Network Functions Virtualisation

An Introduction, Benefits, Enablers, Challenges & Call for Action

OBJECTIVES

This is a non-proprietary white paper authored by network operators.

The key objective for this white paper is to outline the benefits, enablers and challenges for Network Functions Virtualisation (as distinct from Cloud/SDN) and the rationale for encouraging an international collaboration to accelerate development and deployment of interoperable solutions based on high volume industry standard servers.

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Executive Summary

Network Operators' networks are populated with a large and increasing variety of proprietary hardware appliances. To launch a new network service often requires yet another variety and finding the space and power to accommodate these boxes is becoming increasingly difficult; compounded by the increasing costs of energy, capital investment challenges and the rarity of skills necessary to design, integrate and operate increasingly complex hardware-based appliances. Moreover, hardware-based appliances rapidly reach end of life, requiring much of the procure-design-integrate-deploy cycle to be repeated with little or no revenue benefit. Worse, hardware lifecycles are becoming shorter as technology and services innovation accelerates, inhibiting the roll out of new revenue earning network services and constraining innovation in an increasingly network-centric connected world.

Network Functions Virtualisation aims to address these problems by leveraging standard IT virtualisation technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage, which could be located in Datacentres, Network Nodes and in the end user premises. We believe Network Functions Virtualisation is applicable to any data plane packet processing and control plane function in fixed and mobile network infrastructures.

We would like to emphasise that we see Network Functions Virtualisation as highly complementary to Software Defined Networking (SDN). These topics are mutually beneficial but are not dependent on each other. Network Functions can be virtualised and deployed without an SDN being required and vice-versa.

Virtualising Network Functions could potentially offer many benefits including, but not limited to:

- Reduced equipment costs and reduced power consumption through consolidating equipment and exploiting the economies of scale of the IT industry.
- Increased speed of Time to Market by minimising the typical network operator cycle of innovation. Economies of scale required to cover investments in hardware-based functionalities are no longer applicable for software-based development, making feasible other modes of feature evolution. Network Functions Virtualisation should enable network operators to significantly reduce the maturation cycle.
- Availability of network appliance multi-version and multi-tenancy, which allows use of a single platform for different applications, users and tenants. This allows network operators to share resources across services and across different customer bases.
- Targeted service introduction based on geography or customer sets is possible. Services can be rapidly scaled up/down as required.
- Enables a wide variety of eco-systems and encourages openness. It opens the virtual appliance market to pure software entrants, small players and academia, encouraging more innovation to bring new services and new revenue streams quickly at much lower risk.

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To leverage these benefits, there are a number of technical challenges which need to be addressed:

- Achieving high performance virtualised network appliances which are portable between different hardware vendors, and with different hypervisors.
- Achieving co-existence with bespoke hardware based network platforms whilst enabling an efficient migration path to fully virtualised network platforms which re-use network operator OSS/BSS. OSS/BSS development needs to move to a model in-line with Network Functions Virtualisation and this is where SDN can play a role.
- Managing and orchestrating many virtual network appliances (particularly alongside legacy management systems) while ensuring security from attack and misconfiguration.
- Network Functions Virtualisation will only scale if all of the functions can be automated.
- Ensuring the appropriate level of resilience to hardware and software failures.
- Integrating multiple virtual appliances from different vendors. Network operators need to be able to “mix & match” hardware from different vendors, hypervisors from different vendors and virtual appliances from different vendors without incurring significant integration costs and avoiding lock-in.

The authors of this white paper believe (and have in some cases demonstrated) that solutions to these technical challenges are available, or could be made available, and recommend that the IT and Networks industries combine their complementary expertise and resources in a joint collaborative effort to reach broad agreement on standardised approaches and common architectures which address these technical challenges, and which are interoperable and have economies of scale.

