

Network Functions Virtualisation (NFV)

Network Operator Perspectives on Industry Progress

OBJECTIVES

The key objective for this white paper is to provide an update on progress since we published the first joint-operator white paper on Network Functions Virtualisation in October 2012 and initiated the Network Functions Industry Specification Group (NFV ISG) under the auspices of the European Telecommunications Standards Institute (ETSI). ^[1]

This is a non-proprietary white paper authored by network operators who are participating in the NFV ISG. It has been produced independently of the NFV ISG; it is not an NFV ISG document and claims no endorsement by the NFV ISG.

CONTRIBUTING ORGANISATIONS & AUTHORS

AT&T:	Margaret Chiosi, Steve Wright.
BT:	Don Clarke, Peter Willis.
CableLabs:	Chris Donley, Lane Johnson.
CenturyLink:	Michael Bugenhagen, James Feger, Waqar Khan.
China Mobile:	Chunfeng Cui, Hui Deng, Clark Chen.
China Telecom:	Lei Baohua, Sun Zhenqiang.
China Unicom:	Xiaoxia Zhou, Chuan Jia.
Colt:	Javier Benitez.
Deutsche Telekom:	Uwe Michel, Klaus Martiny.
DOCOMO:	Tetsuya Nakamura, Ashiq Khan, Joan Triay Marques.
KDDI:	Kenichi Ogaki, Tetsuro Matsuzaki.
KT:	Kisang Ok, Eun Kyoung PAIK.
NTT:	Katsuhiko Shimano, Kazuaki Obana.
Orange:	Bruno Chatras, Christos Kolias.
Portugal Telecom:	Jorge Carapinha.
SK Telecom:	DK Lee, Kyunghoon Kim.
Softbank:	Satoru Matsushima.
Sprint:	Fred Feisullin.
Swisscom:	Markus Brunner.
Telecom Italia:	Elena Demaria, Andrea Pinnola.
Telefonica:	Diego López, Francisco Javier Ramón Salguero.
Telenor:	Patrick Waldemar, Pål Grønsund, Geir Millstein.
Telstra:	Frank Ruhl.
Verizon:	Prodip Sen, Andrew Malis.
Vodafone:	Susana Sabater, Adrian Neal.

PUBLICATION DATE

October 15-17, 2013 at the “SDN and OpenFlow World Congress”, Frankfurt-Germany.

This white paper is available at the following link: http://portal.etsi.org/NFV/NFV_White_Paper2.pdf

Contents

Executive Summary.....	3
Introduction	5
Overview of the ETSI NFV ISG	5
Structure and Organisation.....	6
NFV ISG Progress Report.....	6
NFV Use Cases Document.....	8
NFV Requirements Document	9
NFV Architectural Framework Document.....	10
NFV Terminology Document.....	12
NFV Proof of Concept Framework Document	12
NFV Industry Landscape.....	13
Open Source and Perspectives on Standardisation	13
Impact on Operations Support Systems (OSS).....	14
Contact Information.....	15
References	15
Glossary.....	16

Executive Summary

This white paper is an update to the seminal white paper published in October 2012 which introduced the concept of Network Functions Virtualisation (NFV) and announced the formation of the Network Functions Virtualisation Industry Specification Group (NFV ISG).

The NFV ISG met for the first time in January 2013 and has grown to over 150 companies, including 28 service providers.

The first NFV ISG output documents have been published after ten months of intensive work, and are openly available from ETSI. These are high level documents intended to inform the on-going work of the NFV ISG and to guide the wider industry.

The key objectives of this paper are to overview these documents and to position them in the wider context of industry progress on NFV:

- **NFV Use Cases document** describes initial fields of application. The uses cases have been selected to span the scope of technical challenges being addressed by the NFV ISG, it is not meant to be an exhaustive list.
- **NFV Requirements document** describes the high level business and technical requirements for an NFV framework including service models. It is a key reference document for the NFV ISG and we encourage the wider industry to also reference these requirements in their work.
- **NFV Architectural Framework document** describes the high-level functional architecture and design philosophy for virtualised network functions and the underlying virtualisation infrastructure. By delineating the different constituents and outlining the reference points between them, it paves the way for fully interoperable multi-party NFV solutions. We encourage other bodies to reference this document to identify which constituents and reference points fall within their scope.
- **NFV Terminology document** is a common repository for terms used within the NFV ISG documents. We request the industry to adopt the terms defined in this document to harmonise NFV terminology, and for other bodies to contribute additional terminology relevant to their work on NFV.
- **NFV Proof of Concept Framework document.** The NFV ISG has launched a global call for multi-party NFV Proof of Concepts (PoC) to validate NFV approaches and to encourage progress towards interoperability and development of an open ecosystem. We would like to see vendors and network operators working together to implement NFV PoCs, and to share their results with the wider industry.

Achieving consensus on these documents is a major step forward for the industry. They represent the position of the majority of the world's network operators on the direction for NFV technology, facilitating global economies of scale, and massively simplifying the on-going commercial engagement between network operators and NFV solutions providers.

These documents will be augmented with more detailed information as the work of the NFV ISG progresses. We expect a further release in the second half of 2014.

