and other CSP-specific software portfolio offering(s) providing the necessary NFV Orchestrator functionality.

HP has a common NFV infrastructure architecture that supports all players in the NFV ecosystem and hence drives a common approach for all players and facilitates innovation. This architecture is based on HP's Converged Infrastructure and CloudSystems offering and provides a hypervisor-independent NFV Orchestrator solution. Various commercial and Open Source hypervisors like VMware ESX, Microsoft Hyper-V, and Linux KVM based are supported. The NFV architecture supports applications from NEPs, industry ISVs, and HP. As the market matures best practices will be established.

HP has a highly scalable infrastructure design for all customers based on COTS components that is designed/engineered to deliver telecommunications applications at an appropriate level of availability and cost and associated SLAs to provide exceptional availability, great performance, and best lifetime total cost of ownership for telecommunications environments.

Using the architecture, a CSP can ensure when they procure applications from multiple providers that they need just one set of infrastructure platform operational procedures.

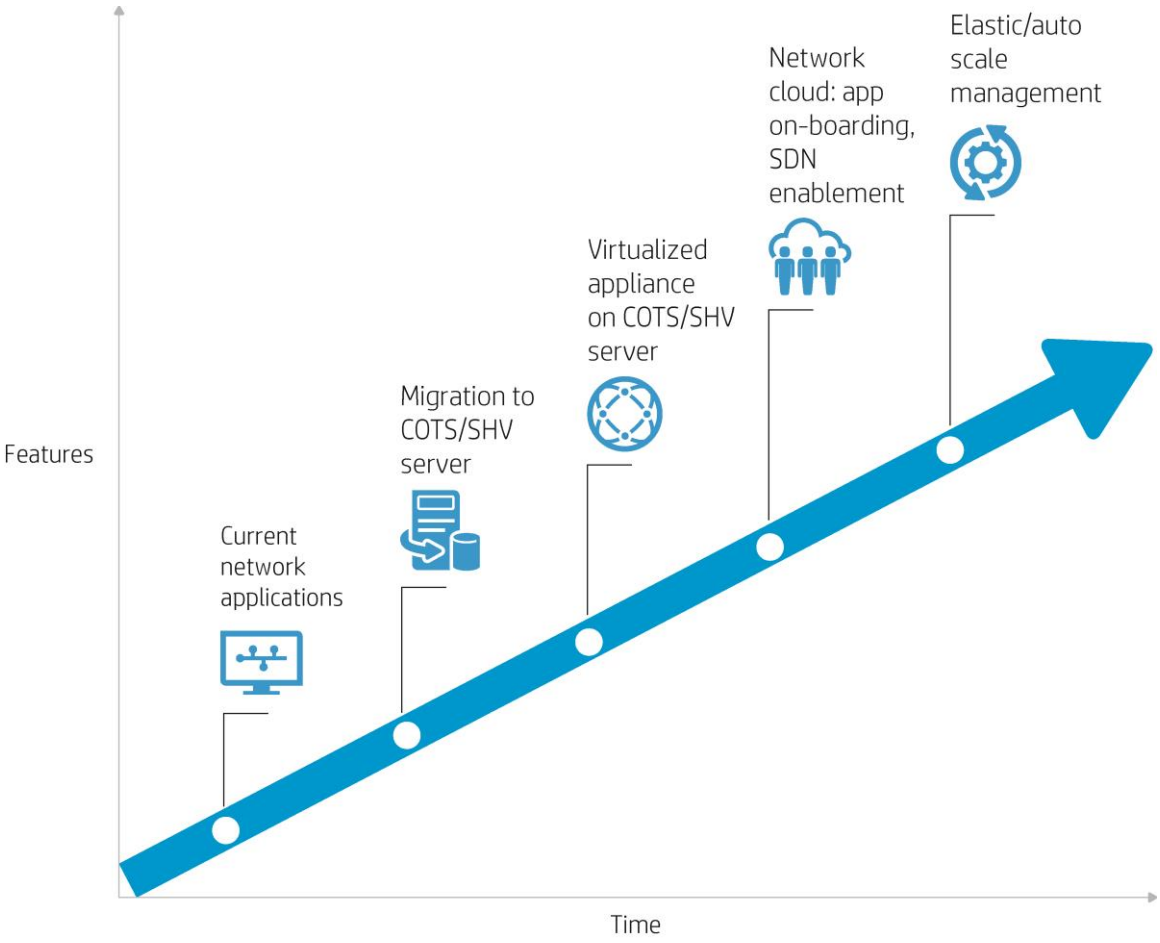
HP's scalable infrastructure can be delivered as converged infrastructure or as a simpler, well-designed componentized solution. In both cases HP is the supplier of components and designs for deployment directly and/or indirectly to CSPs. The indirect channel allows the partner ecosystem to add value to the HP platform, for example, SI practices, middleware, applications.

The network operator-led Industry Specification Group (ISG) in ETSI, which was established to study the technical challenges for NFV, is another key source of requirements feeding into HP's architecture and, in particular, to the NFV Orchestrator. The ETSI ISG goals are to define the requirements for network function virtualization, identify gaps in current standards and best practices, and provide recommendations to fill in the gaps. ETSI ISG in the Management and Orchestration (ETSI MANO) work group is defining a conceptual architecture that shows the applications working using an orchestration and management domain that uses virtual network and compute domains as "providers." The HP NFV Orchestrator corresponds to the orchestration and management domain. It deploys, operates, manages, and coordinates the virtualized network functions (VNF) and the respective NFV infrastructure.

NFV adoption

NFV represents a significant transformation, but HP believes that a staged introduction of technologies will enable early payback and provide a platform for further NFV build out. We believe we will see various stages of NFV deployment in the network, for example, appliance to ISS server, appliance to virtual app, virtual app to network services with an SDN controller.