To accelerate progress, a new network operator-led Industry Specification Group (ISG) with open membership is being setup under the auspices of ETSI to work through the technical challenges for Network Functions Virtualisation as outlined in this white paper. The formal creation process of this ETSI ISG has been started and is expected to be completed by mid-November 2012.

In order to chart the way forward for Network Functions Virtualisation the wider industry is asked to provide feedback as detailed in this white paper.

End - Executive Summary.

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Introduction

Network operators' networks are populated with a large and increasing variety of proprietary hardware appliances. To launch a new network service often requires yet another variety and finding the space and power to accommodate these boxes is becoming increasingly difficult; compounded by the increasing costs of energy, capital investment challenges and the rarity of skills necessary to design, integrate and operate increasingly complex hardware-based appliances. Moreover, hardware-based appliances rapidly reach end of life, requiring much of the procure-design-integrate-deploy cycle to be repeated with little or no revenue benefit. Worse, hardware lifecycles are becoming shorter as technology and services innovation accelerates, inhibiting the roll out of new revenue earning network services and constraining innovation in an increasingly network-centric connected world.

Definition

Network Functions Virtualisation aims to transform the way that network operators architect networks by evolving standard IT virtualisation technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage, which could be located in Datacentres, Network Nodes and in the end user premises, as illustrated in Figure 1. It involves the implementation of network functions in software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need for installation of new equipment.

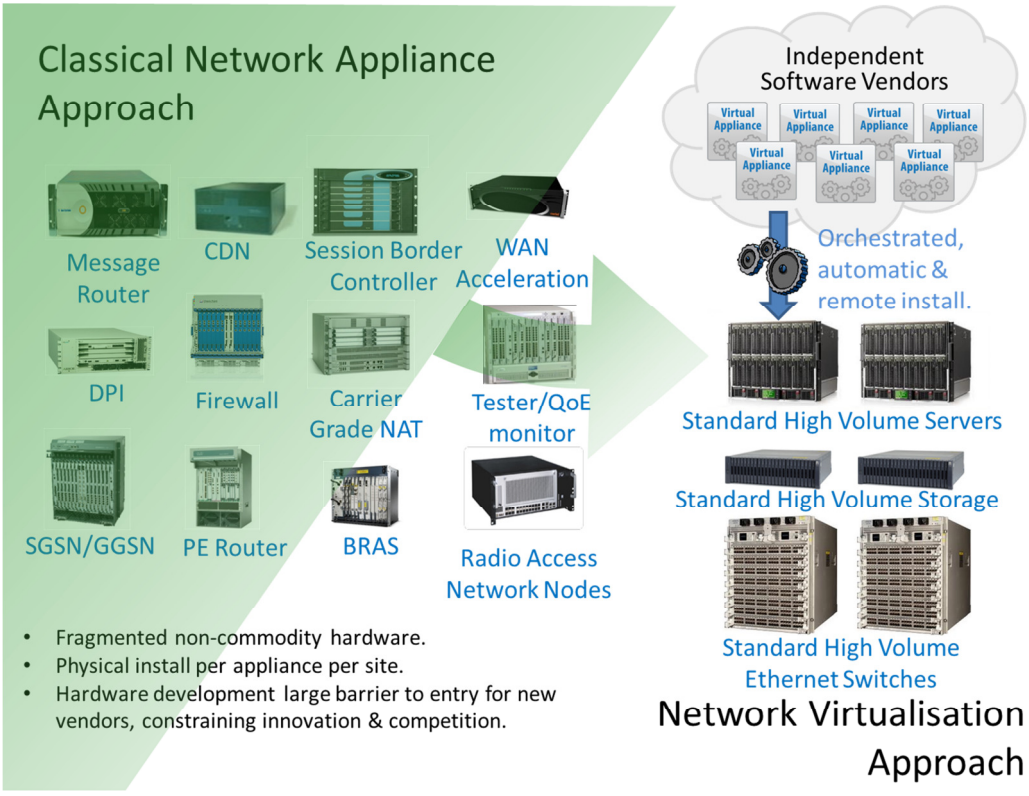

Figure 1: Vision for Network Functions Virtualisation

Relationship with Software Defined Networks (SDN)

As shown in Figure 2, Network Functions Virtualisation is highly complementary to Software Defined Networking (SDN), but not dependent on it (or vice-versa). Network Functions Virtualisation can be

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implemented without a SDN being required, although the two concepts and solutions can be combined and potentially greater value accrued.