We note that Standards Development Organisations (SDOs) have started work on NFV relevant to their scope. We are concerned to maintain momentum by avoiding a protracted standards effort. We are also concerned to avoid duplication and to ensure efficiency by minimising fragmentation

amongst multiple SDOs. In pursuit of these goals, the NFV ISG is progressing a gap analysis to identify what, if any, further work needs to be done, and which bodies are best placed to do it.

Open-source initiatives are complementary to formal standardisation processes, and can produce open reference implementations suitable for faster interoperability assessment and lower the barriers for innovation. We intend to actively collaborate with existing reference open-source initiatives, as well as to encourage and support new ones aligned with our goals.

Integrating an NFV Architectural Framework with constituents from different solutions providers in an open ecosystem is a vital new industry capability which needs to be encouraged.

We believe NFV will accelerate networks and services innovation. New network topologies will emerge and new approaches for operations, service assurance and security will become possible. With this in mind, we encourage industry and academia to create new applied research and study programmes around NFV, using the NFV ISG documents as their starting point.

To exploit its maximum benefits NFV requires new thinking around the OSS and could offer opportunities to gain operational benefits. Depending on their individual strategy, some Network Operators may wish to evolve their OSS incrementally to accommodate NFV, while others may wish to exploit NFV introduction to make a step change in OSS. For those on the step change path, NFV could provide an opportunity to leverage NFV Management and Orchestration to transform the current OSS into a more efficient system. For those who wish to take the incremental path, NFV can also be introduced in a way that minimises the impact on existing OSS and operations models. In both scenarios, Network Operators may wish to leverage existing in-house IT skills to provide and manage NFV infrastructure without requiring a wholesale change out of current network operations models and extensive retraining.

The NFV ISG is expected to sunset in January 2015, two years after the first meeting. During this period, dialogue will be progressed on what comes after the NFV ISG, including which aspects of the work may need to be taken forward in other bodies, and/or if a longer term coordinated effort will be needed to ensure that NFV technology matures quickly. In any event, early NFV deployments are already getting underway and are expected to accelerate during 2014-15.

End – Executive Summary.

Introduction

In our first white paper published in October 2012^[1] we introduced the concept of Network Functions Virtualisation (NFV) and provided information on how NFV relates to Software Defined Networking (SDN). We outlined the benefits and challenges for NFV technologies to be deployed by network operators, and we issued a call for action for the industry to cooperate to address these challenges and to encourage growth of an open ecosystem. To provide a formal umbrella for industry cooperation, we founded the Network Functions Virtualisation Industry Specification Group (NFV ISG) under the auspices of the European Telecommunications Standards Institute (ETSI). We ensured barriers to participation were low with low fees and with open membership (participants do not have to be members of ETSI).

We recommend the reader reviews the first NFV white paper to obtain a complete picture but to recap: NFV aims to transform the way that network operators architect and operate networks and network services by evolving standard IT virtualisation technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage as shown in the classical diagram in Figure 1. NFV transforms network architectures through the implementation of network functions in software that can run on a range of industry standard server hardware, and transforms network operations because the software can dynamically be moved to, or instantiated in, various locations in the network as required, without the need for installation of new equipment.

