European Commission

Implications of the emerging technologies Software-Defined Networking and Network Function Virtualisation on the future Telecommunications Landscape

FINAL REPORT

A study prepared for the European Commission DG Communications Networks, Content & Technology by:

wik CONSULT

IDATE DIGIWORLD

TNO innovation for life

Digital Single Market

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ABSTRACT

This forecast study explored the technological, economic, and regulatory implications of Software Defined Networks (SDN) and Network Function Virtualisation (NFV) using a Delphi panel of experts, workshops, expert interviews, and extensive desk research. It finds that SDN and NFV will play an important role in the future telecommunications landscape with the most important usage scenarios being (1) Virtualisation of Mobile Core Networks, (2) Virtualisation of Content Delivery Networks, and (3) Virtual Network Platform as a Service (VNPaaS).

Focussing on these usage scenarios, the study describes corresponding CapEx and OpEx reductions. While cost reductions – ranging between 3.7% and 9% of total cost – are significant, they appear to be somewhat lower than expectations presented in industry outlooks. Beyond the telecommunications landscape, SDN and NFV are likely to be instrumental in the development and roll-out of innovative services, applications, and products as well as in facilitating major trends with substantial economic and societal impact.

As regards the regulatory implications of SDN and NFV, the present study shares BEREC's view that it is premature to make any specific recommendations. However, the experts involved in this research clearly highlighted access (to virtual networks) regulation as the most likely area where new rules may be necessary.

RÉSUMÉ

Cette étude prospective a permis d'examiner les implications du SDN (*Software Defined Network)*, réseau défini de manière logicielle et du NFV (*Network Function Virtualisation*), virtualisation des fonctions de réseau, sur les aspects technologiques, économiques et réglementaires. L'étude a été réalisée en s'appuyant sur la méthode Dephi avec un panel d'experts, des ateliers de discussion, des entretiens avec des experts ainsi qu'une recherche documentaire étendue. Selon l'étude, le SDN et le NFV joueront un rôle important dans le futur paysage des télécommunications,dont les cas d'usage les plus importants sont (1) la virtualisation des cœurs de réseau mobile, (2) la virtualisation des réseaux de distribution de contenu et (3) le VNPaaS pour *Virtual Network Platform as a Service*.

En se focalisant sur ces 3 cas d'usage, l'étude indique des réductions de CapEx et d'OpEx correspondantes. Bien que les réductions de coûts - entre 3,7% et 9% du coût total des dépenses - restent importantes, elles semblent être inférieures aux prévisions annoncées généralement par l'industrie. Au délà du paysage strictement télécom, le SDN et le NFV sont par ailleurs susceptibles de contribuer au développement et au déploiement de services, d'applications et de produits innovants, mais également de faciliter des développements majeurs ayant un impact économique et sociétal considérable.

Concernant les implications réglementaires du SDN et du NFV, la présente étude partage l'opinion de l'organe des régulateurs européens des communications électroniques (*BEREC*) selon laquelle il est prématuré de formuler des recommandations spécifiques associées à ces technologies. Cependant, les experts impliqués dans cette étude ont clairement mis en évidence la régulation de l'accès (aux réseaux virtuels) comme domaine le plus probable où de nouvelles dispositions pourraient être nécessaires.

EXECUTIVE SUMMARY

This is the Draft Final Study Report for the project "Implications of the emerging technologies Software-Defined Networking (SDN) and Network Function Virtualisation (NFV) on the future Telecommunications Landscape" (SMART 2015/0011). The study set out to explore the most likely SDN and NFV usage scenarios and their technological, business, economic, and regulatory implications in the foreseeable future.

Based on a Delphi Expert Panel of almost 700 experts from 55 countries, three workshops, additional expert interviews, and extensive desk research, the findings can summarised as follows.

The most relevant usage scenarios out of the ones defined ETSI (European Telecommunications Standards Institute) for SDN and NFV appear to be (1) Virtualisation of Mobile Core Network, (2) Virtualisation of Content Delivery Network, and (3) Virtual Network Platform as a Service (VNPaaS), as these were identified by the experts on the panel and in the workshops as being the most significant. Technologically as well as with regards to the alleged business impact, SDN/NFV appears to be approaching a phase of disillusionment. The results of this study confirm that at least some of the expectations have been inflated.

As regards the economic impact beyond the telecommunications landscape, it was found that SDN and NFV are enabling technologies that are likely be instrumental in the development and roll-out of innovative services, applications, and products as well as in facilitating major trends that have substantial economic and societal impact. These trends include connected cars, augmented reality, virtual reality, and universal communications.

BEREC (Body of European Regulators for Electronic Communications) has recently published an input paper on the regulatory implications of SDN and NFV. Their main conclusion is that the implications are difficult to foresee at this point, although some areas of regulatory intervention clearly merit further monitoring as the technology develops and is being deployed. The findings of the present study by and large concur with these findings. The areas to observe critically in the coming years are access to virtual networks, spectrum regulation, and network neutrality.

A SWOT analysis of the ability of the European policy framework to facilitate SDN and NFV development and deployment conducted as part of this study concludes that there is positive and strong support from innovation measures such as Horizon2020 for SDN and NFV, and that the side-by-side development of open-source and traditional standards can be an opportunity to be seized by policy makers. Challenges referring to the transition process from legacy infrastructures to virtual ones is identified as a threat.

Virtualisation of Content Delivery Network

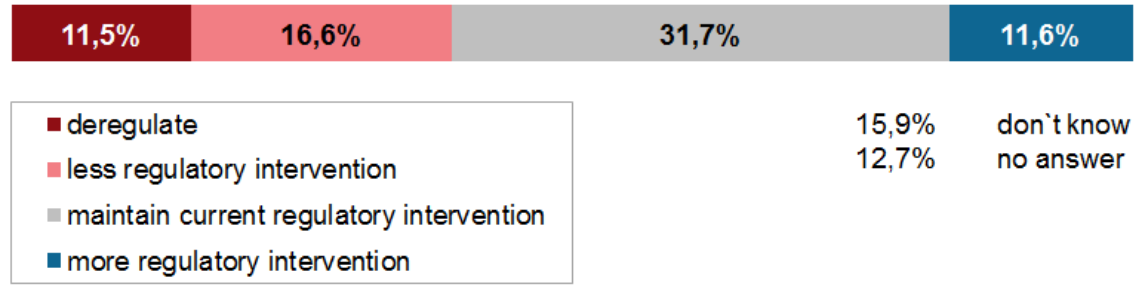
Short description

Streaming content is one of the fastest growing types of traffic in today's networks. This is mostly due to the rise of smartphones, tablets, and laptops – and the increased availability of content delivered over IP. This relates equally to linear (live) and non-linear (on-demand) content. Currently, CDNs are integrated into the operator's network and are typically distributed, in order to be as close as possible to the end user. By basing CDNs on NFV, network operators may profit from higher flexibility in the network as they may assign resources dynamically (e.g. instantiating CDN servers on demand). This enables them to efficiently match the demand for content with its delivery.

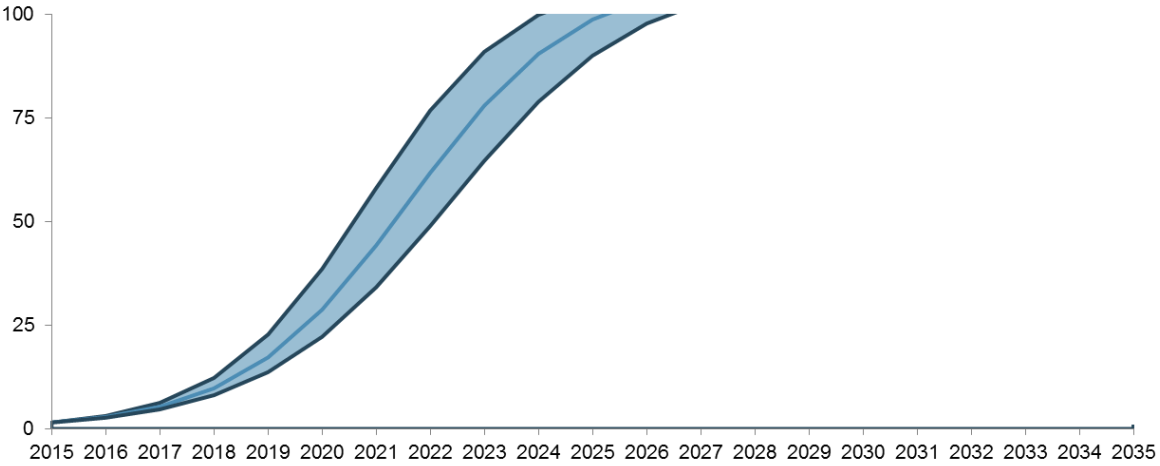
Cost savings are likely to be concentrated on OpEx aspects, with less traffic going through the network. Impacts on CapEx are less obvious. Indeed, impacts in terms of CapEx are unknown, as virtualisation will reduce the need in terms of nodes or servers, but the number of nodes will increase significantly compared with today's architectures, generally using central storage resources.

About 17% of the experts expect virtualised CDN to require less regulation. On the other side, about 12% expect there will be more regulatory intervention.

Please indicate your expectation as regards the need for future regulatory intervention



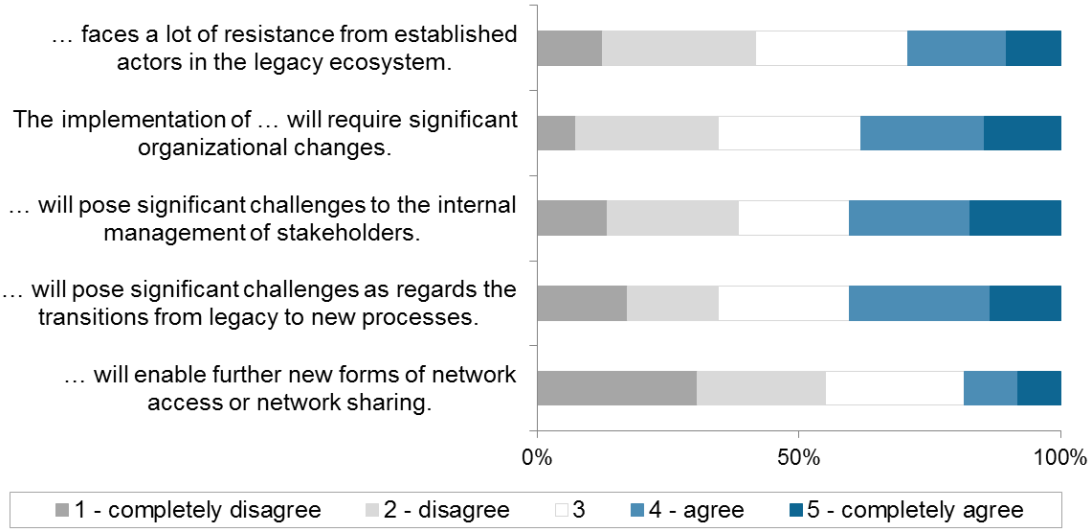
Experts' expectation of vCDN deployment timeframe



Between 2020 and 2022 experts expect that vCDN will be deployed in 50% of the networks.

Especially in comparison to the other scenarios, the experts are somewhat indifferent to whether the barriers will pose a threat for the deployment of vCDN.

For "Virtualisation of the Content Delivery Network", please rate the following statements



Virtual Network Platform as a Service

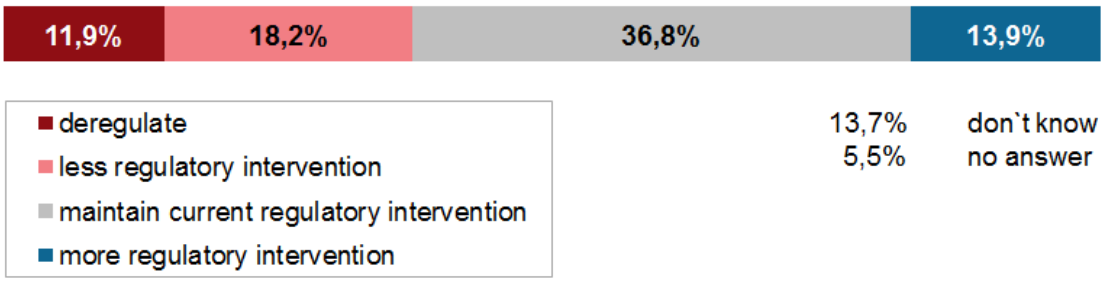
Short description

Some companies want to keep full control over the services that run on their networks; in some cases they might even prefer to develop their own services. Service providers can offer these companies a Virtual Network Platform as a Service (VNPaaS). In that case the company can focus on running their services – now on a virtual network platform. By running services on a platform that is maintained and managed by a third-party (the service provider), the company may realise savings.

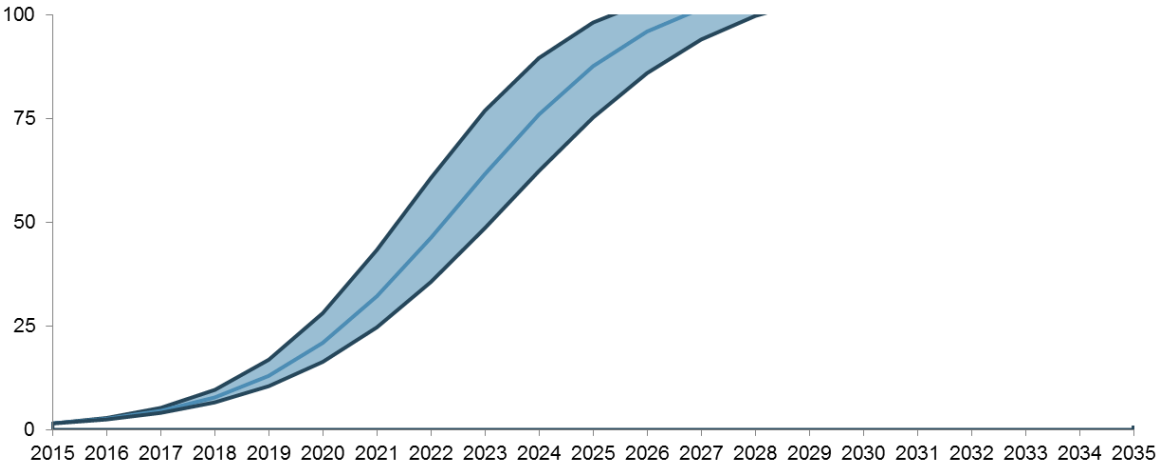
The key benefit of VNPaaS is the ability for the operator to provide services with the actual resources consumed by the end users. The OpEx savings realised through VNPaaS can be compared to those realised through traditional PaaS, like scalability of deployed software with failover and load balancing.

For VNPaaS, experts expect less or roughly the same level of regulatory intervention as today. However, it should be noted that with regard to access to virtual networks, they recognised a potential area of future additional regulatory intervention.