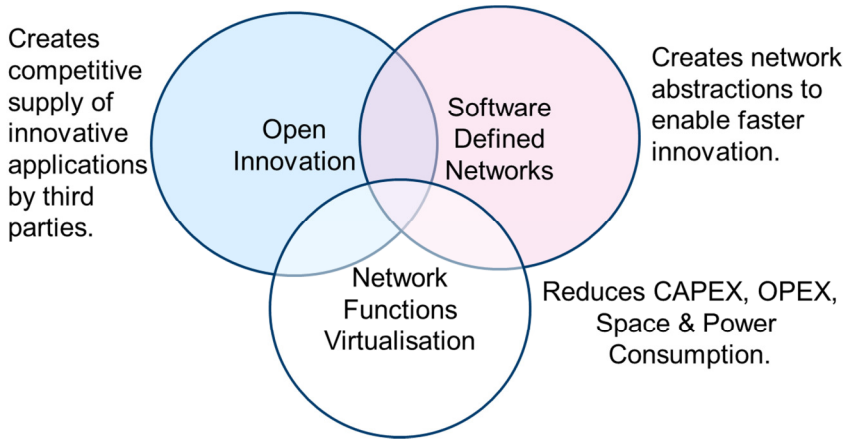

Figure 2: Network Functions Virtualisation Relationship with SDN

Network Functions Virtualisation goals can be achieved using non-SDN mechanisms, relying on the techniques currently in use in many datacentres. But approaches relying on the separation of the control and data forwarding planes as proposed by SDN can enhance performance, simplify compatibility with existing deployments, and facilitate operation and maintenance procedures.

Network Functions Virtualisation is able to support SDN by providing the infrastructure upon which the SDN software can be run. Furthermore, Network Functions Virtualisation aligns closely with the SDN objectives to use commodity servers and switches.

We intend to work closely with organisations progressing work on SDN such as the Open Networking Foundation (ONF) whose work we will specifically take into account.

Fields of Application and Use Cases

Network Functions Virtualisation is applicable to any data plane packet processing and control plane function in mobile and fixed networks. Potential examples that can be listed include (not in any particular order):

- Switching elements: BNG, CG-NAT, routers.
- Mobile network nodes: HLR/HSS, MME, SGSN, GGSN/PDN-GW, RNC, Node B, eNode B.
- Functions contained in home routers and set top boxes to create virtualised home environments.
- Tunnelling gateway elements: IPSec/SSL VPN gateways.
- Traffic analysis: DPI, QoE measurement.
- Service Assurance, SLA monitoring, Test and Diagnostics.
- NGN signalling: SBCs, IMS.
- Converged and network-wide functions: AAA servers, policy control and charging platforms.
- Application-level optimisation: CDNs, Cache Servers, Load Balancers, Application Accelerators.
- Security functions: Firewalls, virus scanners, intrusion detection systems, spam protection.