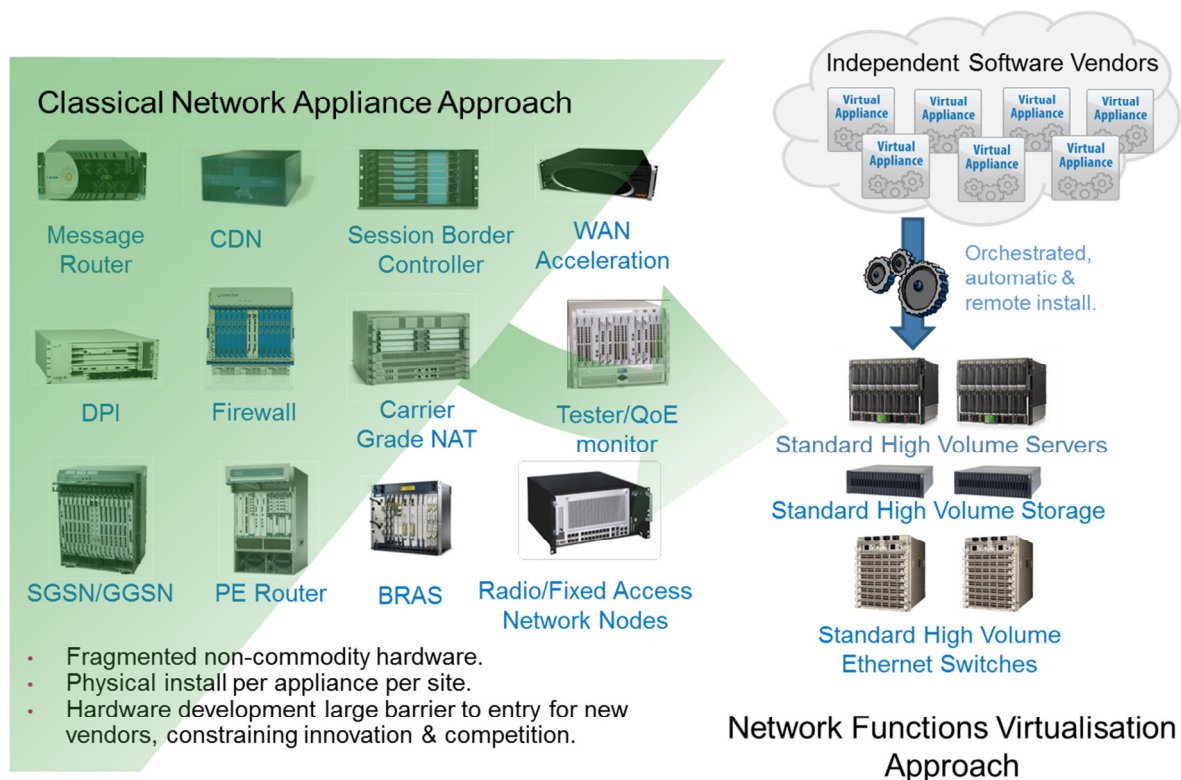


Figure 1: Vision for Network Functions Virtualisation

Overview of the ETSI NFV ISG

The ETSI Board approved foundation of the NFV ISG in time for publication of our first white paper last October. ETSI is a global organisation and has proved to be an excellent environment in which to

progress our work and we extend our thanks to the Director General and the ETSI Board for their accommodation and support.

Although ETSI is a Standards Development Organisation (SDO), the objective of the NFV ISG is not to produce standards. The key objectives are to achieve industry consensus on business and technical requirements for NFV, and to agree common approaches to meeting these requirements. The outputs are openly published and shared with relevant standards bodies, industry fora and consortia to encourage a wider collaborative effort. The NFV ISG will collaborate with other SDOs if any standardisation is necessary to meet the requirements.

The NFV ISG also provides an environment for the industry to collaborate on Proof of Concept (PoC) platforms to demonstrate solutions which address the technical challenges for NFV implementation and to encourage growth of an open ecosystem.

Structure and Organisation

To guide the work of the NFV ISG, a set of high level work items were defined which enabled the NFV ISG to adopt and formalise the scope and challenges outlined in the original NFV white paper. The detailed work is progressed in four working groups: Infrastructure Architecture, Management & Orchestration, Reliability & Availability, and Software Architecture. Two expert groups on Performance & Portability and Security provide input and guidance relevant to their expertise. The collaborative work is contribution driven and mainly progressed electronically and via conference calls. Coordination is provided by the Technical Steering Committee, and the Network Operator Council provides guidance on business priorities but does not have an executive role. The NFV ISG Chair is accountable to the ETSI Board for the conduct of the NFV ISG.

NFV ISG Progress Report

The NFV ISG met in plenary session for the first time in January 2013 and plenary meetings are held approximately quarterly. Participation has grown rapidly to over 150 companies from around the world, including 28 service providers and the cable industry.

The NFV ISG has made excellent progress, and a set of high level reference documents has been developed in only ten months. These documents are openly available on the ETSI website:^[2]

- **NFV Use Cases** document describes initial fields of application selected to span the scope of technical challenges being addressed by the NFV ISG. These are not attributed to particular operators, and it is important to understand that the list of use cases is not intended to be exhaustive and that individual operators will have individual focus and individual plans for NFV adoption.
- **NFV Requirements** document describes the high level business and technical requirements for an NFV framework including service models. It formalises and builds on the original NFV white paper.
- **NFV Architectural Framework** document describes the high-level functional architecture and design philosophy for virtualised network functions and the underlying virtualisation infrastructure. By delineating the different constituents and outlining the reference points between them, it paves the way for fully interoperable multi-party NFV solutions. We

encourage other bodies to reference this document to identify which constituents and reference points fall within their scope.

- **NFV Terminology** document is a common repository for terms used within the NFV ISG documents and seeks to harmonise terminology used across the industry in relation to NFV. It aims to bridge the language gap between the software and networking industries.
- **NFV ISG Proof of Concept Framework** document describes a procedure for industry participants to influence the work of the NFV ISG and to encourage growth of the NFV ecosystem through multi-party implementations of Proof of Concept demonstrations (PoCs).

Achieving consensus on these documents is a major step forward for the industry. They are the first published outputs of the NFV ISG and will be augmented as the work of the NFV ISG progresses. They are described in more detail in this paper.

An important objective for the NFV ISG is to encourage development of an open ecosystem and to stimulate product innovation. The PoC framework has been published alongside the first high level outputs to encourage the wider industry to implement PoCs and to publish their results using a common template.

The timeline for the NFV ISG work programme is shown in Figure 2:

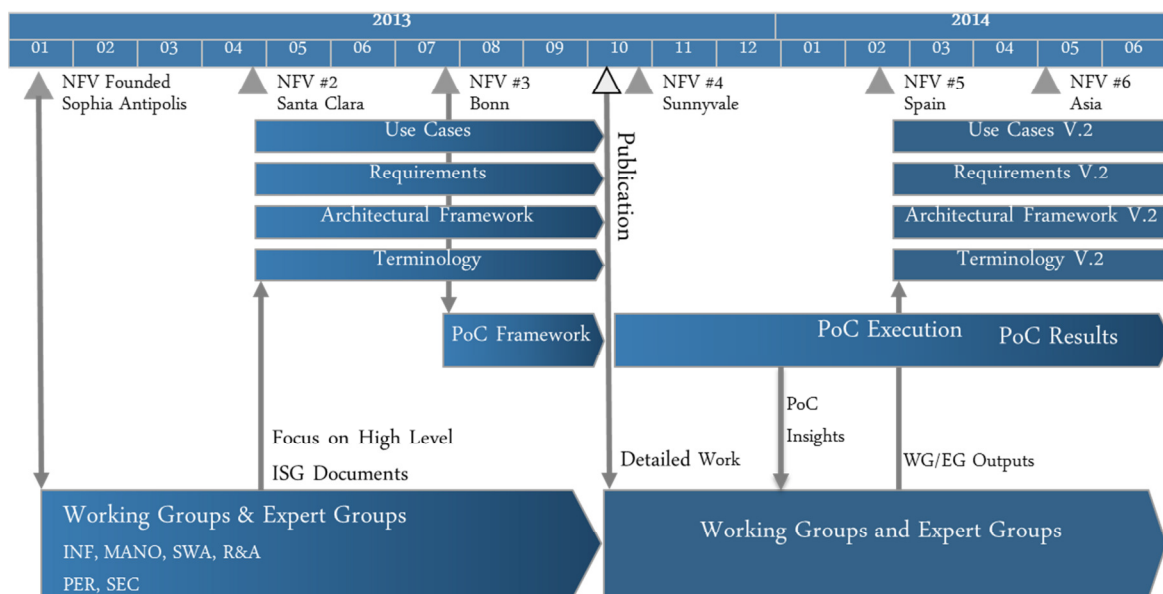


Figure 2: Timeline for ISG Work Programme to mid-2014

The plan depicted above is not intended to communicate specific dates for future document release, but is intended to indicate the process we are following. And it is also not intended to indicate the totality of output from the NFV ISG. The NFV ISG may produce interim deliverables that provide additional guidance to the industry, such as gap analyses and recommendations for standardisation as well as detailed documents from the various Working Groups and Expert Groups.

The NFV ISG is expected to sunset in January 2015, two years after the first meeting. During this period, dialogue will be progressed on what comes after the NFV ISG, including which aspects of the work may need to be taken forward in other bodies, and/or if a longer term coordinated effort will

be needed to ensure that NFV technology matures quickly. In any event, early NFV deployments are already getting underway and are expected to accelerate during 2014-15.

More detailed information on the NFV ISG published documents follows.

NFV Use Cases Document

In the NFV use cases document, the NFV ISG describes fields of application which span the scope of work of the NFV ISG. It is not intended to be exhaustive.

Virtualisation eliminates the dependency between a network function (NF) and its hardware, as seen in typical physical network appliances by creating a standardised execution environment and management interfaces for the Virtualised Network Functions (VNFs). This results in the sharing of the physical hardware by multiple VNFs in the form of virtual machines (VM). Further pooling of the hardware facilitates a massive and agile sharing of NFV Infrastructure (NFVI) resources by the VNFs; a phenomenon which is already seen in cloud computing infrastructures. This creates new business opportunities analogous to the cloud computing Service Models of Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS); where, for example, a VNF owner doesn't necessarily own the NFV Infrastructure needed for the proper functioning and operation of the VNF.

For completeness, the use cases identify the required co-existence of VNFs with non-virtualised NFs and the specific problem description and issues to address while virtualising such NFs. It also identifies some of the expected benefits.

For example in the mobile network, i.e. Evolved Packet Core (EPC) and IP Multimedia System (IMS) NFs, potential candidates for virtualisation can be Mobility Management Entity (MME), Serving and Packet Data Networks Gateway (S/P-GW), Call Session Control Functions (CSCFs), as well as Base Stations using different wireless standards. The EPC and IMS NFs can be consolidated on the same hardware resource pool. Total Cost of Ownership (TCO) reduction can be achieved by leveraging NFVI sharing as well as automated operation of load-based resource allocation, fault avoidance and recovery. Base Station (BS) functions, e.g. PHY/MAC/Network stacks that handle different wireless standards (e.g. 2G, 3G, LTE, WiMax, etc.) can share the hardware resources in a pooled and centralised environment and achieve dynamic resource allocation as well as reduced power consumption.

Content Delivery Networks (CDN) are also a potential target. CDN service providers commonly deploy content caches near the edge of a network to improve customers' quality of experience. Today, caches use dedicated hardware on a per-CDN provider, per-operator basis. As hardware resources are dimensioned for peak load, such resources remain under-utilised for most of their lifetime as peak load is a temporal phenomenon. By utilising and deploying virtualised caches, the underlying hardware resources could be consolidated and shared among multiple providers' CDN caches and potentially other VNFs in a more dynamic way thus improving resources usage.

Once different non-virtualised NFs are virtualised into VNFs, it is necessary to organise the VNFs into an ordered graph to realise a network service. In NFV, such graphs are called VNF Forwarding Graphs. The concept of a "Forwarding Graph" is used in preference to "Service Chain" in order to account for the fact that end-to-end forwarding within virtualised overlay service networks is not exclusively a

one dimensional chain. Instead they may, and often will, have branches. Thus more dimensionality is implicit. Along with the examples of VNFs mentioned previously, any VNFs, e.g., middle boxes like Network Address Translation (NAT), load balancer, firewall, etc., could be an element of a VNF Forwarding Graph. VNF Forwarding Graphs provide the required level of abstraction to an operator for dynamic and simplified service composition, which is reinforced and empowered by the virtualisation of such network functions.