Please indicate your expectation as regards the need for future regulatory intervention



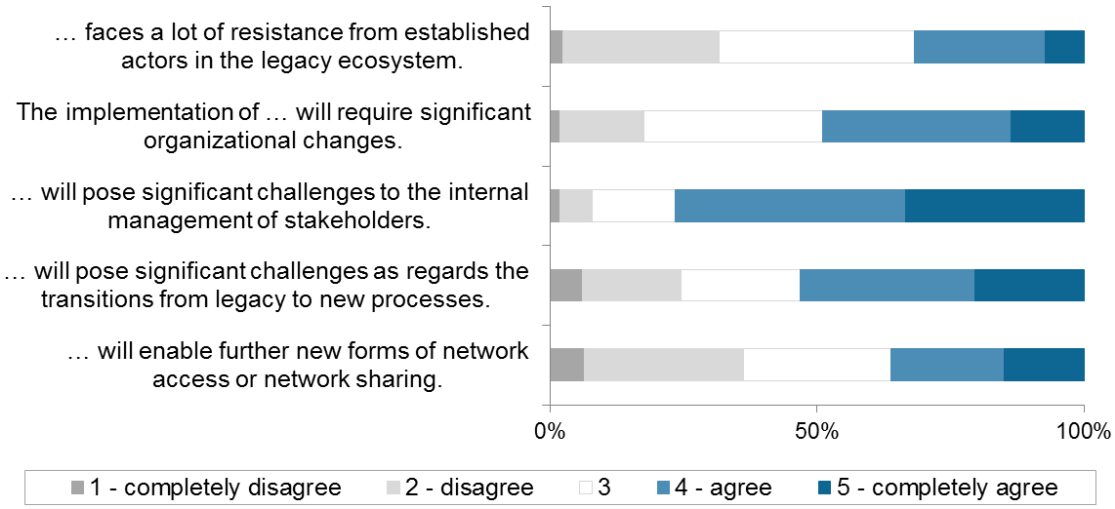
Experts' expectation of VNPaaS deployment timeframe



Following the expectations of the Delphi experts, the use case VNPaaS will be implemented in over 50% of the networks between 2021 and 2023.

Most of the experts agreed on significant challenges to the internal management of stakeholders posed by VNPaaS.

For "Virtual Network Platform as a service", please rate the following statements



Virtualisation of Mobile Core Network

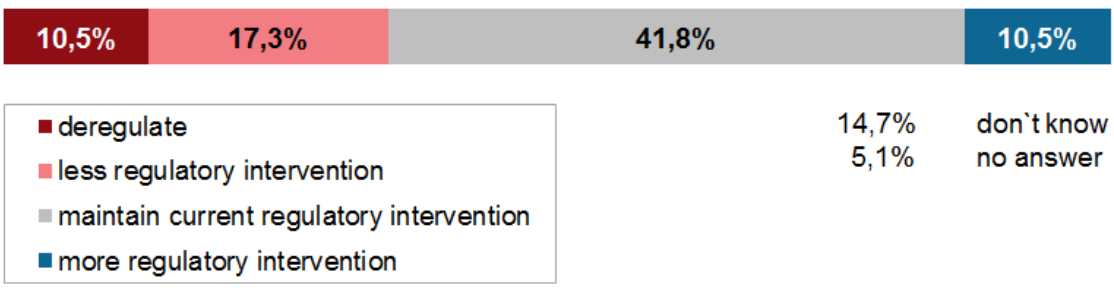
Short description

NFV aims at the reduction of the network's complexity and thus wants to reduce operational costs by using standardised virtualisation technologies, and map them to high-volume hardware. By virtualising the mobile network core, network operators can assign available resources in a flexible manner and dynamically adapt to the current load of the network. This flexibility is important due to a high level of complexity in the mobile core network and fluctuating demand for network resources of end users over time. Virtualising the mobile network core helps mobile network operators to save energy by activating the "sleep-mode" for some of its base stations. Mobile core network resources can then be used for some other purpose until they are needed again.

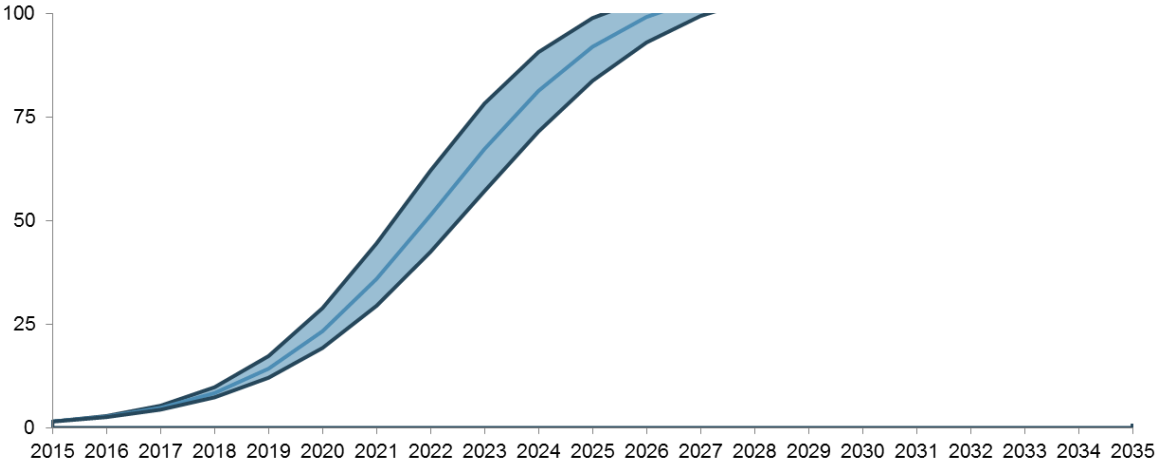
Benefits from vEPC are globally generic to SDN/NFV. By running each network function of the EPC on VNFs running on standard servers instead of dedicated appliances, the industry expects a reduction in terms of OpEx and CapEx along with operational benefits.

For virtualisation of the Mobile Core Network, experts overall expect the level of regulatory intervention to remain the same. Notably, the assignment of spectrum frequencies may have to be revised if SDN/NFV come into full effect.

Please indicate your expectation as regards the need for future regulatory intervention



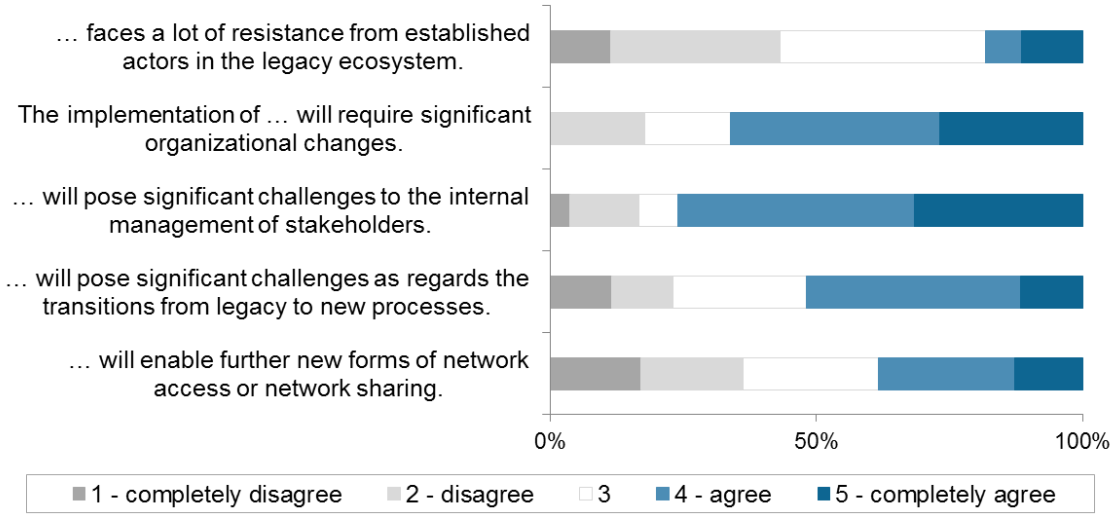
Experts' expectation of Virtualisation of Mobile Core Network deployment timeframe



Most experts expect 50% of the deployment of Virtualisation of the Mobile Core Network before 2022.

Similar to VNPaaS, the main barriers for the scenario Virtualisation of the Mobile Core Network are the need for significant organisational changes and the challenges for the internal management of stakeholders.

For "Virtualisation of the Mobile Core Network", please rate the following statements



SOMMAIRE EXÉCUTIF

Ce document est le rapport final de l'étude «Implications des technologies émergentes SDN (*Software Defined Network)*, réseau défini de manière logicielle et du NFV (*Network Function Virtualisation*), virtualisation des fonctions de réseau sur le futur paysage des télécommunications» (SMART 2015/0011). L'étude avait pour but d'examiner les scénarios d'utilisation du SDN et du NFV les plus probables et leurs implications en termes technologiques, commerciales, économiques et réglementaires dans un avenir proche.

A partir d'une consultation Delphi d'un groupe d'experts de près de 700 experts provenant de 55 pays, de trois ateliers de discussion, d'entretiens complémentaires d'experts et d'une recherche documentaire étendue, les conclusions peuvent se résumer comme suit.

Les cas d'usage les plus pertinents pour le SDN et le NFV parmi ceux définis par l'ETSI (European Telecommunications Standards Institute) semblent être: (1) la virtualisation du cœur de réseau mobile, (2) la virtualisation des réseaux de distribution de contenu et (3) la plate-forme de réseaux virtuels accessibles sous forme de service (VNPaaS pour *Virtual Network Platform as a Service*). Ces derniers ont en effet été identifiés par les experts du panel ainsi que lors des ateliers comme étant les plus importants. D'un point de vue technologique et au regard de l'impact commercial, le SDN/NFV semble entrer dans une phase de désillusion (classique pour les nouvelles technologies); les premiers développements ne remplissent en effet pas les attentes initiales, elles-mêmes un peu demesurées.

En ce qui concerne l'impact économique au-delà du paysage des télécommunications, il a été établi que SDN et NFV sont des technologies susceptibles de contribuer au développement et au déploiement de services, d'applications et de produits innovants et peuvent être des facilitateurs pour des tendances lourdes ayant un impact économique et sociétal important. Parmi ces tendances sont notamment inclus les voitures connectées, la réalité augmentée ou encore la réalité virtuelle.

L'organe des régulateurs européens des communications électroniques (*BEREC*) a récemment publié un document sur les implications réglementaires du SDN et du NFV. La principale conclusion est que les implications sont difficiles à anticiper actuellement, bien que certains aspects d'intervention de la réglementation méritent clairement un suivi approfondi à mesure que la technologie se développe et se déploie. Les résultats de la présente étude concordent globalement avec les conclusions du BEREC. Les domaines à étudier en détail dans les années à venir sont l'accès aux réseaux virtuels, la régulation du spectre et la *Net Neutrality.*

Une analyse SWOT sur la capacité d'un cadre réglementaire européen à faciliter le développement et le déploiement du SDN et du NFV a été réalisée dans le cadre de cette étude et a conclu qu'il existe un soutien important pour le SDN et le NFV via des mesures innovantes telles que Horizon2020 et que le développement conjoint de standards open source et traditionnels peut être une opportunité à exploiter. Les défis liés au processus de transition des infrastructures existantes vers les infrastructures virtuelles ont été identifiés comme la menace principale.

La virtualisation des réseaux de distribution de contenu (ou CDN – Content Delivery Network)

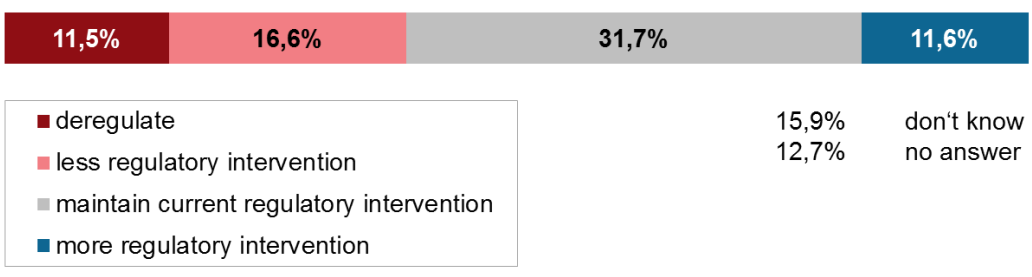
Brève description

Le *streaming de contenus* représente la plus forte croissance de trafic dans les réseaux actuels. Cela est principalement dû à l'adoption croissante des smartphones, des tablettes et des ordinateurs portables et à la disponibilité accrue de contenus livrés sur IP. Cela concerne aussi bien le contenu linéaire (en direct) et non linéaire (à la demande). Actuellement, les serveurs de CDN sont intégrés à la périphérie du réseau de l'opérateur et sont généralement distribués, de manière à être le plus proche possible de l'utilisateur final. En basant les CDN sur le NFV, les opérateurs de réseau peuvent bénéficier d'une flexibilité plus importante dans le réseau en pouvant affecter les ressources dynamiquement (par exemple, instancier des serveurs CDN sur demande). Cela leur permet de répondre de manière efficace à la demande de contenu.

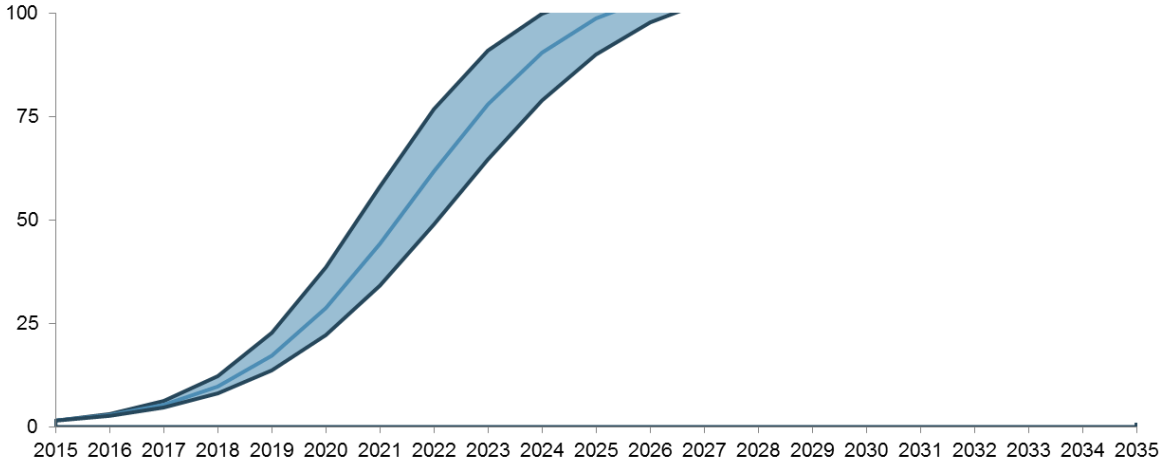
Les économies de coûts sont concentrées sur les OpEx, découlant de la baisse de trafic transitant par le réseau. Les impacts sur le CapEx sont moins évidents. En effet, les impacts en termes de CapEx sont inconnus, car la virtualisation réduira le besoin en termes de nœuds ou de serveurs, mais le nombre de nœuds augmentera significativement par rapport aux architectures actuelles, utilisant aujourd'hui des ressources de stockage centralisées.