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Further studies are required to identify those network functions for which virtualisation yields most benefits. Use cases of interest to the authors include (not in any particular order):

- A software-based DPI, providing advanced traffic analysis and multi-dimensional reporting, and showing the possibility of making off-the-shelf hardware work at actual line rates. Software-based DPI can be pervasively deployed in the network, providing much better analysis capabilities, as well as simpler mechanisms for deployment, update, testing, and to scale it to changing workloads.
- IP node implementations, supporting - for example, but not limited to: CG-NAT and BRAS capabilities on standard high-end servers, offering the opportunity for an effective re-use of hardware as the demand for such capabilities evolves.
- The virtualisation of services and capabilities that presently require dedicated hardware appliances on customer premises (home environment to small branch office to large corporate premises), including but not restricted to: firewall, web security, IPS/IDS, WAN acceleration and optimisation, and router functions. The virtualisation of the home environment including routers, hubs and set top boxes would potentially enable a simpler and seamless migration to IPv6, reduce energy consumption and avoid successive hardware updates as broadband applications and services evolve.
- The virtualisation of Content Distribution Networks (CDN), with the initial goal of extending and scaling Content Delivery Services more easily, and also with the objective of maximizing hardware re-use in PoPs by being able to install other Service Delivery Applications (e.g. Web Acceleration) on demand. Virtualisation of CDNs will also allow the hosting of CDN services from potential business partners, like external CDN providers.
- The virtualisation of a mobile core network targeting at a more cost efficient production environment, which allows network operators to cope with the increasing traffic demand in mobile networks, and leading to better resource utilization (including energy savings), more flexible network management (no need to change hardware for nodes' upgrades), hardware consolidation, easier multi-tenancy support and faster configuration of new services. Network Functions Virtualisation in mobile networks can also be used to create core network instances optimized for specific services, e.g. for Machine-to-Machine communications (M2M).
- Co-ordinated implementation of cloud and networking for enterprises, allowing on-demand services to be offered and providing capital efficiency for enterprise customers and network operators.
- Hybrid fibre-DSL nodes are located deep in the external network in street cabinets, underground and on poles. These nodes must be very low power consumption and very low/zero maintenance to be economic. Virtualisation could be used to reduce hardware complexity at the remote node, saving energy and providing an enhanced degree of future proofing as services evolve. These remote nodes could more economically provide both fixed and wireless access if key functions were virtualised on a common platform.
- Network Functions Virtualisation can also be used to provide an efficient production environment which can commonly be used by different applications, users and tenants, thus

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supporting the coexistence of several versions and variants of a network service (including test versions and beta versions).

Benefits of Network Functions Virtualisation

We believe the application of Network Functions Virtualisation brings many benefits to network operators, contributing to a dramatic change in the telecommunications industry landscape. Benefits we foresee include (not in any particular order):

- Reduced equipment costs and reduced power consumption through consolidating equipment and exploiting the economies of scale of the IT industry (~9.5M Servers shipped in 2011 compared with ~1.5M routers forecast for 2012).[1,2]
- Increased velocity of Time to Market by minimising the typical network operator cycle of innovation. Economies of scale required to cover investments in hardware-based functionalities are no longer applicable for software-based development, making feasible other modes of feature evolution. Network Functions Virtualisation should enable network operators to significantly reduce the maturation cycle.
- The possibility of running production, test and reference facilities on the same infrastructure provides much more efficient test and integration, reducing development costs and time to market.
- Targeted service introduction based on geography or customer sets is possible. Services can be rapidly scaled up/down as required. In addition, service velocity is improved by provisioning remotely in software without any site visits required to install new hardware.
- Enabling a wide variety of eco-systems and encouraging openness. It opens the virtual appliance market to pure software entrants, small players and academia, encouraging more innovation to bring new services and new revenue streams quickly at much lower risk.
- Optimizing network configuration and/or topology in near real time based on the actual traffic/mobility patterns and service demand. For example, optimisation of the location & assignment of resources to network functions automatically and in near real time could provide protection against failures without engineering full 1+1 resiliency.
- Supporting multi-tenancy thereby allowing network operators to provide tailored services and connectivity for multiple users, applications or internal systems or other network operators, all co-existing on the same hardware with appropriate secure separation of administrative domains.
- Reduced energy consumption by exploiting power management features in standard servers and storage, as well as workload consolidation and location optimisation. For example, relying on virtualisation techniques it would be possible to concentrate the workload on a smaller number of servers during off-peak hours (e.g. overnight) so that all the other servers can be switched off or put into an energy saving mode.[3]
- Improved operational efficiency by taking advantage of the higher uniformity of the physical network platform and its homogeneity to other support platforms:

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- IT orchestration mechanisms provide automated installation, scaling-up and scaling-out of capacity, and re-use of Virtual Machine (VM) builds.[4]
- Eliminating the need for application-specific hardware. The skills base across the industry for operating standard high volume IT servers is much larger and less fragmented than for today's telecom-specific network equipment.
- Reduction in variety of equipment for planning & provisioning. Assuming tools are developed for automation and to deal with the increased software complexity of virtualisation.
- Option to temporarily repair failures by automated re-configuration and moving network workloads onto spare capacity using IT orchestration mechanisms. This could be used to reduce the cost of 24/7 operations by mitigating failures automatically.
- The potential to gain more efficiency between IT and Network Operations.
- The potential to support in-service software upgrade (ISSU) with easy reversion by installing the new version of a Virtualised Network Appliance (VNA) as a new Virtual Machine (VM). Assuming traffic can be transferred from the old VM to the new VM without interrupting service. For some applications it may be necessary to synchronise the state of the new VM with the old VM.

The Changing Telecoms Industry Landscape

Although Network Functions Virtualisation brings many advantages to the telecommunications industry it is likely to transform the vendor landscape. Each player will need to position/re-position itself in the new Network Functions Virtualisation market.

This is not as disruptive as it may seem because network equipment vendors already implement some of their solutions by combining their proprietary software with industry standard hardware and software components, but in a proprietary way. Enabling their proprietary software to run on industry standard hardware in a standardised way may be a significant opportunity for existing players because their software and networking know-how is where the real value is in many cases. Some major industry players are already moving in this direction by offering virtualised versions of their products. The challenge for network operators is how to migrate their operations and skill base to a software based networking environment while carefully re-targeting investment to maximise re-use of existing systems and processes.

Enablers for Network Functions Virtualisation

Several recent technology developments make the goals of Network Functions Virtualisation achievable. This section describes these enablers and briefly discusses relevance.

Cloud Computing

Network Functions Virtualisation will leverage modern technologies such as those developed for cloud computing. At the core of these cloud technologies are virtualisation mechanisms: hardware virtualisation by means of hypervisors, as well as the usage of virtual Ethernet switches (e.g. vswitch) for connecting traffic between virtual machines and physical interfaces. For communication-oriented

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functions, high-performance packet processing is available through high-speed multi-core CPUs with high I/O bandwidth, the use of smart Ethernet NICs for load sharing and TCP Offloading, and routing packets directly to Virtual Machine memory, and poll-mode Ethernet drivers (rather than interrupt driven, for example Linux NAPI and Intel's DPDK).

Cloud infrastructures provide methods to enhance resource availability and usage by means of orchestration and management mechanisms, applicable to the automatic instantiation of virtual appliances in the network, to the management of resources by assigning virtual appliances to the correct CPU core, memory and interfaces, to the re-initialisation of failed VMs, to snapshot VM states and the migration of VMs.

Finally, the availability of open APIs for management and data plane control, like OpenFlow, OpenStack, OpenNaaS or OGF's NSI, provide an additional degree of integration of Network Functions Virtualisation and cloud infrastructure.

Industry Standard High Volume Servers

The use of industry standard high volume servers is a key element in the economic case for Network Functions Virtualisation. Network Functions Virtualisation leverages the economies of scale of the IT industry. An industry standard high volume server is a server built using standardised IT components (for example x86 architecture) and sold in the millions. A common feature of industry standard high volume servers is that there is competitive supply of the subcomponents which are interchangeable inside the server.