Figure 3 provides an overview of some of the NFV use cases.

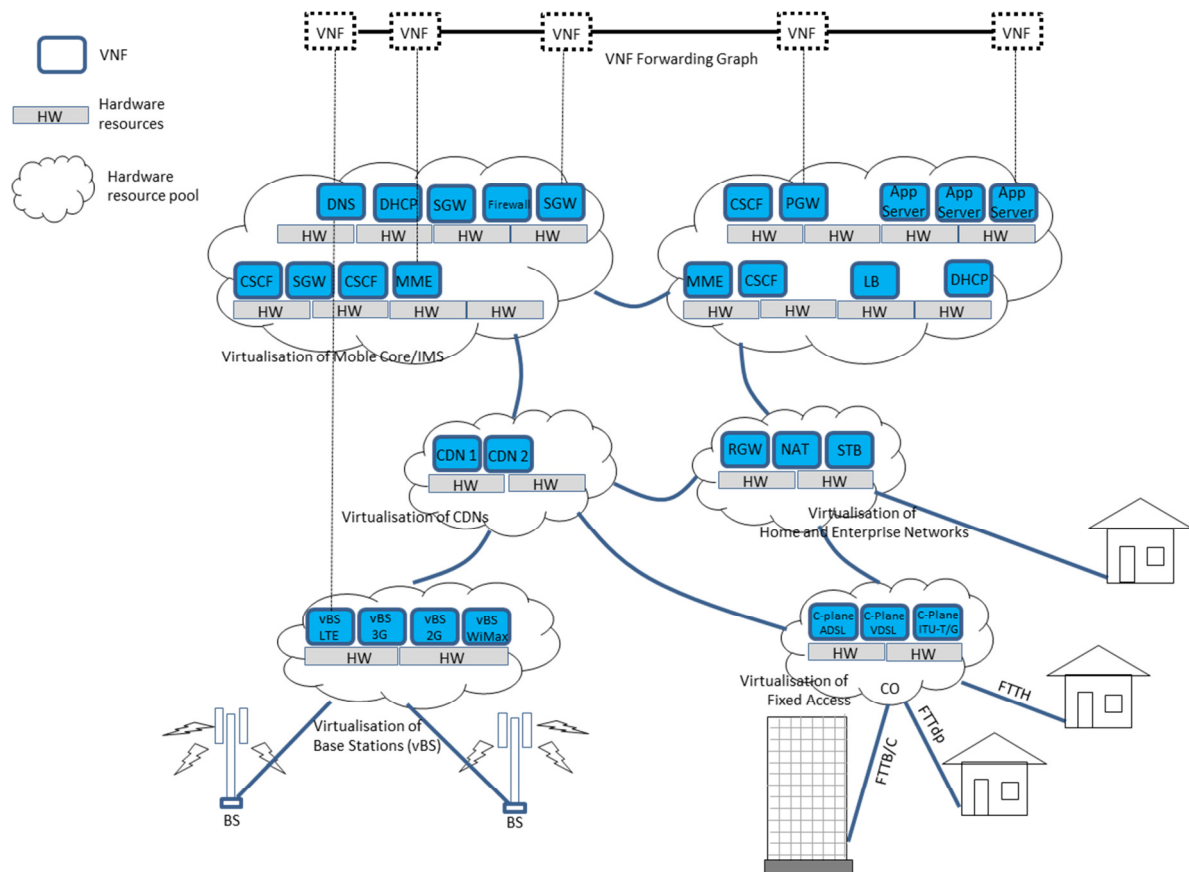


Figure 3: Overview of NFV Use Cases

This picture is not intended to imply any relation between the type of virtualised functions and how to allocate resources in the same or different resource pools.

NFV Requirements Document

The nature of the Telecom environment (i.e. carrier grade operations) implies technical challenges that need to be addressed in order to facilitate interoperability and seamless evolution towards fully virtualised networks. The Requirements document focuses primarily on the differences introduced by NFV, and not on aspects of the NF interfaces, protocols and management that are identical whether the implementation is physical or virtual.

The NFV Requirements document addresses the following areas:

- **Portability**, addressing the capabilities to load, execute and move software functions across different but standard data centres.
- **Performance**, listing the abilities required to describe the infrastructure requirements for specific performance targets of software functions.
- **Management and Orchestration**, placing requirements for mechanisms to exist in order to orchestrate and manage the software functions lifecycle, the infrastructure resources and the different operations performed on those.
- **Elasticity**, addressing the capabilities to provide an easier way to scale up/down and in/out hardware resources as traffic demands increase/decrease.
- **Security**, outlining the aspects to be analysed as the virtualisation environment can be exposed to external attacks in ways that are not expected with current telecom architectures
- **Resiliency and Network Stability**, pointing to the capabilities demanded to limit disruption and return to normal operation in order to secure service availability and continuity, without functionalities becoming single points of failure.
- **Service Continuity**, stating the capabilities needed for the continuous delivery of service in conformance with the service specification and Service Level Agreement (SLA) requirements.
- **Operations**, targeting the requirements needed for automation of operational functions, e.g. network capacity adaptation to load, software upgrades, intervention on detected failures, etc.
- **Energy Efficiency**, addressing the technical capabilities that will help minimise the energy consumption of large scale virtualised networks.
- **Migration and co-existence with existing platforms**, pointing to the requirements to support a transition path from today's networks where non-virtualised networks coexist with virtualised ones without disruption of the services or impacts to the users.