Environ 17% des experts pensent que le CDN virtualisé impliquera moins de réglementation qu'ajourd'hui. En revanche, environ 12% s'attendent à ce qu'il y ait une intervention réglementaire accrue.

Merci d'indiquer vos attentes concernant la nécessité d'une intervention réglementaire dans le futur



Calendrier prévisionel de déploiement du vCDN selon les experts



Entre 2020 et 2022, les experts prévoient que le vCDN sera déployé dans 50% des réseaux.

Contrairement aux autres scénarios, les experts n'ont pas identifié de barrières plus significatives que les autres pour le déploiement de vCDN.

Merci d'évaluer les affirmations suivantes avec la «Virtualisation du CDN»

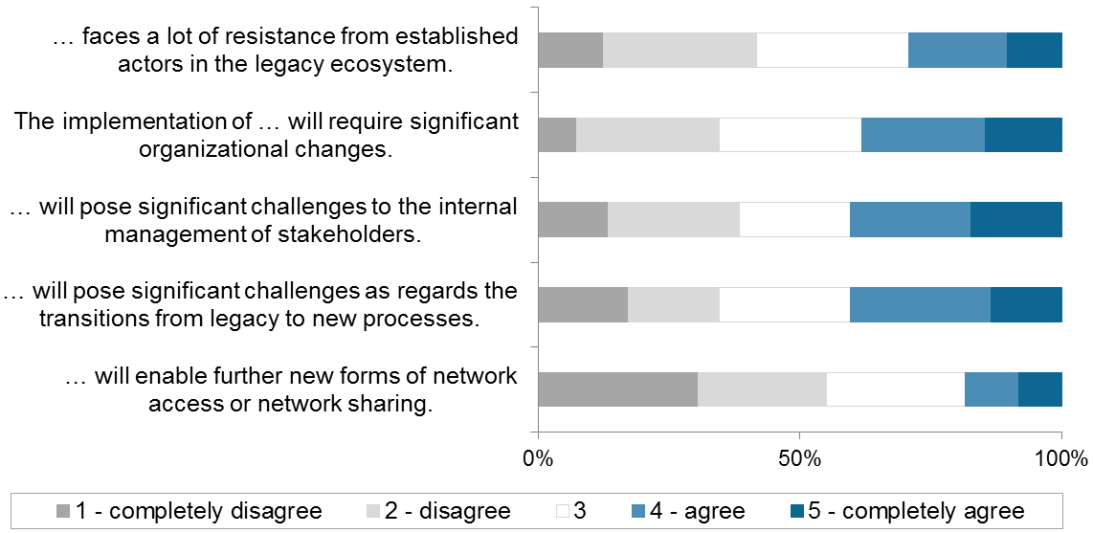


Plate-forme de réseaux virtuels sous forme de service (Virtual Network Platform as a Service)

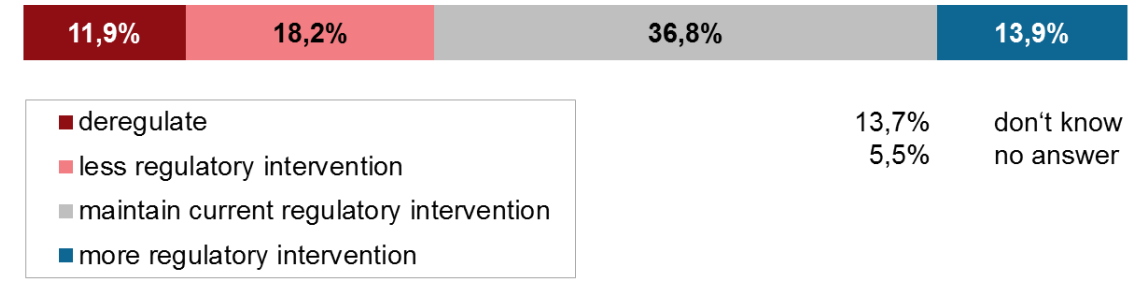
Brève description

Certaines entreprises veulent garder le contrôle total sur les services qui fonctionnent sur leurs réseaux; dans certains cas, ils préféreraient même développer leurs propres services. Les opérateurs peuvent offrir à ces entreprises une plate-forme de réseau virtuel sous forme de service (VNPaaS). Ainsi, l'entreprise peut se concentrer sur la gestion de ses services - désormais disponible via la plate-forme de réseau virtuel. En exécutant des services sur une plate-forme opérée et gérée par un tiers (le fournisseur de services), l'entreprise peut réaliser des économies.

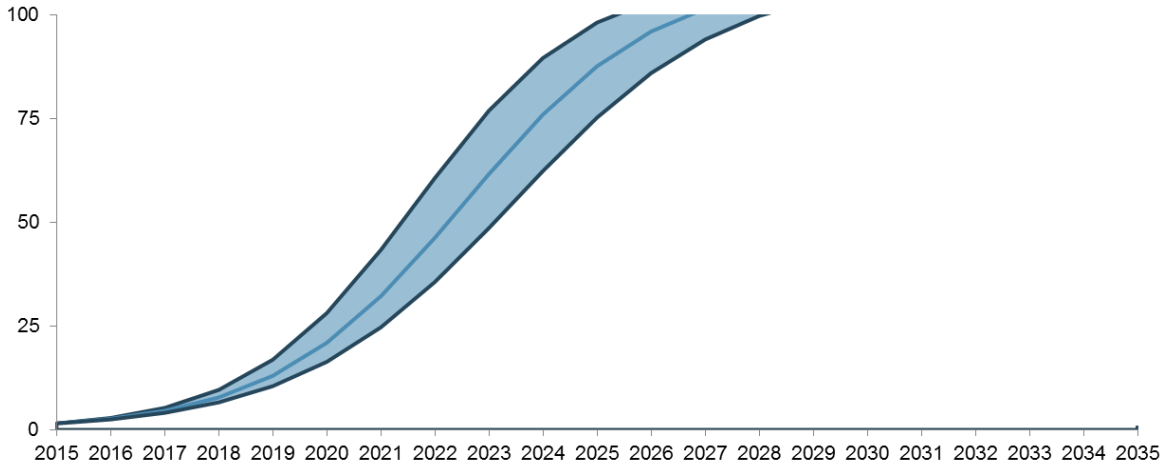
Le principal avantage du VNPaaS est la capacité pour l'opérateur de fournir des services avec uniquement les ressources réellement consommées par les utilisateurs finaux. Les économies d'OpEx réalisées à travers le VNPaaS sont similaires à celles obtenues via le PaaS classique, notamment l'évolutivité à grande échelle des logiciels déployés et une meilleure répartition de la charge (*load balancing*).

Pour le VNPaaS, les experts attendent à peu près le même niveau d'intervention de la réglementation qu'actuellement. Cependant, il convient de noter qu'en ce qui concerne l'accès aux réseaux virtuels, les experts reconnaissent ici un domaine nécessitant potentiellement une intervention réglementaire additionnelle dans le futur.

Merci d'indiquer vos attentes concernant la nécessité d'une intervention réglementaire dans le futur



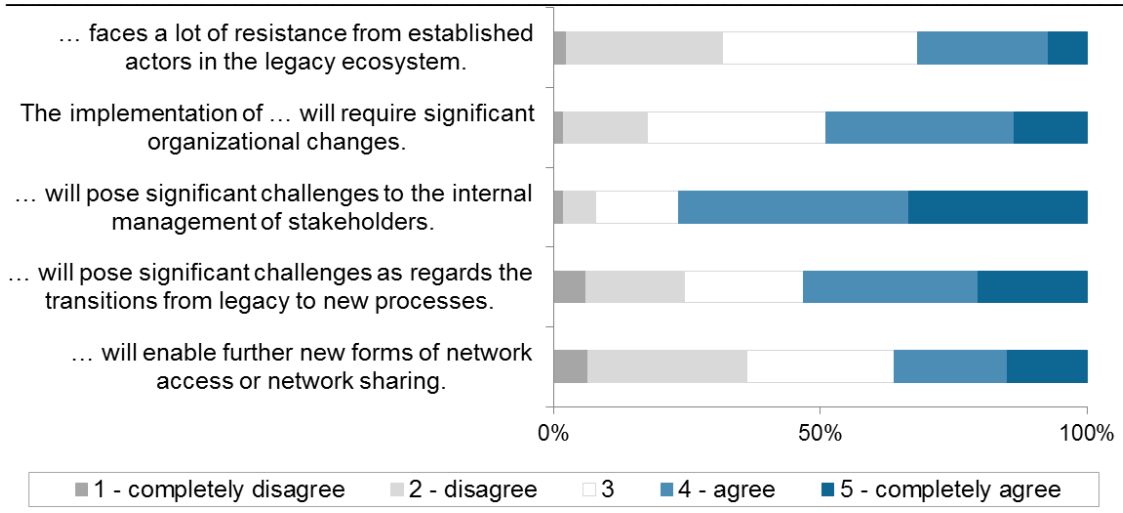
Calendrier prévisionel de déploiement du VNPaaS selon les experts



D'après les attentes des experts lors du Delphi, le cas d'utilisation VNPaaS sera implémenté dans plus de 50% des réseaux entre 2021 et 2023.

La plupart des experts sont en phase sur les grands enjeux, à savoir les défis importants concernant l'écosystème suscités par le VNPaaS.

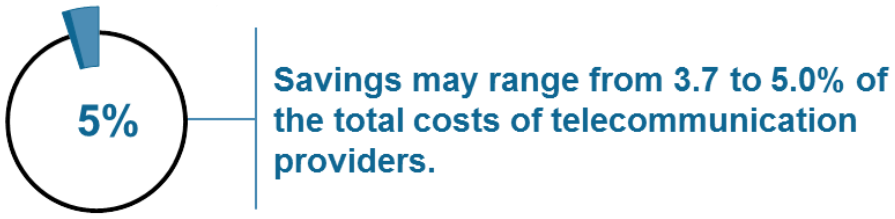
Merci d'évaluer les affirmations suivantes avec la «Plate-forme de réseaux virtuels sous forme de service »



La virtualisation du cœur de réseau mobile

Brève description

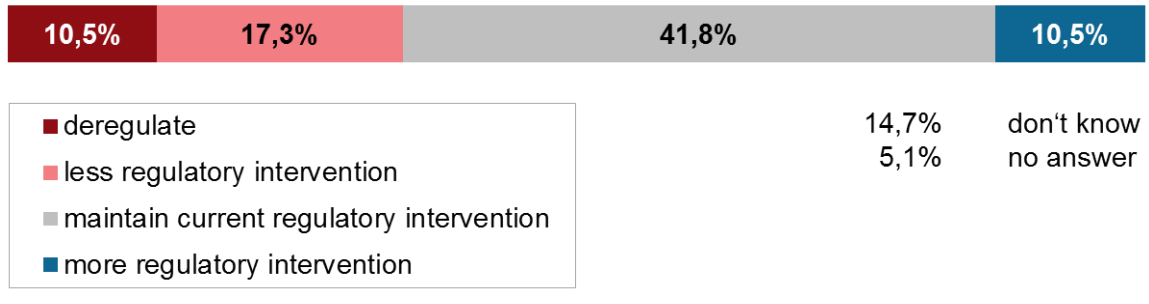
Le NFV vise à réduire la complexité des réseaux et veut ainsi réduire les coûts opérationnels en utilisant des technologies de virtualisation standardisées, et les adapter à du matériel offrant de grandes capacités. En virtualisant le coeur du réseau mobile, les opérateurs peuvent affecter les ressources disponibles de manière plus flexible et s'adapter dynamiquement à la charge actuelle de leur réseau. Cette flexibilité est importante compte tenu du niveau élevé de complexité dans le cœur de réseau mobile et de la fluctuation de la demande de ressources réseau des utilisateurs finaux avec le temps. La virtualisation du coeur de réseau mobile permet aux opérateurs de réseau mobile de réaliser des économies d'énergie en activant le mode « veille » pour certaines stations de base. Les ressources du cœur de réseau mobile peuvent ainsi être utilisées à d'autres fins jusqu'à ce qu'elles soient de nouveau utiles.



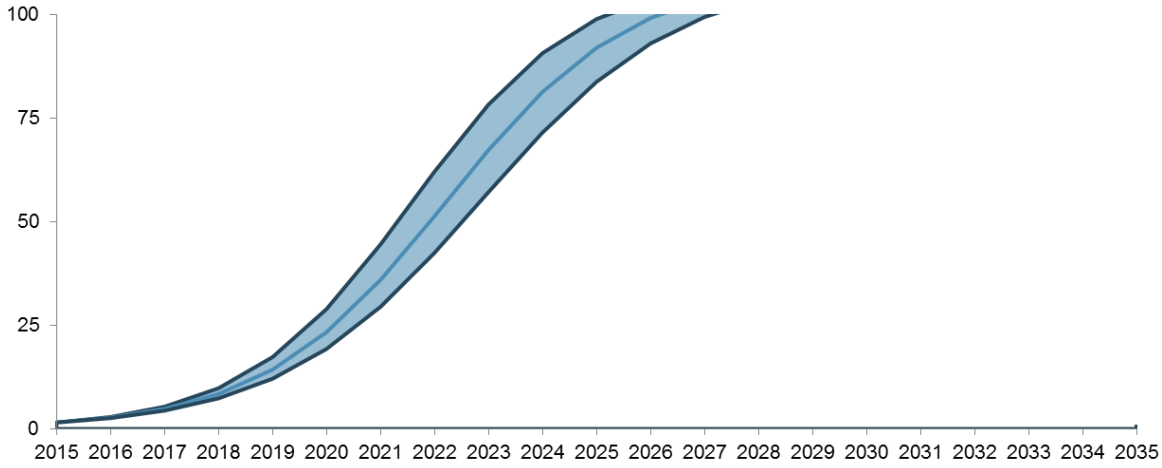
En exécutant chaque fonction de réseau de l'EPC (fonction clé du cœur de réseau) sur des VNF fonctionnant sur des serveurs standards au lieu de matériels dédiés, l'industrie s'attend à une réduction de coûts en termes d'OpEx et CapEx, ainsi que des benefices opérationnels.

Pour la virtualisation du cœur de réseau mobile, les experts s'attendent globalement à ce que le niveau d'intervention réglementaire reste le même. En particulier, l'allocation du spectre pourrait être à révisiter si le SDN/NFV prend de l'ampleur.