We believe that Network Appliances which depend on the development of bespoke Application Specific Integrated Circuits (ASICs) will become increasingly uncompetitive against general purpose processors as the cost of developing ASICs increases exponentially with decreasing feature size.[5] Merchant silicon will still be applicable for commodity functions implemented at scale, and ASICs will still be applicable for some types of very high throughput applications.

Challenges for Network Functions Virtualisation

There are a number of challenges to implement Network Functions Virtualisation which need to be addressed by the community interested in accelerating progress. How this effort could be progressed is described later in this document. Challenges we have identified are (not in any particular order):-

- **Portability/Interoperability.** The ability to load and execute virtual appliances in different but standardised datacentre environments, provided by different vendors for different operators. The challenge is to define a unified interface which clearly decouples the software instances from the underlying hardware, as represented by virtual machines and their hypervisors. Portability and Interoperability is very important as it creates different ecosystems for virtual appliance vendors and datacentre vendors, while both ecosystems are clearly coupled and depend on each other. Portability also allows the operator the freedom to optimise the location and required resources of the virtual appliances without constraints.
- **Performance Trade-Off.** Since the Network Functions Virtualisation approach is based on industry standard hardware (i.e. avoiding any proprietary hardware such as acceleration

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engines) a probable decrease in performance has to be taken into account. The challenge is how to keep the performance degradation as small as possible by using appropriate hypervisors and modern software technologies, so that the effects on latency, throughput and processing overhead are minimized. The available performance of the underlying platform needs to be clearly indicated, so that virtual appliances know what they can get from the hardware. The authors of the white paper believe that using the right technology choice will allow virtualisation not only of network control functions but also data/user plane functions.

- **Migration and co-existence of legacy & compatibility with existing platforms**. Implementations of Network Functions Virtualisation must co-exist with network operators' legacy network equipment and be compatible with their existing Element Management Systems, Network Management Systems, OSS and BSS, and potentially existing IT orchestration systems if Network Functions Virtualisation orchestration and IT orchestration are to converge. The Network Functions Virtualisation architecture must support a migration path from today's proprietary physical network appliance based solutions to more open standards based virtual network appliance solutions. In other words, Network Functions Virtualisation must work in a hybrid network composed of classical physical network appliances and virtual network appliances. Virtual appliances must therefore use existing North Bound Interfaces (for management & control) and interwork with physical appliances implementing the same functions.
- **Management and Orchestration**. A consistent management and orchestration architecture is required. Network Functions Virtualisation presents an opportunity, through the flexibility afforded by software network appliances operating in an open and standardised infrastructure, to rapidly align management and orchestration North Bound Interfaces to well defined standards and abstract specifications. This will greatly reduce the cost and time to integrate new virtual appliances into a network operator's operating environment. Software Defined Networking (SDN) further extends this to streamlining the integration of packet and optical switches into the system e.g. a virtual appliance or Network Functions Virtualisation orchestration system may control the forwarding behaviours of physical switches using SDN.
- **Automation.** Network Functions Virtualisation will only scale if all of the functions can be automated. Automation of process is paramount to success.
- **Security & Resilience.** Network operators need to be assured that the security, resilience and availability of their networks are not impaired when virtualised network functions are introduced. Our initial expectations are that Network Functions Virtualisation improves network resilience and availability by allowing network functions to be recreated on demand after a failure. A virtual appliance should be as secure as a physical appliance if the infrastructure, especially the hypervisor and its configuration, is secure. Network operators will be seeking tools to control and verify hypervisor configurations. They will also require security certified hypervisors and virtual appliances.
- **Network Stability.** Ensuring stability of the network is not impacted when managing and orchestrating a large number of virtual appliances between different hardware vendors and hypervisors. This is particularly important when, for example, virtual functions are relocated, or during re-configuration events (e.g. due to hardware and software failures) or due to cyber-attack. This challenge is not unique to Network Functions Virtualisation. Potential instability might also occur in current networks, depending on unwanted combinations of diverse control and optimization mechanisms, for example acting on either the underlying transport network or on the higher layers' components (e.g. flow admission control, congestion control, dynamic routing and allocations, etc.). It should be noted that

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occurrence of network instability may have primary effects, such as jeopardizing, even dramatically, performance parameters or compromising an optimized use of resources. Mechanisms capable of ensuring network stability will add further benefits to Network Functions Virtualisation.