In addition, the ability to remotely deploy and run virtualised network functions on NFV Infrastructure provided by different Service Providers permits an efficient service to global customers, and enables additional commercial offerings to directly support, and accelerate, the deployment of NFV Infrastructure.

The commercial and deployment aspects of inter-service provider agreements are out of the scope of the NFV requirements document. Only the technical requirements to facilitate these Service Models are covered.

Last, but not least, the Requirements document addresses the basic business need for maintainability, particularly in multi-vendor and multi-provider deployments. It needs to be assured that all necessary service and maintenance tasks can be executed as new interactions arise with such a multiplicity of actors.

NFV Architectural Framework Document

The Architectural Framework document is one of the most important NFV ISG deliverables as it provides the foundation for the future industry-wide NFV ecosystem as envisaged by the operator community. By delineating the different constituents and outlining the reference points between them, it explicitly defines certain functional building blocks which can be provided by different players in the industry, thus paving the way for a fully interoperable multi-party NFV solution.

The Architectural Framework is shown in Figure 4. It illustrates which building blocks vendors can choose to implement in order to provide “NFV compatible products”.

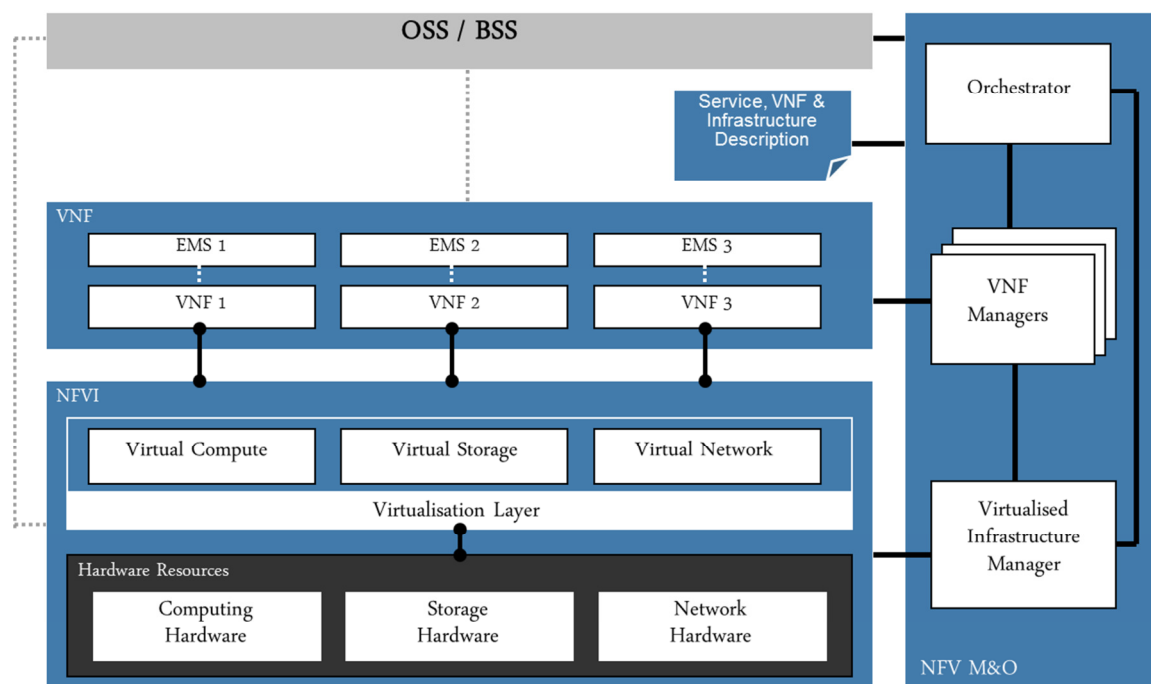


Figure 4: NFV Architectural Framework

The main architectural constituents of the NFV Architectural Framework are:

- **The NFVI (Network Functions Virtualisation Infrastructure)**, which provides the virtual resources required to support the execution of the Virtualised Network Functions. It includes Commercial-Off-The-Shelf (COTS) hardware, accelerator components where necessary, and a software layer which virtualises and abstracts the underlying hardware.
- **The VNF (Virtualised Network Function)** is the software implementation of a network function which is capable of running over the NFVI. It can be accompanied by an Element Management System (EMS), as long as it is applicable to the particular function, which understands and manages an individual VNF and its peculiarities. The VNF is the entity corresponding to today’s network nodes, which are now expected to be delivered as pure software free from hardware dependency.
- **The NFV M&O (Management and Orchestration)**, which covers the orchestration and lifecycle management of physical and/or software resources that support the infrastructure virtualisation, and the lifecycle management of VNFs. NFV Management and Orchestration focuses on the virtualisation-specific management tasks necessary in the NFV framework. The NFV M&O also interacts with the (NFV external) OSS/BSS landscape, which allows NFV to be integrated into an already existing network-wide management landscape.
- The entire NFV system is driven by a set of metadata describing Service, VNFs and Infrastructure requirements, so that the NFV Management & Orchestration systems can act accordingly. These descriptions along with the Services, VNFs and Infrastructure can be provided by different industry players.