Merci d'indiquer vos attentes concernant la nécessité d'une intervention réglementaire dans le futur



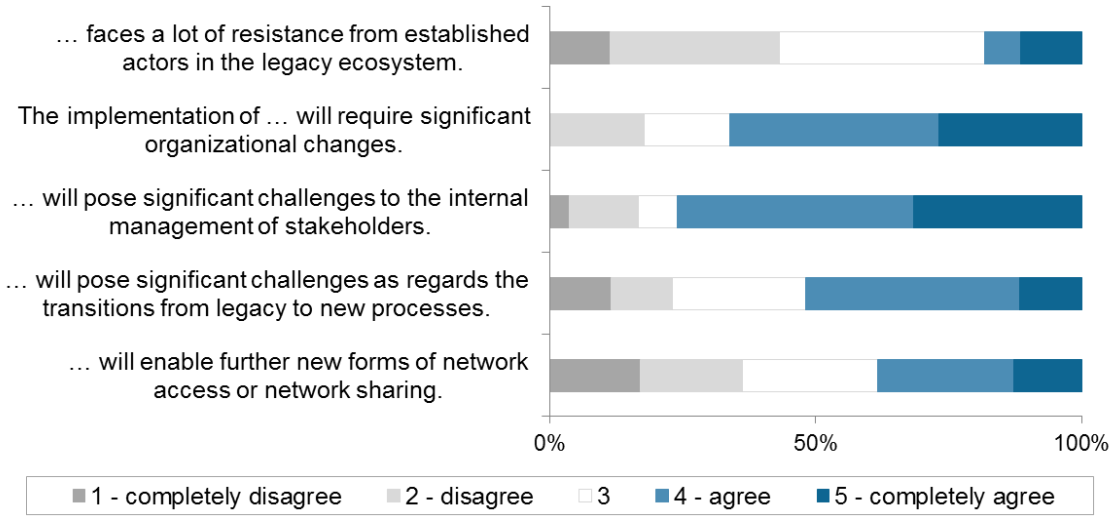
Calendrier prévisionel de déploiement de la virtualisation du cœur de réseau mobile selon les experts



La plupart des experts anticipent 50% de déploiement de la virtualisation du cœur de réseau mobile avant 2022.

À l'instar de VNPaaS, les principaux obstacles au scénario de virtualisation du cœur de réseau mobile sont la nécessité de changements importants au niveau organisationel et de l'écosystème.

Merci d'évaluer les affirmations suivantes avec la « Virtuallisation du cœur de réseau mobile »



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Abbreviations

2G	2nd Generation Mobile Network
3GPP	3rd Generation Partnership Project
4G	4th Generation Mobile Network
5G	5th Generation Mobile Network
5G-PPP	5G Infrastructure Public Private Partnership
ABNO	Application-based Network Operations
ACI	Application Centric Infrastructure
API	Application Programming Interface
ATT	American Telephone and Telegraph Company
BEREC	Body of European Regulators for Electronic Communications
BRAS	Broadband Remote Access Server
BSS	Business Support System
CapEx	Capital Expenditure
CDN	Content Delivery Network
CDN-I	Content Delivery Network Interconnection
CLI	Command Line Interface
CMS	Content Management System
CPE	Customer Premises Equipment
DDoS	Distributed Denial of Service
DFZ	Default-Free Zone
DNS	Domain Name System
DPI	Deep Packet Inspection
DRM	Digital Rights Management
DT	Deutsche Telekom
ECI	European Color Initiative
EE	Everything Everywhere (Ltd.)
eMBMS	evolved Multimedia Broadcast Multicast Service
EMS	Element Management System
eNB	evolved NodeB
eNodeB	evolved NodeB
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
ETSI NFV ISG	ETSI NFV Industry Specification Group
EU	European Union
FG	Forwarding Graph
G&A	General & Administrative Expense
GDP	Gross Domestic Product

GGSN	Gateway GPRS Support Node
GMPLS	Generalized Multi-Protocol Label Switching
GPRS	General Packet Radio Service
GS	Group Specification
GSM-R	Global System for Mobile Communications – Rail(way)
GUI	Graphical User Interface
HD	High Definition
HPE	Hewlett Packard Enterprise
HQ	High Quality
HSS	Home Subscriber Server
HW	Hardware
IaaS	Infrastructure as a Service
IJARCCE	International Journal of Advanced Research in Computer and Communication Engineering
IMS	IP Multimedia Subsystem
IoT	Internet of Things
IP	Internet Protocol
IP-PBX	Internet Protocol Private Branch Exchange
Ipsec	Internet Protocol Security
IPTV	Internet Protocol Television
ISG	Industry Specification Group
ISP	Internet Service Provider
IT	Information Technology
LSO	Lifecycle Service Orchestration
LTE	Long Term Evolution
M2M	Machine-to-Machine
MANO	(NFV) Management and Orchestration
MCN	Mobile Core Network
ME	Mobile Edge
MEC	Mobile Edge Computing
MME	Mobility Management Entity
MNO	Mobile Network Operator
MPLS	Multi-Protocol Label Switching
MTC	Machine-Type Communications
MVNA	Mobile Virtual Network Enablers
MVNE	Mobile Virtual Network Aggregators
MVNO	Mobile Virtual Network Operator
MWC	Mobile World Congress
NAT	Network Address Translation

NE	Network Element
NEP	Network Equipment Providers
NFV	Network Functions Virtualisation
NFVI	Network Function Virtualisation Infrastructure
Nf-Vi	NFVI - Virtualised Infrastructure Manager
NFVIaaS	Network Function Virtualisation Infrastructure as a Service
NGMN	Next Generation Mobile Networks alliance
NOC	Network Operations Center
nPVR	Network Personal Video Recorder
NS	Network Service
NW	Network
OC	Open Cache
OCA	OpenConnect Appliances
ONF	Open Networking Foundation
OpEx	Operational Expenditures
Or-Vi	Orchestrator - Virtualized Infrastructure Manager
OS	Operating System
Os-Ma	OSS/BSS - NFV Management and Orchestration
OSS	Operations Support System
OTT	Over-The-Top service provider
PaaS	Platform as a Service
PBX	Private Branch Exchange
PCCW	Pacific Century Cyberworks
PCRF	Policy and Charging Rules Function
PGW	Packet Data Gateway
PoP	Point of Presence
QoE	Quality of Experience
QoS	Quality of service
R&D	Research and Development
RAN	Radio Access Network
RCS	Revision Control System
RG	Residential Gateway
ROI	Return on Investment
SA	Service and System Aspects
SaaS	Software as a Service
SBC	Session Border Controller
SDN	Software-Defined Networking
SFC	Service Function Chain
SGSN	Serving GPRS Support Node

SGW	Serving Data Gateway
SLA	Service Level Agreement
SME	Small and Medium-Sized Enterprise
SMS	Short Message Service
SOHO	Small Office, Home Office
SSL	Secure Sockets Layer
STB	Setup Box
SVoD	Subscription Video on Demand
TCO	Total Cost of Ownership
TCP	Transport Control Protocol
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek
TS	Technical Specification
US	United States
USA	United States of America
vBRAS	Virtual Broadband Remote Access Server
vCDN	Virtualised Content Delivery Network
vEPC	Virtual Evolved Packet Core
vGGSN	Virtual Gateway GPRS Support Node
vMCN	Virtualised Mobile Core Network
vMME	Virtual Mobility Management Entity
VNF	Virtual Network Function
VNFaaS	Virtual Network Function as a Service
VNI	Virtual Network Interface
VNO	Virtual Network Operator
VNPaaS	Virtual Network Platform as a Service
VoD	Video on Demand
VoLTE	Voice over LTE
vPCRF	Virtual Policy and Charging Rules Function
VPN	Virtual Private Network
vSGSN	Virtual Serving GPRS Support Node
vSGW	Virtual Serving Gateway
vSIP	Virtual Session Initiation Protocol
WAN	Wide Area Network
Xaas	Everything as a Service

1 Introduction

This document is the Final Study Report for the project "Implications of the emerging technologies Software-Defined Networking and Network Function Virtualisation on the future Telecommunications Landscape" (SMART 2015/0011).

In light of the expected impact of Software-Defined Networking (SDN) and Network Function Virtualisation (NFV), this study sets out to fulfil five overarching research objectives:

A. Identify the most likely deployment scenarios including associated timelines and possible migration paths from existing networking technologies
B. Identify current and new usage scenarios of SDN- and NFV-based networks, including trends and possible new services
C. Assess the impact of SDN and NFV on existing business models in the telecom sector, and identify their innovation potential in terms of possible new business models with current and new stakeholders
D. Assess the general market and industrial potential for SDN and NFV
E. Position SDN and NFV within the current and future telecommunications regulatory framework and in relation to growth opportunities

To fulfil these five objectives, this study conducted an online Delphi study with almost 700 experts on SDN and NFV from 55 countries. The Delphi study was supported by three workshops with experts recruited from the panel as well as external speakers, expert interviews, and extensive desk research.

The three most relevant usage scenarios that were analysed in detail for this study are:

1. Virtualisation of Mobile Core Network
2. Virtualisation of Content Delivery Network
3. Virtual Network Platform as a Service (VNPaaS)

They were selected from the ETSI use cases for SDN/NFV based on the results of the first round of the Delphi study and the inputs received at the first two workshops for the study. The assessment of the technological, business, economic, and regulatory implications reflected in the remaining research objectives were analysed revolving around these three usage scenarios. Given the state of deployment of SDN and NFV, it was possible to describe the impact of the technology and likely deployment scenarios as well as the immediate business impact on telecommunications operators in detail. For the regulatory and economic implications, however, only high-level analyses were feasible.

The report is structured as follows:

- Chapter 2 provides the background to the study and exemplifies the expectations commonly held for the deployment of SDN and NFV
- Chapter 3 describes the design of the study
- Chapter 4 revolves around the usage scenarios' technological impact
- Chapter 5 presents an analysis of the business impact of the selected usage scenarios based on the IDATE telecommunications cost model
- Chapter 6 frames the selected usage scenarios as enablers for important digitisation trends that are likely to have substantial economic and societal impact
- Chapter 7 summarises the findings of this study as regards potential regulatory implications of SDN and NFV
- The Annex presents the full documentation of the cost model, the Delphi questionnaires, and the discussion guides that were used for the expert interviews

2 Background to the Study

The Internet has led to the creation of a digital society, where almost everything is connected and accessible from anywhere and at any time. However, despite their widespread adoption, traditional IP networks are complex, very hard to manage, and lack the necessary flexibility. It is both difficult to configure the network according to predefined policies, and to reconfigure it to respond to faults, load, and changes. To make matters even more difficult, current networks are also vertically integrated where the control and data planes are bundled together. Moreover, it takes quite a long time to launch new services and products, and as regards administrative domains it is very difficult to implement them across network boundaries.

Software-Defined Networking (SDN) is an emerging paradigm that promises to change this state of affairs. It is designed in such a way that it breaks this vertical integration, separating the network's control logic from the underlying specialised and expensive hardware such as routers and switches, promoting logical centralisation of network control, and introducing the ability to program the network. The separation of elements introduced between the definition of network policies, their implementation in switching hardware, and the forwarding of traffic are key factors to achieve the desired flexibility. By breaking the network control problem into tractable pieces, SDN makes it easier to create and introduce new abstractions in networking, simplifying network management, and facilitating network evolution.

Network Functions Virtualisation (NFV) focusses on the orchestration of network functions, including the combined control of computing, storage, and networking resources. SDN was developed across several research groups focusing on specific issues along the network, and is in a standardisation process within the Open Network Foundation (ONF). NFV was developed and standardised by the NFV industry specification group (ISG) within the European Technology Standards Institute (ETSI). NFV and SDN concepts are independent technologies but they are considered to be complementary, sharing the aim of accelerating innovation inside the network by allowing programmability, and altogether changing the network operational model through automation and a real shift to software-based platforms.

Since SDN and NFV are seen as enabling technologies with substantial benefits for the European Union and significant technological, economic, and business potential, it is essential to assess them in order to get a clear picture of the implications of these emerging technologies on the future of the telecommunications landscape and across several dimensions of European Union policies such as research, innovation, industrial, and telecommunications policy. More specifically, the introduction of SDN and NFV in operational networks is expected to enable more efficient utilisation of existing telecommunication links (cables, wireless links, access lines), significant quickening of the process of introduction of new services, lower operational costs due to efficient use of infrastructure, increased customer satisfaction, and ease of upgrades. Consequently,

the promise is that SDN and NFV will bring significant savings in CapEx and OpEx for network operators, but more importantly they will open a field of innovations for new parties, e.g. to content providers who will be able to create their own CDN (Content Delivery Network) on demand.

Also, they promise to provide telecommunications operators with the ability to provide services in new domains, because of the multi-tenancy and flexibility opportunities that SDN and NFV offer. In this study, we will focus on the telecommunications sector, but also on several other sectors and areas that could benefit from SDN and NFV, e.g. the automotive sector, video-entertainment sector, and cyber security sector.

The expected increased flexibility actually originates from several technical characteristics of SDN and NFV networks, such as separation of network control and network-forwarding elements, virtualisation of hardware resources (storage and computing power), abstractions of the infrastructure, the ability to run multiple virtual functions on a single hardware platform, and the ability to run a single virtual function on multiple platforms. This enables, for instance, fine-grained resource sharing, faster roll-out of new features and services, more efficient use of (generic) hardware, improved multi-tenancy and user-driven service deployment and development through northbound APIs, reduced TCO, and increased revenues because of improved service provisioning and the potential to enter new markets.

The main tasks addressed in this project are the following five research objectives:

A. Identify the most likely deployment scenarios including associated timelines and possible migration paths from existing networking technologies
B. Identify current and new usage scenarios of SDN- and NFV-based networks, including trends and possible new services
C. Assess the impact of SDN and NFV on existing business models in the telecom sector, and identify their innovation potential in terms of possible new business models with current and new stakeholders
D. Assess the general market and industrial potential for SDN and NFV
E. Position SDN and NFV within the current and future telecommunications regulatory framework and in relation to growth opportunities

The study attended these objectives by the following:

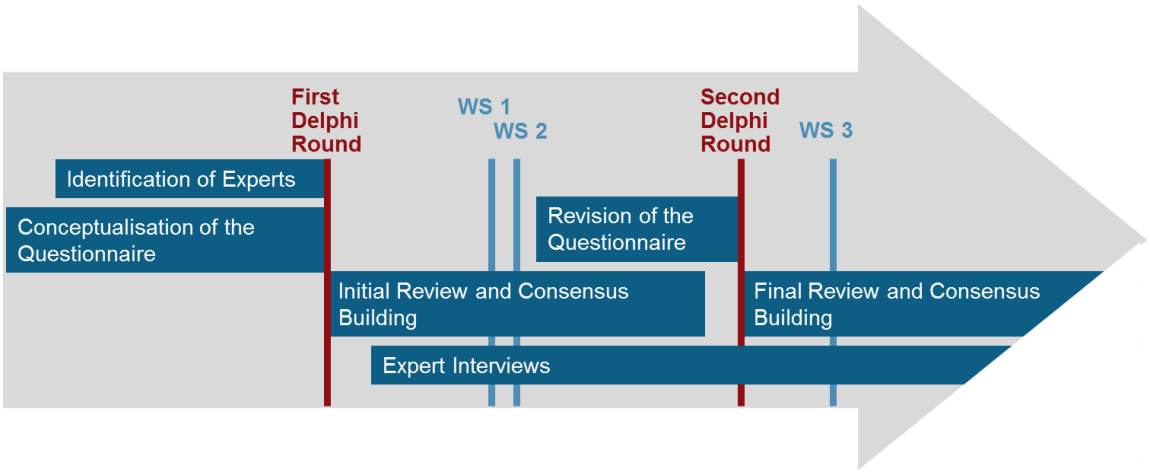
- Identify the most likely deployment scenarios including associated timelines and possible migration paths from existing networking technologies.
- Identify current and new usage scenarios of SDN- and NFV-based networks including trends and possible new services.