- **Simplicity.** Ensuring that virtualised network platforms will be simpler to operate than those that exist today. A significant and topical focus for network operators is simplification of the plethora of complex network platforms and support systems which have evolved over decades of network technology evolution, while maintaining continuity to support important revenue generating services. It is important to avoid trading one set of operational headaches for a different but equally intractable set of operational headaches.
- **Integration.** Seamless integration of multiple virtual appliances onto existing industry standard high volume servers and hypervisors is a key challenge for Network Functions Virtualisation. Network operators need to be able to "mix & match" servers from different vendors, hypervisors from different vendors and virtual appliances from different vendors without incurring significant integration costs and avoiding lock-in. The ecosystem must offer integration services and maintenance and third-party support; it must be possible to resolve integration issues between several parties. The ecosystem will require mechanisms to validate new Network Functions Virtualisation products. Tools must be identified and/or created to address these issues.

Recommendations/Call for Action

Network Functions Virtualisation is already occurring. In a few years, we can expect the communications industry to look and feel similar to the IT industry. There will be a wider range of business models more suited to a software industry. Operations complexity will be abstracted away by more automation and self-provisioning will be more common. As detailed in this white paper, Network Functions Virtualisation will deliver many benefits for network operators and their partners and customers whilst offering the opportunity to create new types of eco-systems (alongside traditional supply models based on preferred strategic partners) which will encourage and support rapid innovation with reduced cost and reduced risk. To reap these benefits the technical challenges, as described above, must be addressed by the industry.

The authors of this white paper believe that solutions to these technical challenges are available (or could be made available) and recommend that the IT and Network industries combine their complementary expertise and resources in a joint collaborative effort to reach broad agreement on standardised approaches and common architectures which address these technical challenges, and which are interoperable and have economies of scale.

To accelerate progress, a new network operator-led Industry Specification Group (ISG) with open membership is being setup under the auspices of ETSI to work through the technical challenges for Network Functions Virtualisation as outlined in this white paper. The formal creation process of this ETSI ISG has been started and is expected to be completed by mid-November 2012.

While ETSI will provide the organisation for this initiative, the ISG will downstream its work to all relevant organisations and seek to encourage convergence of IT and Network Standardisation efforts in this space.

The key objectives, activities and outputs of the ISG are expected to be:

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- The ISG will initiate joint studies which address the technical challenges for Network Functions Virtualisation as documented in this white paper. With consensus outputs detailed in white papers openly published to the wider industry. It is expected that study items would be identified in a "Network Operator Requirements" white paper prepared by the ISG as an initial deliverable.
- Although parented under ETSI, the ISG will not be a Standards Development Organisation (SDO) in itself; it will reference the work of existing SDOs where applicable. Where there are gaps, it will encourage member contributions to SDOs requesting them to take into account the recommendations of the ISG (i.e. requesting updates to existing standards, or to create new standards if appropriate).
- The ISG will identify other expert bodies that could assist with this work, and request that they undertake studies related to their scope to help move the industry forward.
- The ISG will facilitate members to share technical learning in a collaborative way which does not compromise confidentiality.
- The first meeting of the ISG will take place in January 2013. Details will be announced as soon as possible after publication of this white paper.

In order to chart the way forward for Network Functions Virtualisation, the wider industry is asked to provide feedback:

- **Network Operators:** To state their interest in joining the ISG, thus subscribing to the targets and approach as outlined in this white paper.
- **Existing organizations and forums:** To state if they see themselves being impacted by the work addressed in the ISG, and to provide information on how they would like to interact with it.
- **Vendors:** To state their interest in joining the ISG. Vendors are furthermore requested to state the study items in which they are most interested.