The Architectural Framework constituents interact via defined reference points so that the various entities can be clearly decoupled to promote an open and innovative NFV ecosystem. The reference points between VNF and NFVI (and those between entities within the NFVI) deal with the abstraction and virtualisation of resources and the hosting of VNFs, so that VNFs can not only be ported from one NFVI to another, but also to ensure that different choices of underlying hardware are possible. The reference points between NFV M&O and VNF and between M&O and NFVI (as well as those between entities within the M&O) deal with the management and operation of the NFV system. The related building blocks are designed in a way that allows the reuse of existing solutions (e.g. cloud management systems) and also interaction with an existing OSS/BSS environment to which the NFV system needs to be connected.

This Architectural Framework is now being used to guide the future work in the different NFV ISG working groups where the details of each of the building blocks are being further analysed and described. It is also informing the basis for a “gap analysis” to scope and prioritise the on-going work within the NFV ISG, and what should be the strategy for interactions with other bodies with an interest in the functional blocks and the interfaces between them.

NFV Terminology Document

The Terminology document provides terms and definitions in order to achieve a "common language" across all the NFV ISG working groups. It provides the terminology and semantic description for conceptual NFV entities used commonly in all NFV ISG working groups. It is also intended to contribute to creating a common NFV terminology across the industry. The document focuses on a few (~20) commonly used terms and it avoids a proliferation of derived terms in order to make the NFV ISG outputs more readable.

NFV Proof of Concept Framework Document

Proof of Concepts (PoC) are an important tool to demonstrate NFV as a viable technology, and results from PoCs are useful to provide information on feasibility, test strategies, interoperability and other technical issues such as integration and migration strategies. The public demonstration of NFV concepts also helps to build commercial awareness and confidence in NFV approaches, and helps to develop a diverse and open NFV ecosystem. Any given PoC demonstration event impacts its immediate audience, but the cumulative set of PoC demonstration events provides a measure of industry effort towards developing NFV solutions.

In pursuit of these goals, the NFV ISG has initiated a global PoC activity based on the PoC Framework document which is published simultaneously with the first high level outputs of the NFV ISG. The PoC activity is intended to extend beyond the membership of the NFV ISG to include organisations who are not members of the NFV ISG, provided that PoC proposals meet the following criteria:

- The PoC Proposal must be submitted using the template provided in the PoC Framework document.
- The organizations participating in a PoC Project must include at least two vendors and at least one network operator/service provider who is a member of the NFV ISG.
- The PoC Proposal should address at least one goal relevant to the NFV ISG published documents.

- The PoC Proposal should contain a time line and there must be commitment to demonstration and a technical report.
- PoC results are encouraged to be published to the wider industry as long as no claims of endorsement by the NFV ISG are made.

Results from PoCs may guide the work in the NFV ISG by providing feedback on interoperability and other technical challenges.

Just as the NFV ISG rotates its meeting locations and schedules to reflect the needs of its global participants, the NFV ISG's PoC Framework is expected to result in open public demonstrations of NFV concepts in PoC Team member's labs, trade shows, research networks etc., around the globe to build a global NFV ecosystem. The NFV PoC Projects are open for participation by all interested parties in conformance with the NFV ISG POC Framework.

Enquiries relating to the NFV ISG PoC activity, including how to submit PoC proposals can be found on the ETSI website. ^[3]

NFV Industry Landscape

In our original white paper we highlighted the benefit of increased flexibility in operations and service development by reducing the typical Service Provider cycle of innovation, Time to Market, etc. 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 on a programmable NFV infrastructure.

Integrating NFV Architectural Frameworks with constituents from multiple vendors in an open ecosystem is a vital new industry capability which needs to be encouraged.

We believe NFV will accelerate networks and services innovation. New network topologies will emerge and new approaches for operations, service assurance and security will become possible. With this in mind, we are engaging academia to encourage research and study around NFV.

The NFV ISG is addressing the call to action outlined in our original white paper, but for NFV to reach its full potential to transform today's static and stove-piped network infrastructures into a more agile, programmable infrastructure, a broader industry effort will be required for the longer term.

Open Source and Perspectives on Standardisation

We are interested to ensure that the Open Source community actively engages in NFV to help create virtualised network capabilities. We also see a role for SDOs to quickly update existing specifications or quickly create new specifications to ensure interoperability, but we are anxious to ensure that NFV implementation progresses quickly and is not delayed by standardisation.

Traditional standardisation processes require delicate and well-balanced mechanisms to guarantee accurate specifications on which prototyping and testing efforts can be based. On the other hand, the IT industry has embraced the model of open-source where a community of developers contribute and integrate pieces of software under terms that facilitate open collaboration and usage. The process of building elements based on these open pieces is driven according to short code-build-test cycles of software prototypes and less stringent agreement rules, based on what has

been termed “rough consensus”. NFV concepts are derived from initial prototypes that rely on several of these open-source initiatives in areas like operating systems, hypervisors, cloud infrastructure managers, and even network infrastructure. Furthermore it is worth noting that the recent evolution of SDN relies heavily on several open-source projects.