- Assess the impact of SDN and NFV on existing business models in the telecom sector, and identify their innovation potential in terms of possible new business models with current and new stakeholders.
- Assess the general market and industrial potential for SDN and NFV.
- Position SDN and NFV within the current and future telecommunications regulatory framework and in relation to growth opportunities.

3 Design of the Study

The Delphi method, including workshops and expert interviews, was selected to reach consensus between SDN and NFV experts in this still quite uncertain terrain. This study is based on two Delphi panel rounds using an online questionnaire, workshops to discuss the findings and enable discussions between the experts, and interviews for additional information. Figure 3-1 shows the process of the study.

Figure 3-1: Process of the study



Source: WIK-Consult

The remainder of this chapter first provides details on the Delphi questionnaire, then the workshops and the expert interviews conducted for this study.

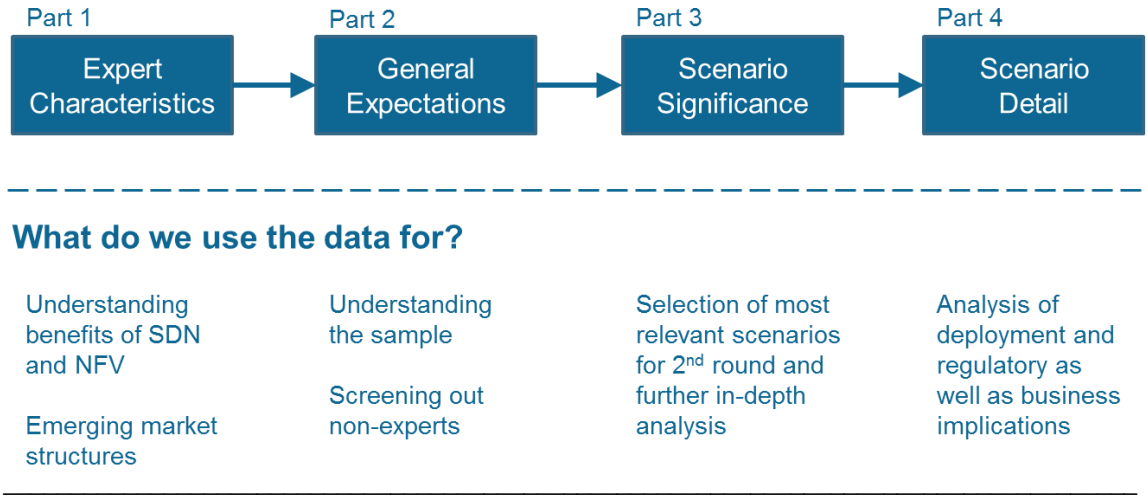
3.1 Delphi Questionnaire

The two questionnaires addressed the following five questions regarding SDN and NFV:

- impact on business models
- general market potential
- position within the regulatory framework
- most likely deployment scenarios
- most likely usage scenarios

To answer these main questions, the questionnaires consisted of two major sections. The first section included more general questions on SDN and NFV, and the second section concentrated on the deployment and usage scenarios with regards to their occurrence probability, outcomes, and impact. Figure 3-2 shows the structure of the first questionnaire.

Figure 3-2: Delphi Questionnaire Structure



Source: WIK-Consult

One of the main differences between the first and second questionnaires was the number of the usage scenarios tested. As the first Delphi round and workshops were used to identify the most likely deployment and usage scenarios, the mandatory part of the second questionnaire dealt only with the identified scenarios. The second questionnaire also contains a few additional questions, and some of the definitions and questions were rephrased for a better understanding.[1]

3.2 Workshops

As part of the Delphi method, three workshops gave the opportunity for discussion and consensus-building between the experts. The first two workshops dealt with the technological and regulatory aspects of SDN and NFV. The outcomes of the first Delphi round and presentations of experts built the base for lively discussions. The third workshop regarding the business impact of SDN and NFV took place after the second Delphi round discussed the new outcomes of the study and provided insights to the ongoing development of business cases as regards SDV and NFV.

In general, the speakers at the first workshop pointed out the importance of standardisation and open source. One speaker argued for the need to keep standardisation limited to just interfaces between OSI layers, and provide freedom to vendors to speed up design process by not specifying and standardising innards of network elements at each layer. Further, there was recognition of the need for a change in the way of thinking on how to build network services: with SDN and NFV, the principles from the software development world are entering the telecommunications

1 The questionnaire is presented in Annex 8.4.1.

domain. This will lead to another set of challenges, typical for software development-testing, and version control.

The most relevant outcome of the workshop on regulation is that it is impossible to regulate something that has no market yet. Instead of a too early regulation that might hinder the development of an SDN and NFV market, experts suggest to observe the progression closely and act as soon as there is a need for regulation – but not beforehand.

The most relevant outcome of the workshop on business impact was that it is very likely that the cost reduction that are usually reported publicly for SDN and NFV shrink when considered in the full set of the telecommunication operator cost model.

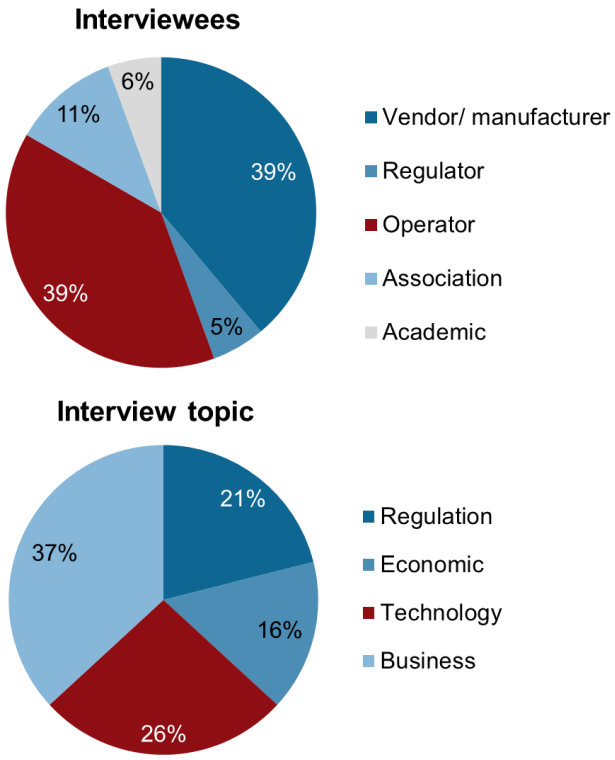
3.3 Interviews

The interviews conducted for this study provided detailed insights in already ongoing processes in the companies and authorities. Due to the open character of the semi-structured interviews, insights reached beyond the planned questions. Before each interview, questions were selected from a pre-prepared list and sent to the interviewee. This way all important questions could be prepared while also giving the interviewee room to add subjects important to them.

Along with a few general questions, the list of questions addressed the topics of business implications, policy implications, regulatory implications, and technology implications.[2] The selected experts and the topic of the interviews are shown in Figure 3-3. The upper part shows their main affiliation and the bottom part the main topic of the interview.

2 For the full list of questions please see Annex 8.5.

Figure 3-3: Selection of Experts for the Interviews



Source: WIK-Consult

4 Technological Potential of SDN and NFV

4.1 Selection of most relevant usage scenarios

To identify the three most relevant usage scenarios of SDN and NFV the initial set of usage scenarios was drawn from the following set of eight usage scenarios identified by ETSI:[3]

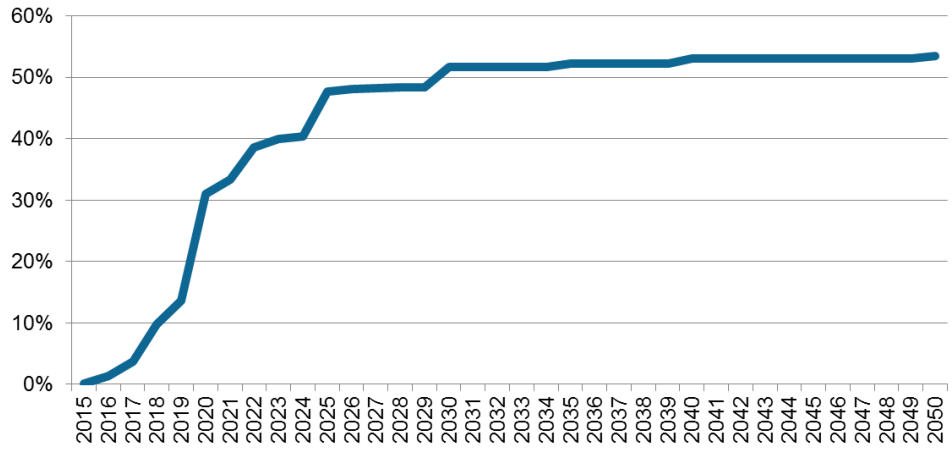
- **Network Function Virtualisation Infrastructure as a Service (NFVIaaS)**
  Virtualised infrastructure provided as a service:
  Use network infrastructure, don't own or maintain it.
- **Virtual network function as a service**
  Virtualised functions provided as a service:
  Build a network from available building blocks, wherever they are.
- **Virtual network platform as a service**
  Virtualised platform provided as a service:
  Run your services on a platform that you do not own.
- **Virtualisation of mobile core network**
  Flexible connectivity in the mobile core network:
  Elasticity of connectivity in the mobile network can bring savings.
- **Virtualisation of mobile base station**
  Base station on demand:
  Make and break base stations when and where needed.
- **Virtualisation of home environment**
  Virtualised home network as a service:
  Intelligence moves from home networks to the operator's domain.
- **Virtualisation of Content Delivery Networks (CDN)**
  Virtualised Content Delivery Network provided as a service:
  Content delivery network flexibility – created and moved on demand, when and where needed.
- **Virtualisation of fixed access network functions**
  Virtualised fixed access network provided as a service:
  Provision of fixed access to users with a few clicks – near-real-time.

In the questionnaire, we have asked respondents to give us their expectation of the year when at least 50% of the networks will be deployed for each given scenario (one of 8) and for each given type of network (home, SME business, Large enterprise network,

3 For a further description please see Annex 8.4.1 or ETSI Network Function Virtualisation (NFV) Use Cases, available online at:
http://www.etsi.org/deliver/etsi_gs/nfv/001_099/001/01.01.01_60/gs_nfv001v010101p.pdf

Data centre, access networks, and WAN). It is a slow migration path, with on average 3% penetration per year. Figure 4-1 shows over 50% of the experts think that by 2030 over 50% of the networks will be deployed with SDN and NFV.

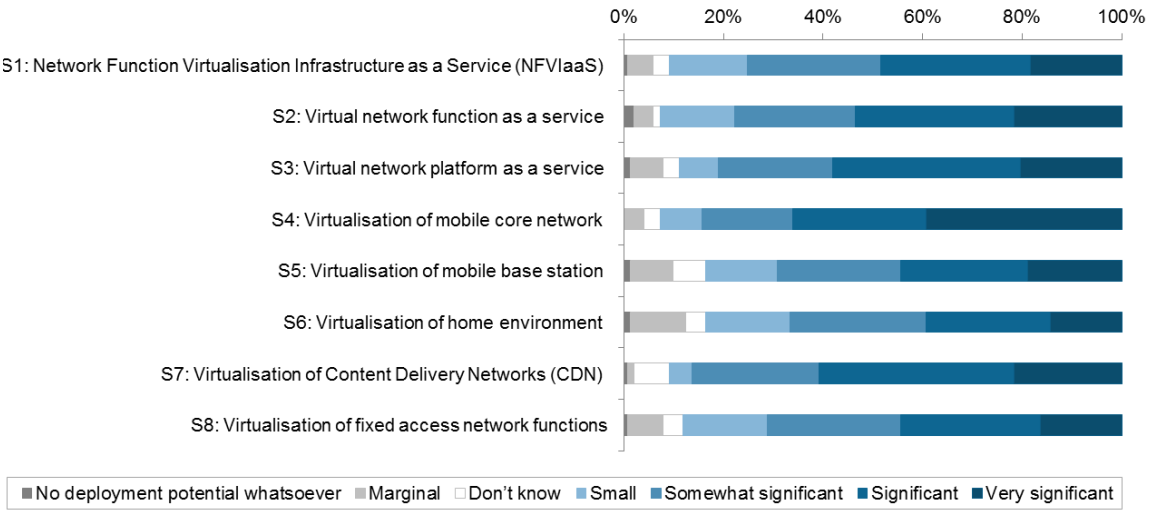
Figure 4-1: Average expectation of SDN/NFV deployment for all scenarios



Source: Delphi-Questionnaire

Out of these eight usage scenarios, the three usage scenarios with the highest significance according to the answers from the first Delphi questionnaire were selected. These three scenarios were analysed in great detail in the rest of the study. Figure 4-2 shows the experts' answers regarding the expected deployment likelihood and resulting market significance of all eight scenarios from the first questionnaire.

Figure 4-2: Significance of the eight usage scenarios



Source: Delphi-Questionnaire

The answers were weighted. Based on the expected significance and deployment likelihood, the following three usage scenarios were selected:

1. Virtualisation of Mobile Core Network
2. Virtualisation of Content Delivery Network
3. Virtual Network Platform as a Service (VNPaaS)

In the workshop on technological implications of SDN and NFV, experts mentioned that the most promising use cases in terms of success rate of service or function are hard to predict. The key point is that SDN and NFV have the potential to enable a whole new ecosystem, in which any software developers can enter and come up with their own services. This open innovation model is expected to be possible from a technical perspective, and would change the "commodity" market of network technology into a dynamic space for network innovation. The increase in the number of parties that can design and provide services will increase competition, which may lead to lower prices and improved quality of network services provided to businesses and consumers.

This conclusion from the workshop is addressed in the study by the VNPaaS usage scenario. This scenario focuses on a platform on which all kinds of services can be developed, rather than on a specific usage scenario.

A third response to the proposed scenarios was related to vertical network slicing. Although there is not yet a definition of network slicing on which experts agree, it was mentioned that multi-tenancy and network sharing are important aspects (e.g. in the development of 5G). The suggestion, however, was to merge the aspect of *vertical slicing* with the VNPaaS scenario, as a specific case of VNPaaS. This was introduced into this study as a sub-scenario of VNPaaS.