Please provide your input to the originators of this white paper as soon as possible and no later than 16th November 2012. Contact details below.

Contact Information

Please provide your feedback to any of the following. Please be clear on what you are asking us to do with the information provided. **Your input must not be confidential.**

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References

1. Server shipments (9.5M units in 2011): http://www.crn.com/news/data-center/232601815/gartner-2011-server-sales-grow-but-hard-drive-issues-take-a-toll.htm
2. Router shipments (1.5M units forecast for year 2012): http://www.isuppli.com/Manufacturing-and-Pricing/MarketWatch/Pages/EMS-Router-Shipments-Backed-by-Market-Growth-in-2012.aspx
3. http://labs.chinamobile.com/cran/wp-content/uploads/CRAN_white_paper_v2_5_EN.pdf
4. http://en.wikipedia.org/wiki/Orchestration_(computing)
5. http://www.edac.org/downloads/resources/profitability/HandelJonesReport.pdf

Glossary

AAA	Authentication-Authorisation-Accounting
API	Application Programming Interface (a set of routines, protocols, and tools for building software applications)
ASIC	Application Specific Integrated Circuit
BNG	Broadband Network Gateway
BRAS	Broadband Remote Access Server
BSS	Business Support System
CDN	Content Distribution Network
CG-NAT/NAT	Carrier Grade Network Address Translation
CPU	Central Processing Unit
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Service
DPDK	Data Plane Development Kit

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DPI	Deep Packet Inspection
DSL	Digital Subscriber Line (typically ADSL2/+, VDSL2, G.fast)
Ecosystem	Equipment and software vendors, integration services vendors, network operators, service providers, academia, etc.
EMS	Element Management System
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute (in practise ETSI has global membership, including the Americas and Asia) .
HSS	Home Subscriber Service
HV	Hypervisor
I/O	Input/Output
IMS	IP Multimedia System
Industry Standard High Volume Server	A server built using standardised IT components (for example x86 architecture) and sold in the millions.
IPR	Intellectual Property Rights
IPSec/SSL	IP Security/ Secure Sockets Layer
IPv6	Internet Protocol version 6
ISG	Industry Specification Group. An organisation under the auspices of the European Telecommunications Standards Institute (ETSI).
ISSU	In Service Software Upgrade
IT	Information Technology
KVM	Kernel based Virtual Machine
LAN	Local Area Network
LB	Load Balancer
M2M	Machine-to-Machine communications
MME	Mobility Management Entity
MVNO	Mobile Virtual Network Operator
NFV	Network Functions Virtualisation
NGN	Next Generation Network
NIC	Network Interface Controller
NMS	Network Management System
OAM	Operations Administration & Maintenance
OGF	Open Grid Forum
ONF	Open Networking Foundation
OpenFlow	Specifications developed by the Open Networking Foundation
OpenNaaS	Specifications developed by the OpenNaaS community
OpenStack	Specifications developed by the OpenStack Foundation
OSS	Operations Support System
PDN-GW	Packet Data Network Gateway
PE Router	Provider Edge Router
PoP	Point of Presence
QoE	Quality of Experience
SBC	Session Border Controller
SDN	Software Defined Network
SDO	Standards Development Organisation
SGSN/GGSN	Serving GPRS support node/Gateway GPRS support node
SLA	Service Level Agreement

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TCP	Transmission Control Protocol
VM	Virtual Machine
VMWare	Proprietary Hypervisor
VNA	Virtualised Network Appliance
VPN	Virtual Private Network
vswitch	Any Ethernet switch implemented in software alongside or inside a hypervisor. There are proprietary and open implementations of vswitch.
WAN	Wide Area Network
Xen	Proprietary Hypervisor

END

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