An open-source approach is extremely useful for the production of open reference implementations of standards at the same pace, or even guiding them and producing de-facto standards. The availability of such reference implementations translates into two main benefits:

1. Much simpler interoperability and conformance assessments for both vendors and operators.
2. Provides the substrate for an innovation ecosystem based on the incremental competitive differentiation of the common solution.

Open-source initiatives should not be considered as an alternative to formal standardisation processes. On the contrary, they are complementary, with the former acting as an enabler and accelerator of the latter. Hence, we see both formal standardisation and open-source as key instruments to achieve our goals.

Therefore, in addition to engaging SDOs, we intend to actively collaborate with existing reference open-source initiatives in the areas relevant to NFV, as well as to encourage and support new ones aligned with the NFV goals, especially when addressing new issues identified by the NFV community.

Impact on Operations Support Systems (OSS)

The NFV architectural framework identifies a Management & Orchestration (M&O) domain which includes three management components that complement the functionality of current OSS. The interfaces between the M&O entity and the current OSS and between the three management components need to be standardised to reduce integration effort in a multi-vendor environment.

To obtain maximum benefits from NFV automation and agility, the current OSS and the NFV Management and Orchestration entities need to align their interfaces and associated Information Models as well as their Business Processes (i.e. Fulfilment, Assurance, Billing, Security) in an efficient way through Resource Management & Operations and through Service Management & Operations. The level of impact on the OSS will be highly dependent on the existing OSS environment for each Operator: ranging from simple existing tool configuration to complete change or roll-out of new OSS component(s), including potentially incorporating EMS functionality, service management, or network management control into M&O.

The expectations are that Operations complexity and associated OPEX will be reduced, but all these aspects need to be further and thoroughly studied and standards need to be progressed in order to achieve the NFV promise on the Operations side.

Therefore, as for Open Source, also for OSS, Management and Orchestration we intend to actively collaborate with existing Bodies and Fora and encourage discussions and the emergence of suitable standards for NFV Management, Orchestration and Operations.

Contact Information

If your organisation has any comment on the contents of this white paper, please contact any of the following:

AT&T:	Margaret Chiosi, mchiosi@att.com
BT:	Don Clarke, don.clarke@bt.com
CableLabs:	Chris Donley, C.Donley@cablelabs.com
CenturyLink:	Michael Bugenhagen, michael.k.bugenhagen@centurylink.com
China Mobile:	Chih-Lin I, icl@chinamobile.com
China Telecom:	Lei Baohua, leibh@ctbri.com.cn
China Unicom:	Xiaoxia Zhou, zhouxx1@chinaunicom.cn
Colt:	Javier Benitez, javier.benitez@colt.net
Deutsche Telekom:	Uwe Michel, uwe.michel@telekom.de
DOCOMO:	Tetsuya Nakamura, tetsuya.nakamura.cu@nttdocomo.com
KDDI:	Kenichi Ogaki, ke-oogaki@kddi.com
KT:	Kisang Ok, ksok@kt.com
NTT:	Kazuaki Obana, obana.kazuaki@lab.ntt.co.jp
Orange:	Bruno Chatras, bruno.chatras@orange.com
Portugal Telecom:	Jorge Carapinha, JorgeC@ptinovacao.pt
SK Telecom:	DK Lee, dongkee.lee@sk.com
Softbank:	Satoru Matsushima, satoru.matsushima@g.softbank.co.jp
Sprint:	Fred Feisullin, Farid.Feisullin@sprint.com
Swisscom:	Markus Brunner, Markus.Brunner3@swisscom.com
Telecom Italia:	Elena Demaria, elena.demaria@telecomitalia.it
Telefonica:	Diego López, diego@tid.es
Telenor:	Patrick Waldemar, Patrick.Waldemar@telenor.com
Telstra:	Frank Ruhl, frank.ruhl@team.telstra.com
Verizon:	Prodip Sen, prodip.sen@verizon.com
Vodafone:	Susana Sabater, susana.sabater@vodafone.com

References

1. Joint-operator white paper introducing NFV published October 2012: http://portal.etsi.org/NFV/NFV_White_Paper.pdf
2. NFV ISG Published Documents: <http://www.etsi.org/nfv>
3. NFV ISG PoC Enquiries: <http://www.etsi.org/nfv-poc>

This white paper is available at the following link: http://portal.etsi.org/NFV/NFV_White_Paper2.pdf

Glossary

BBU	Baseband Processing Unit
BS	Base Station
BSS	Business Support System
CDN	Content Distribution Network
COTS	Commercial-off-the-Shelf
CSCF	Call Session Control Functions
EMS	Element Management System
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute (in practise ETSI has global membership, including the Americas and Asia)
IaaS	Infrastructure as a Service
IMS	IP Multimedia System
ISG	Industry Specification Group.
IT	Information Technology
M&O	Management and Orchestration
MME	Mobility Management Entity
NAT	Network Address Translation
NF	Network Function
NFV	Network Functions Virtualisation
NFVI	Network Functions Virtualisation Infrastructure
OSS	Operations Support System
PaaS	Platform as a Service
PoC	Proof of Concept.
SaaS	Software as a Service
SDN	Software Defined Network
SDO	Standards Development Organisation
SLA	Service Level Agreement
S/P-GW	Serving and Packet Data Networks Gateway
TCO	Total Cost of Ownership
VM	Virtual Machine
VNF	Virtual Network Function

END