4.2 Technological Potential of Virtualisation of Content Delivery Network

Currently, most CDNs are not integrated into the operator's network, however CDN cache servers are usually placed as close as possible to the operator network. On a global scale, CDNs are distributed in nature in the sense that they have caches around the world. CDN caches are usually located in a data centre next to an Internet exchange or in a data centre directly connected to an operator core network. By basing CDNs on NFV, network operators may profit from higher flexibility in the network, which enables them to assign resources dynamically (e.g. instantiating CDN servers on demand). This ensures a match between the demand for content and the resources needed, and thus leads to efficient delivery.

The scenario *vCDN using MEC* describes the situation in which a CDN provider uses MEC components of a network operator to deploy its CDN network functions, e.g. content caches. The edge locations are in this way part of the NFV Infrastructure.

Pushing CDNs towards the operator edge can have advantages in terms of achieving lower latencies for content delivery services and offloading core networks. Also, MEC can be used to offload end-user devices from computing-intensive and storage-intensive tasks to save battery power and memory. It should be noted that although MEC has the term "mobile" in it, it is likely that MEC will become part of 5G and that in this architecture edge computing in fixed access networks will also be included.

It should be noted that CDN edge servers mainly require storage functionality and not so much computing power. Since MEC strongly focuses on computation-intensive applications, the use cases for MEC are much more diverse than only CDN. The use cases for MEC can be categorised[4] into three groups:

- Consumer-oriented services, e.g. gaming, remote desktop applications, augmented and assisted reality.
- Operator and third-party services, e.g. active device location tracking, big data, security, safety and enterprise services.
- Network performance and QoE improvements, e.g. content caching, performance optimisation, and video optimisation.

4.2.1 High-level functional decomposition

For the high-level functional decomposition of CDN, we will take the CDN provider Akamai, who published a technical paper[5] on its CDN platform, as an example. Based on this, we describe the following high-level functional components for a CDN:

- The *origin*, which hosts the original content
- The *edge servers*, on which the original content is replicated based on several parameters, such as user interest and the round trip time between user and server
- A *transport system* is responsible for the correct and efficient download of content to the edge servers
- *Redirection,*[6] which directs the user's service request to the most optimal edge server
- *Management and monitoring systems* to for example assess the characteristics of connections between origin and edge servers, status of edge servers, and possibly management functions towards a user

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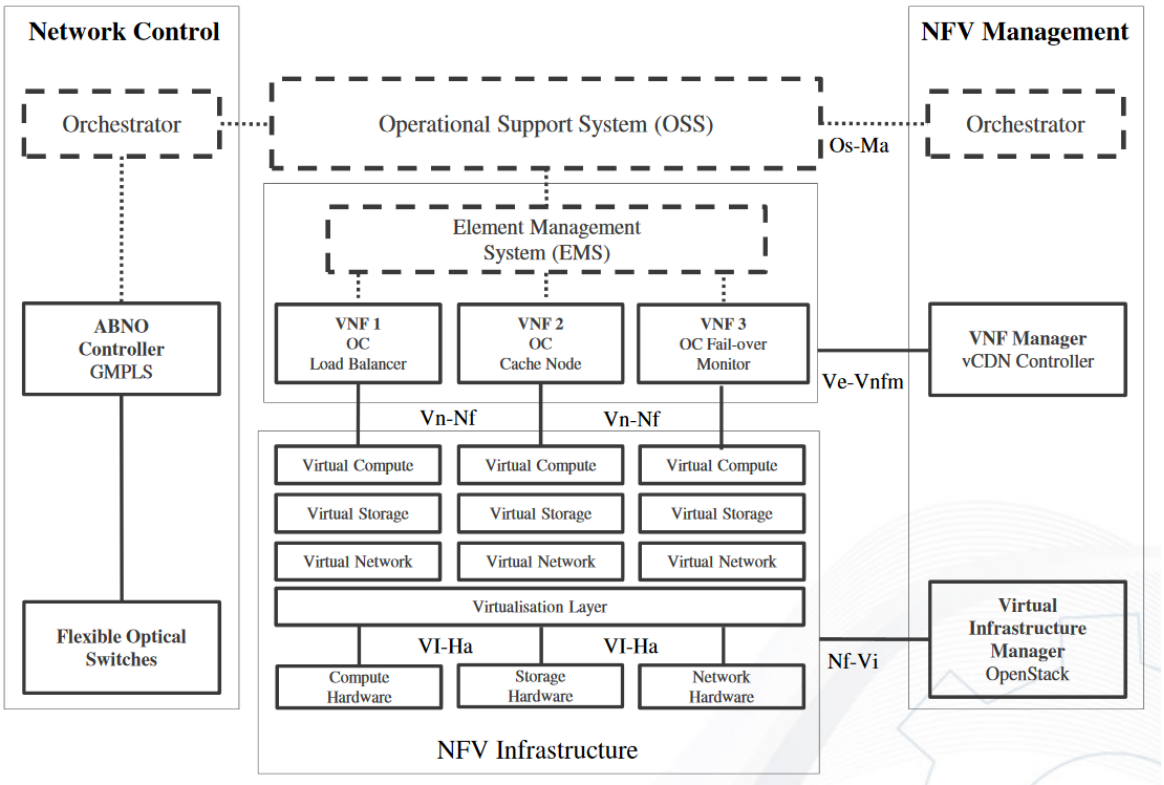
4 ETSI GS MEC 002 – Mobile Edge Computing (MEC); Technical Requirements, V1.1.1, March 2016.

5 Nygran, E.; Sitaraman, R.K. and Sun, J.(2010): The Akamai Network: A Platform for High-Performance Internet Applications. Available online: https://www.akamai.com/us/en/multimedia/documents/technical-publication/the-akamai-network-a-platform-for-high-performance-internet-applications-technical-publication.pdf

6 Akamai uses the term *mapping system.*

When looking into virtualised CDN, the abovementioned functionality is run on top of an NFV infrastructure. Figure 4-3 shows the architecture of a vCDN in relation to the ETSI NFV reference architecture. Note that the vCDN software resides mainly on the VNF-layer of the architecture.

Figure 4-3: OpenCache vCDN approach mapped on the ETSI NFV reference architecture[7]



Source: Lancaster University

The concept of MEC is being studied in an ETSI Industrial Study Group.[8] MEC basically provides cloud-computing functionality at the edge of the operator network. Application and content providers can use this functionality in their services. Data caching is just one of the services that can be made possible with MEC. From a technical perspective, the reference architecture[9] for MEC describes the following main components:

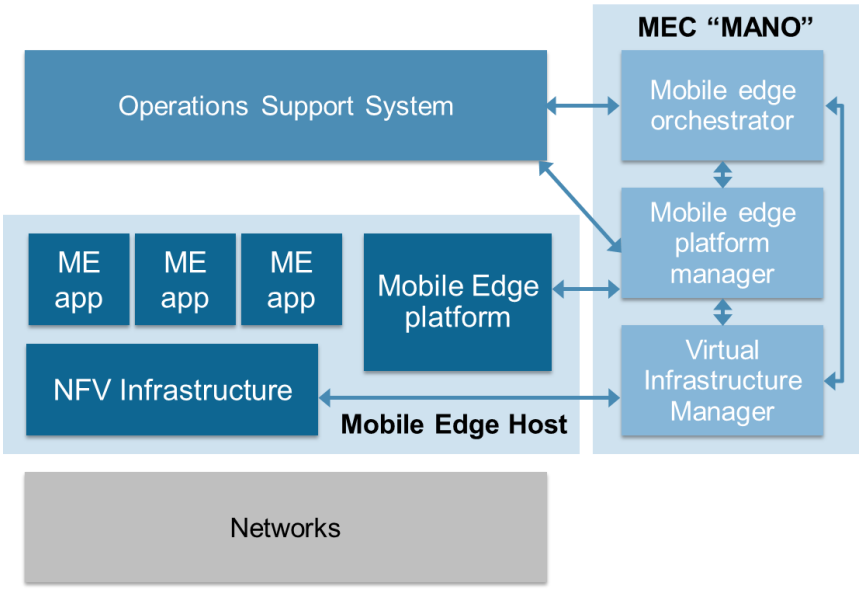
7 King, D.; Broadbent, M. and Hutchison, D. (2015): Evolution of OpenCache: an OpenSource Virtual Content Delivery Network (vCDN) Platform, Lancaster University. Available online: http://cwbackoffice.co.uk/Presentation/VirtualNetworkSIG_07.05.15_DanielKing_Lancaster.pdf

8 ETSI ISG MEC, http://www.etsi.org/technologies-clusters/technologies/mobile-edge-computing

9 ETSI GS MEC 003, Mobile Edge Computing (MEC);Framework and Reference Architecture, V1.1.1, March 2016.

- Mobile edge host
- Mobile edge management and orchestration (Mobile Edge MANO)[10]

Figure 4-4: Simplified version of ETSI MEC's mobile edge system reference architecture, showing the management interfaces between components

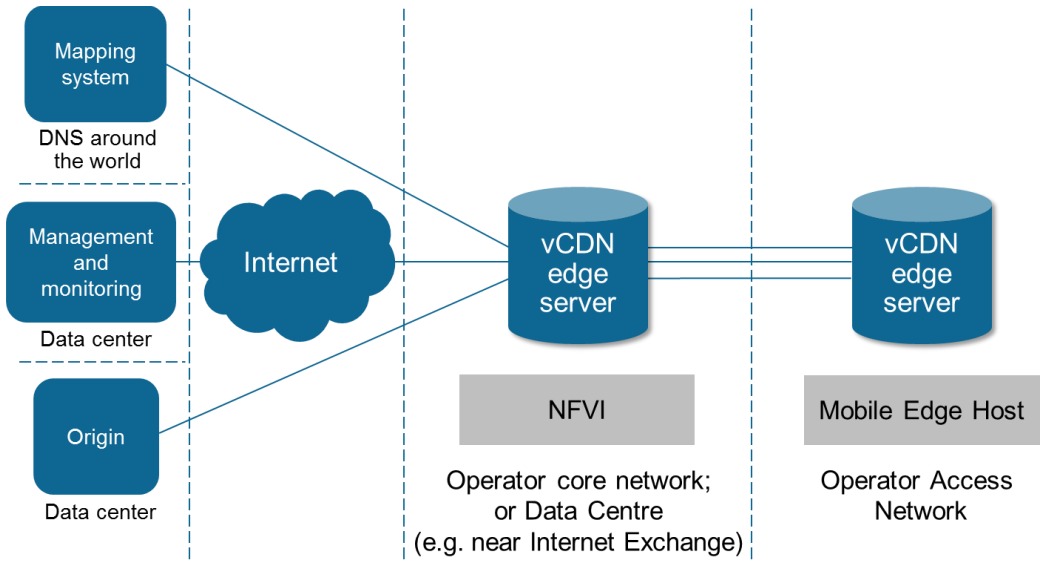


Source: TNO

Figure 4-4: Simplified version of ETSI MEC's mobile edge system reference architecture, showing the management interfaces between components shows a simplified version of the mobile edge system reference architecture. The mobile edge host is a hardware box with a virtualised infrastructure component on which mobile edge (ME) applications can be run. A mobile edge platform on the host provides all the functionality that is needed to make this possible. The mobile edge host is managed by 3 components: a Virtual Infrastructure Manager (VIM) to manage the NFVI, a mobile edge platform manager, and a mobile edge orchestrator, which has the overview of the whole edge platform and selects the appropriate mobile edge host(s) for application instantiation. In case a vCDN makes use of MEC, a significant part of the CDN edge servers are run on Mobile Edge Hosts as shown in Figure 4-5. Also note that (parts of) the redirection system may also run on NVI components and even partly on mobile edge hosts, e.g. in case of DNS.

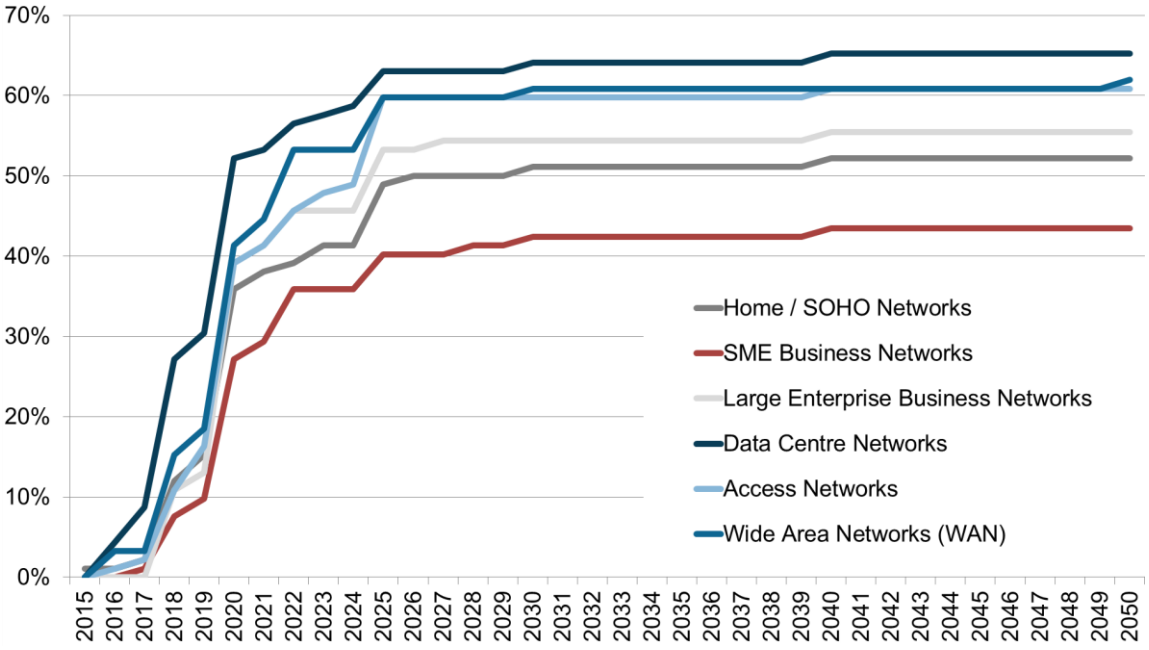
10 The term "MANO" is not used in the ETSI MEC documentation, but is introduced here to indicate the similarity between several components of the ETSI MEC reference architecture and the ETSI NFV reference architecture, which does use the term "MANO" to refer to management and orchestration functions. ETSI MEC explicitly targets to reuse as much ETSI NFV functionality as possible to ensure interworking between MEC and NFV systems (ETSI GS MEC 002).

Figure 4-5: vCDN using NFVI and Mobile Edge Hosts



Source: TNO

Figure 4-6: Deployment of Virtual Content Delivery Network



Source: Delphi-Questionnaire

In this figure, we see some elements' need for CDN come to light – Data centre, WAN, and Access network. These results are again not surprising when looking at the networks that an OTT needs in order to provide their service.