Figure 4. NFV application evolution



Most telecommunication control plane applications are already delivered on industry-standard servers. HP has been very active in this transition, especially in supporting NEPs porting applications from platforms like ATCA to more cost-efficient and high-performance industry-standard servers.

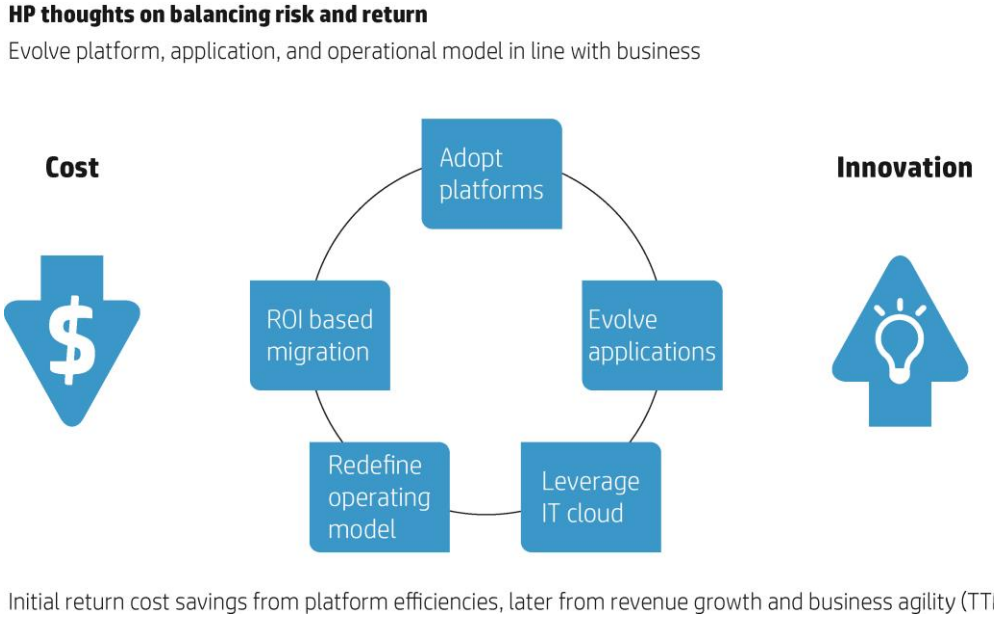
Most of these applications are now being virtualized and will naturally serve as the first wave of NFV applications. HP is involved in several carrier proof of concept (PoC) projects where control plane applications from different vendors are being deployed on shared HP infrastructure.

Senior-level client discussions now tend to focus on where to start rather than simply on feasibility. What's the initial use case that can bootstrap NFV deployment? Virtual CPE seems a compelling case. So does LTE-based last mile for mobile operators wanting to provide high-speed Internet to the home. PoCs are in place for additional scenarios.

Such deployment enables evolution toward an NFV-based network in three critical dimensions:

1. Other existing applications will over time become available and optimized for NFV infrastructure, and can therefore be moved or deployed on the infrastructure as they become available.
2. New applications designed for NFV can rapidly be introduced and scaled or retired depending on market success, leading to an accelerating TTM for new services and capabilities.
3. The infrastructure itself will evolve with the pace of the IT industry, enabling an ever-increasing class of applications, including bearer plane applications. This, in line with evolution of the necessary operational models, will lead to acceleration of 1 and 2.

Figure 5. Balancing risk and return



HP believes that the evolution of the supporting operational model is a critical element for the success of NFV. This must include a broader deployment of IT-based management systems that separate the application and infrastructure management, combined with the necessary infrastructure capability to deliver end-to-end application monitoring and control. This requirement is reflected in the HP implementation architecture for NFV, which leverages HP's widely deployed IT management software and expertise.

Conclusion

The introduction of NFV is a core structural change in the telecommunication infrastructure marketplace. NFV will bring cost efficiencies, time-to-market improvements, and innovation to the telecommunication industry infrastructure and applications. NFV will achieve this through disaggregation of the traditional roles and technology involved in telecommunications applications.

As a **network virtualization platform provider,** HP will build on our existing position as the largest provider of standards-based computer platforms deployed in telecommunications. This is the basis for a significantly improved cost and innovation curve for many telecommunications applications, and HP will extend this to NFV through its NFV platform.

For more information, visit hp.com/go/nfv.

Acronyms

ATCA	Advanced Telecommunications Computing Architecture
COTS	Commercial Off The Shelf
CPE	Customer Premise Equipment
CSP	Communications Service Provider
DPDK	Data Plan Development Kit
ETSI ISG	ETSI Industry Specification Group
ETSI MANO	ETSI Management and Orchestration
ETSI	European Telecoms Standards Institute
GTM	Go-to-Market
HA	High Availability
HLR	Home Location Register
HSS	Home Subscriber Server
ISS	Industry Standard Server
ISV	Independent Software Vendor
LTE	Long-Term Evolution
M2M	Machine to Machine
NEBS	Network Equipment Building System
NEP	Network Equipment Provider
NFV	Network Functions Virtualization
NFVO	NFV Orchestration
NIVR	Network Interactive Voice Response
OSS	Operations Support System
OTT	Over the Top
PoC	Proof of Concept
SDN	Software-Defined Network
SI	Systems Integrator
SLA	Service Level Agreement
TTM	Time-to-Market
VCPE	Virtual Customer Premise Equipment
VFW	Virtual Firewall
VIMS	Virtual Infrastructure Management System
VLB	Virtual Load Balancer
VMM	Virtual Machine Manager
VNF	Virtualized Network Functions.
VSR	Virtual Service Router

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