4.2.2 Share of SDN and NFV technology in the scenario

In terms of NFV, vCDN uses the NFV Infrastructure to run the components of the vCDN, most notably the CDN edge servers,[11] but possibly also the other components. In contemporary CDNs the content is already dynamically cached on the edge servers, and the locations of those edge servers are known a priori. vCDN adds the capability of instantiating and moving CDN edge servers using NFV orchestration technology. The question is, how beneficial this actually is when compared to the current way CDNs are managed. A good example for comparison is Netflix's OpenConnect,[12] which is a programme in which ISPs can partner with Netflix by introducing so-called Open Connect Appliances (OCA) in their network, which Netflix then uses for content caching. OpenConnect includes failover functionality between OCAs in the operator's network. The main driver for using OpenConnect is that when having a CDN cache in the operator network, the costs for transit and peering can be greatly reduced: instead of every single user session to the CDN cache going via a transit of peering connection via e.g. an Internet Exchange, these sessions can go directly to a CDN cache in the network of the operator, saving peering and transit costs. What NFV adds here is that it offers the network operator a means to instantiate such OCAs wherever it is needed, optimising the use of its network and the services running on top of it. The Netflix's OCAs would, in an NFV scenario, be run as a Virtual Network Function (VNF) in the operator network.

The usage scenario of vCDN using MEC offers the use of mobile edge hosts in the operator's access network on which CDN edge servers can be instantiated, which means that content can be cached close to the user, allowing for lower latency applications and traffic-offload from the core network, especially for e.g. interactive video services, for which multicast is no viable alternative. For edge nodes, instantiation of this vCDN edge server on the most appropriate mobile edge host might be a valuable feature for CDN.

Concerning the relation between MEC and NFV, both architectures show comparable entities. A mobile edge host is part of the NFV Infrastructure (NFVI), that this NFVI is managed by a Virtual Infrastructure Manager (VIM) and that there is also an orchestrator for the mobile edge. This mobile edge orchestrator will have to coordinate

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11 Note that in CDN edge server, the word "edge" typically refers to the edge of the global Internet (so close to operator core, but not necessarily inside the operator network), while in a Mobile Edge Server, the word "edge" refers to a location in the operator's access network close to the eNB that serves the end-user.

12 https://openconnect.netflix.com/en/

with the generic NFV orchestrator of the operator to support this vCDN with MEC (or any other MEC) usage scenario. Another similarity is the fact that mobile edge applications, just as VNFs, are run on the NFVI using Virtual Machines. ETSI MEC explicitly mentions in its technical requirements[13] that ETSI NFV components should be reused as much as possible.

With respect to SDN in this usage scenario, the mobile edge host will need some forwarding functionality to make it possible that traffic can flow through the correct mobile edge applications and can be forwarded to the next external node if needed. This is essentially Service Function Chaining. As such, a mobile edge host may need to act as a SDN switch as well.

Another role of SDN in this usage scenario could be the networks underlying the CDN transport system. These are the networks on the Internet (transit providers, default-free zone (DFZ)) that are used to transport content from the CDN origin towards its edge servers over the world. The most efficient way in terms of traffic volume, and with that minimising transit costs, is to multicast traffic towards the CDN edge servers. This is an approach that CDN providers use for proactive provisioning of their caches. In practice, however, many ISPs and transit providers do not support multicast on the core of the Internet[14, 15] and therefore this is not possible in all situations. SDN could pose a solution by being able to realise multicast data streams,[16] without having to use a multicast routing protocol. This, however, does require negotiation/management between SDN controllers over these different domains to cooperate to ensure a reliable end-to-end multicast SDN data flow.

4.2.3 Involved stakeholders

In vCDN the following main stakeholder groups can be identified:

- The vCDN service provider
- The operator offering NFVI, mobile edge servers, and possibly other components or semi-finished products to the CDN service provider
- Transit providers between CDN origin and edge servers
- The consumer who uses the service to obtain content

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13 ETSI GS MEC 002.

14 http://www.streamingmedia.com/Articles/Editorial/Featured-Articles/The-Return-of-Multicast-Why-it-Succeeds-in-a-Live-Linear-World-108621.aspx

15 Diot, C.; Levine, B. N.; Lyles, B.; Kassem, H. and Bakensiefen, D. (2000): Deployment Issues for the IP Multicast Service and Architecture, IEEE Network, p.78-88. Available online: http://inst.eecs.berkeley.edu/~ee290t/sp04/lectures/rdr_paper40.pdf

16 Plattner, B.: SDN-assisted IP Multicast. Available online: http://www.tik.ee.ethz.ch/file/8aebff90b4a9d80c35568af84b0b3565/SDN-assisted

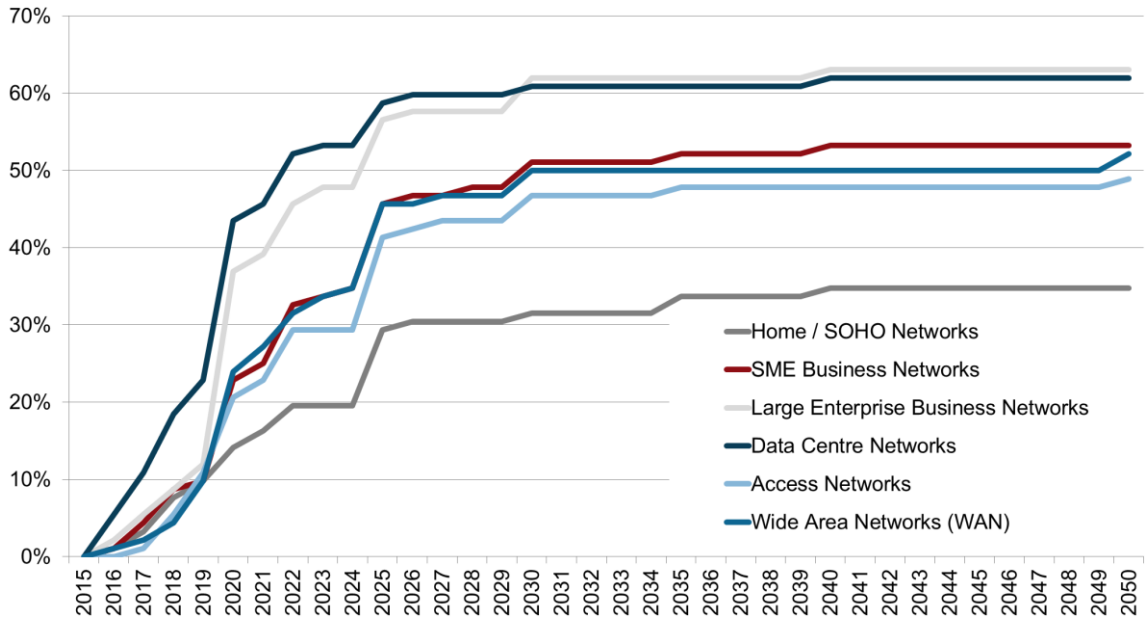
From the SDN and NFV perspective the interfaces are similar to the ones described in VNPaaS. Here we describe interfacing with the stakeholder that is specific to this usage scenario, namely the CDN provider. When using Netflix's OCA as an example, two interfaces can be defined. One is the interface between the OCA and the operator NFV network. In this case the OCA can be viewed as a Virtual Network Function (VNF) running on the NFV Infrastructure of the network operator, as was shown in Figure 4-3. The other interface deals with service requirements (e.g. performance and security) that the NFV orchestrator of the operator should take into account when orchestrating and managing the vCDN service and the VNFs. This is probably an interface between the CDN provider's management and orchestration functions and the network operator's management and orchestration functions. Such an interface doesn't currently exist. It could be a service-specific interface or some standardised northbound interface that is suitable for multiple applications.

One other notion that is relevant when discussing stakeholders is how to operate a CDN that covers multiple administrative domains. A solution called CDN Interconnection is standardised for interfacing between CDN components hosted in different domains, e.g. a CDN provider and a telecommunications operator. In a SDN/NFV world, these CDN Interconnection interfaces may not be necessary anymore, given that operators and CDN providers obey the SDN/NFV architecture (Figure 4-3), and use standardised interfaces on the NFV-level. In this way no interfacing on the CDN service level would be necessary anymore.

4.3 Technological Potential of Virtual Network Platform as a Service

Virtual Network Platform as a Service (VNPaaS) is a service that can be offered to companies that want to keep full control over their network services, that in some cases might even prefer to develop their own services, but that don't want to manage the underlying infrastructure and bring their own full range of software components. Using VNPaaS, a company can focus on running their services – now on a virtual network platform that includes infrastructure, software components, and may include management functionality. By running services on a platform, which is maintained and managed by a third party (the VNPaaS service provider), the company may realise cost savings and doesn't need extensive expertise to run its own network services. The platform can be used by multiple third parties simultaneously, and therefore this scenario includes multi-tenancy and network-sharing aspects.

Figure 4-7: Deployment of Virtual Network Platform as a Service



Source: Delphi-Questionnaire

This figure shows the split of expectations of deployment of VNPaaS in particular networks. As expected home/SOHO deployment scores low, as it is not likely that home/SOHO will have enough processing power or the connectivity needed to run VNPaaS. Expectation is not zero, but it is significantly delayed and shifted to the future, meaning a rise in processing and communication capabilities.

For VNPaaS, it is clear that experts await it to be deployed firstly and most likely in data centre networks, closely followed by large enterprise networks, WAN, and access networks. This is not surprising, as it will provide flexibility to businesses (with their own or outsourced IT departments managing their network). Moreover, VNP will likely run on data centre networks, explaining their high ranking.

The applications that are possible using VNPaaS are virtually unlimited. Depending on the VNFs that the platform supports, and because of the possibility to create new ones by a third party, theoretically any network service could be built, ranging from just one network function (e.g. a firewall) to services consisting of a larger number of network functions (e.g. an IMS).

Looking more towards the future, this scenario could also cover the multi-tenancy aspects required for 5G. However, it is still uncertain how network sharing and/or slicing is implemented and what it precisely covers: it could be for example multi-tenant VNPaaS, it could be multi-tenant NFVIaaS, a combination of those, or even partly physical infrastructure multi-tenancy.

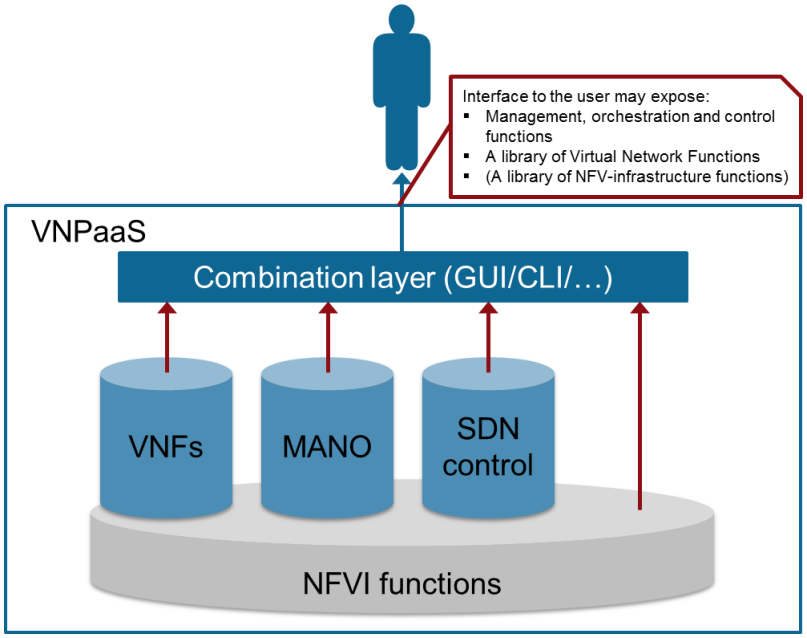
Although VNPaaS has a lot of similarities with PaaS, there is a big difference, being that the concept of VNPaaS includes telecommunication and Internet networks, both in the core and access and both fixed and mobile, whereas PaaS is a cloud or data centre service.

4.3.1 High-level functional decomposition

Companies can use VNPaaS to create their own virtual network services. This means that VNPaaS should contain all components necessary to create such a service. Here, we present two perspectives to look at the functional decomposition of this scenario: the API-perspective and the virtual network instantiation perspective.

Figure 4-8 shows a possible functional decomposition of VNPaaS from the API-perspective, showing that through VNPaaS different kinds of functions will be exposed to user. These functions can be used by the users to build their network service. A library of virtual network functions will be available from which the users can pick the VNFs, or combinations of VNFs, they want to include in their service. Besides that, there may already be preconfigured network services available. Also management, orchestration and control functions could be exposed to the users. A "combination" layer has been introduced in the figure which takes care of how all these functions are presented to the users. Note that virtual infrastructure functions could also be exposed to the users, who could use these functions e.g. to build their own VNF. Note however, that for VNPaaS we assume that if users use NFVI functions, they do so in conjunction with any of the other VNF, MANO, or SDN control functions. Otherwise, if the NFVI-interfaces would be used without using any other functions of the platform, it would essentially be an NFVIaaS scenario.

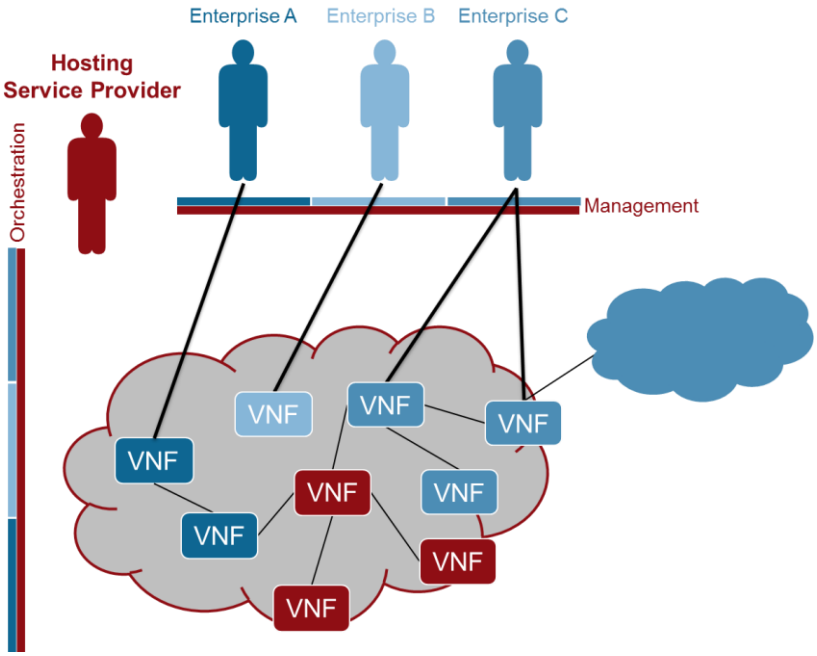
Figure 4-8: VNPaaS components from the API-perspective



Source: TNO

Figure 4-9 shows VNPaaS from the virtual network service instantiation perspective (meaning: what does the network service look like after configuration when it is running). After network service instantiation, the network services are actually run on top of the shared infrastructure. The management and orchestration of the platform is done by the VNPaaS provider (the "hosting service provider"), while each tenant (enterprises A, B, and operator A) is able to operate management and orchestration of their own network service as well. Note that VNPaaS can be used in combination with VNPaaS from other providers or in combination with a company's own infrastructure, as is shown in the figure for Operator A.

Figure 4-9: Third parties sharing the service provider's infrastructure via VNPaaS



Source: ETSI[17]

4.3.2 Share of SDN and NFV technology in the scenario

This is a full NFV usage scenario, depending almost fully on NFV technology. While this usage scenario was written from a NFV perspective, SDN control functions could be offered as part of VNPaaS in a similar way as NFV functionality. Additionally, SDN technology may be underlying the orchestration and configuration functions of the virtual network platform service.

4.3.3 Involved stakeholders

- NFVI provider – data centre owners, switching equipment owners, cable (physical connectivity) owners
- The vMCN provider – packages needed functionality and provides vMCN to different parties
- The vMCN software vendor – vendors of mobile core network functions (either elements of it or integrated solutions)
- Users of vMCN

17 ETSI (2013): Network Functions Virtualization (NFV); Use cases. ETSI GS NFV 001 v1.1.1. Available online: http://www.etsi.org/deliver/etsi_gs/NFV/001_099/001/01.01.01_60/gs_NFV001v010101p.pdf

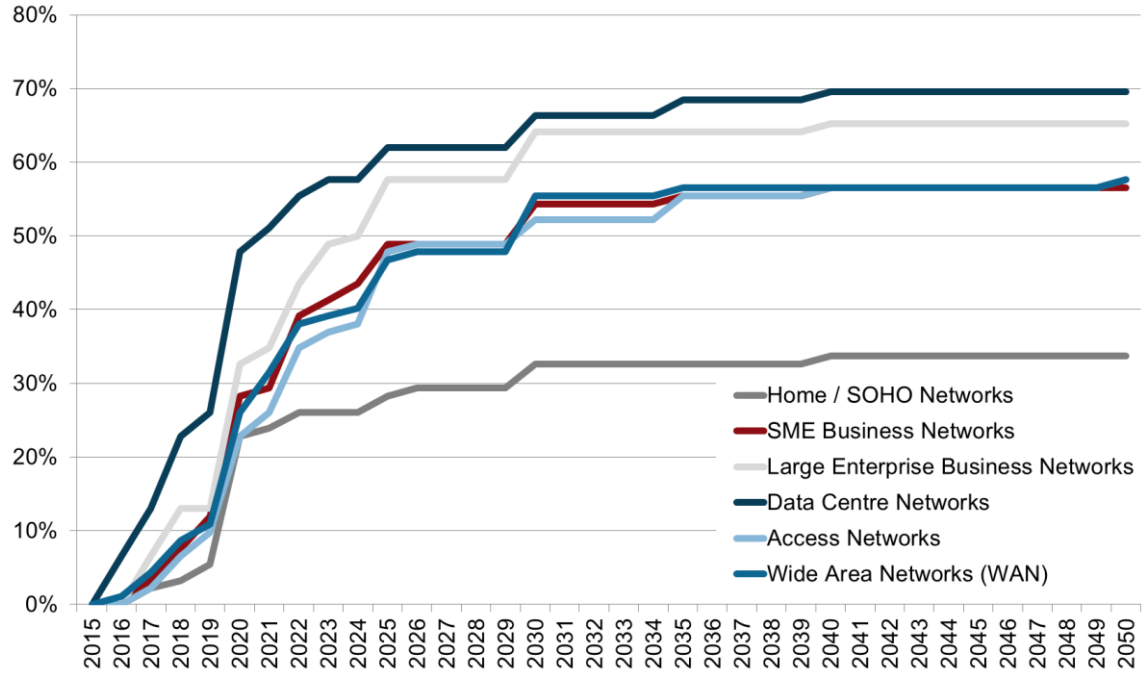
4.4 Technological Potential of Virtualisation of Mobile Core Network

The mobile core network is one of the elements of the overall mobile network that has the purpose of providing connectivity and services to wirelessly connected (mobile) users. The types of devices that end users have vary, with smartphones being most widely used. Other types of mobile end-user devices are laptops and tablets. Besides these, there are other devices (machine-to-machine devices, and soon Internet of Things devices) that are collecting and receiving data, and which are used for remote control or monitoring purposes.

Due to the mobility of end users, traffic streams coming to and going through a mobile core network are also changing. In the core network, the operator has the choice to either dimension the network links it needs in its core and access networks based on the maximum capacity demand by base stations, or to dimension the network links using statistical approaches based on (realistic) capacity forecasts.

A virtualised Mobile Core Network (vMCN) runs on a virtual network infrastructure (NFVI) instance for more efficient use of resources, scalability, resilience against network element failures, and cost. By consolidating multiple network functions on a single platform built using commodity hardware, vMCN solutions can operate more efficiently, and operators are able to deploy new software versions and add new functionality quickly and in a uniform manner. Also, many different vMCN, each for different customers, each with different configurations and feature sets, might coexist on the same platform.

Figure 4-10: Deployment of virtualisation of mobile core network



Source: Delphi-Questionnaire

Figure 4-10 shows a split of opinions regarding the expectations of deployment of virtualisation of the core network in particular networks. As expected home/SOHO deployment scores low, due to limited impact of mobile core network on it. Only when a home network is used as a part of the mobile core network is there an impact, e.g. mobile edge computing or femtocells at end users.

For this scenario it is clear that the major expectation is that it will be deployed firstly and predominantly in data centre networks, closely followed by large enterprise networks, WAN, and access networks. This is not surprising, as it will provide flexibility to operators and businesses (with their own or outsourced IT departments managing their network).

Typical applications for vMCN include cases that 3GPP, 5G-PPP[18],[19] and NGMN[20] have defined:

18 European Commission (2016): 5G empowering vertical industries, Brochure. Available online: https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

19 Bedo, J-S.; Barani, B. and Kemos, A. (2015): Making 5G a real booster for vertical markets – How to build 5 G as a flexible platform towards the digitalization of vertical markets, 5G for vertical industries – 6th Usage Areas Workshop at EUCNC 2015, Paris, 01.07.2015. Available online: https://5g-ppp.eu/wp-content/uploads/2015/12/5GandVerticalSectorsEUCNCpaper.pdf

- Support for verticals – providing MCN as a service to different MVNOs, and enable them to create slices for machine-type communication (MTC) and the IoT for vertical industries (e.g. health, automotive, home, energy)
- Integration of non-3GPP communication technologies
- Quick creation of networks for congested areas - disaster relief, events

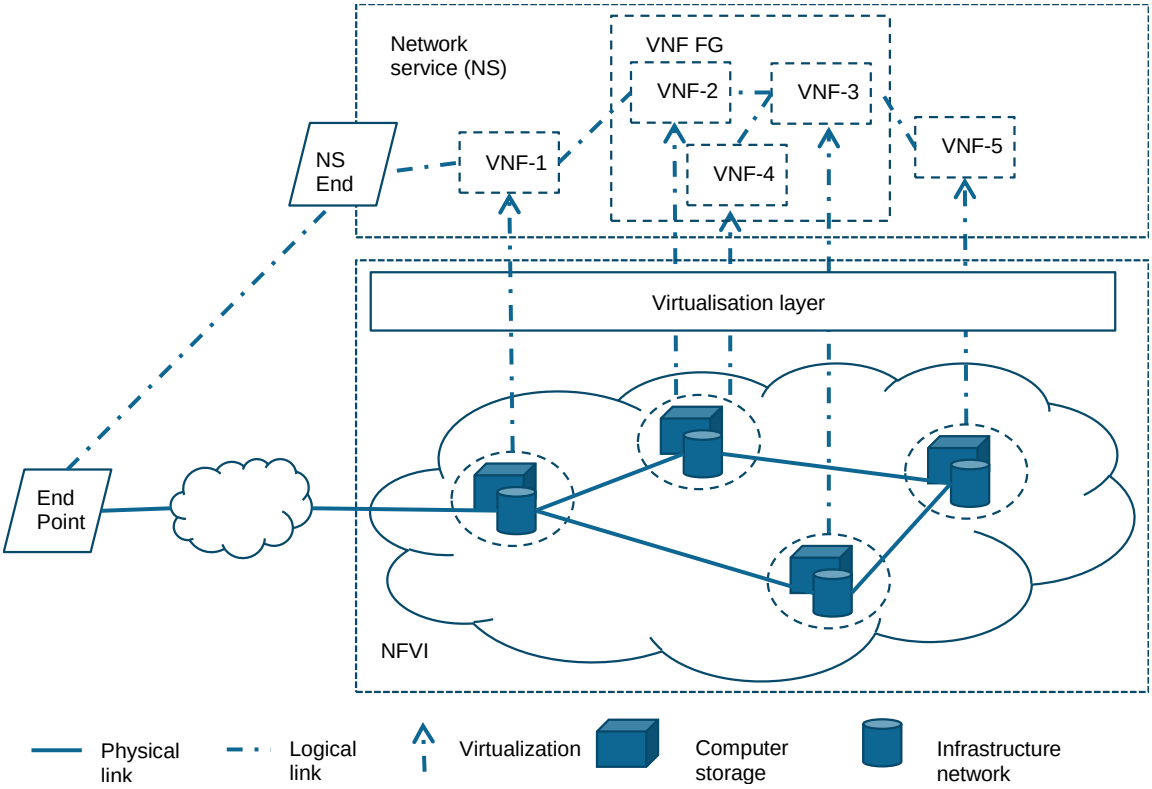
4.4.1 High-level functional decomposition

Virtual mobile core network is based on the NFV infrastructure on which the vMCN operators are running their own networks. That infrastructure consists of the following:

- Controllable switching elements in the network – SDN switches and SDN controller(s)
- Fixed (legacy) switching elements in the network – routers, gateways
- Dedicated network elements – PGW (packet Data Gateway), SGSN
- Data centres – where VMs are located, on which VNFs are running
- VNFs
- NFVI management system
- (Overall) management functionality integrating SDN and NFV elements of the network into one integral vMCN
- Orchestration functionality for resource efficiency, resilience against failovers, etc.

20 NGMN Alliance (2015): NGMN 5G Initiative White Paper. Available online: https://www.ngmn.org/5g-white-paper.html

Figure 4-11: Providing end-to-end service on top of NFVI



Source: TNO

ETSI NFV defined mechanisms that link virtual network interfaces[21] of any VNF instances by means of virtual links as shown in Figure 4-11. Such links are defined along with the VNF template at the time of VNF instantiation. This results in connecting VNF instances monolithically using what the virtual interface is described in the template, limiting versatility for packet forwarding. Combined with SDN, however, forwarding rules among VNF instances can be dynamically modified after a network function instantiation. This is also defined by ETSI NFV as MANO (Management and Network Orchestration).[22] Moreover, SDN provides many more packet-forwarding rules among network functions not limited by predefined virtual network interface on a virtual network function.

21 ETSI (2014): Network Functions Virtualization (NFV); Terminology for Main Concepts in NFV. ETSI GS NFV 003 v1.2.1., Section 6.1. Available online: www.etsi.org/deliver/etsi_gs/NFV/001_099/003/01.02.01_60/gs_nfv003v010201p.pdf

22 ETSI (2013): Network Functions Virtualization (NFV); Architectural Framework. ETSI GS NFV 002 v1.1.1, Section 5.2. Available online: www.etsi.org/deliver/etsi_gs/nfv/001_099/002/01.01.01_60/gs_nfv002v010101p.pdf

4.4.2 Share of SDN and NFV technology in the scenario

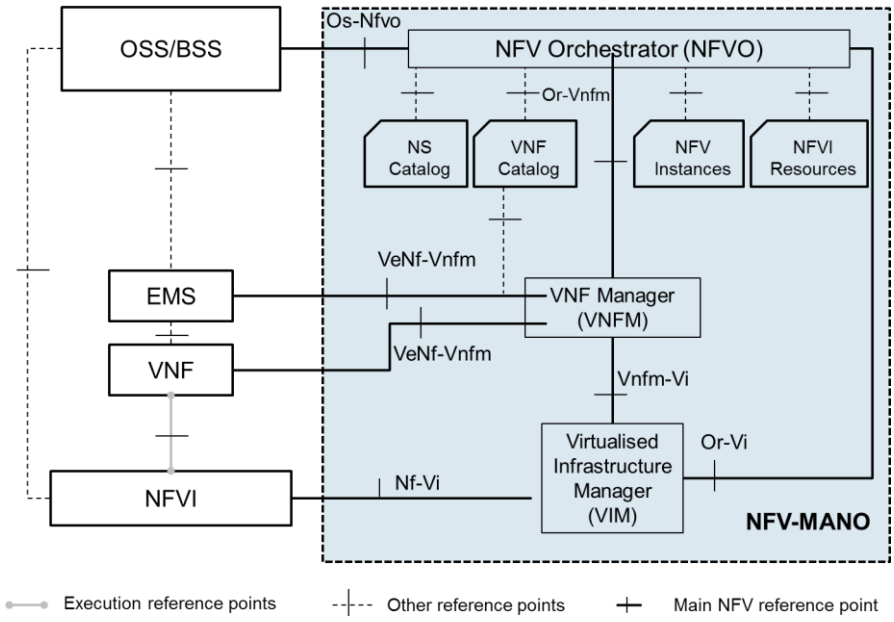
SDN and NFV are essential in this scenario. In vMCN, flexibility is provided by using SDN for steering traffic within the network, while the functionality of the mobile core network elements is located in data centres. Another element of flexibility is enabled by NFV and it originates from placing VNFs into data centres, and linking them into Service Function Chains (SFC) for fulfilling a network service.

4.4.3 Involved stakeholders

- NFVI provider – data centre owners, switching equipment owners, cable (physical connectivity) owners
- The vMCN provider – packages needed functionality and provides vMCN to different parties
- The vMCN software vendor – vendors of mobile core network functions (either elements of it or integrated solutions)
- Users of vMCN

Interfaces can be seen at ETSI NFV Infrastructure overview (document GS NFV-INF 005).

Figure 4-12: NFV management and orchestration architecture[23]



Source: IETF

23 (fair use only) Ersue, M. (2013): ETSI NFV Management and Orchestration – An Overview, IETF 88, Vancouver, Canada. Available online: https://www.ietf.org/proceedings/88/slides/slides-88-opsawg-6.pdf

ETSI NFV interfaces

ETSI NFV has defined in its reference infrastructure a number of interfaces to be used:

- Nf-Vi: between NFVI infrastructure provider and vMCN provider
- VeNf-Vnfm: vMCN software vendor and vMCN vendor if vMCN software vendor does not provide packaging
- VeNf-Vnfm and Os-Nfvo: vMCN software vendor and vMCN vendor

3GPP interfaces

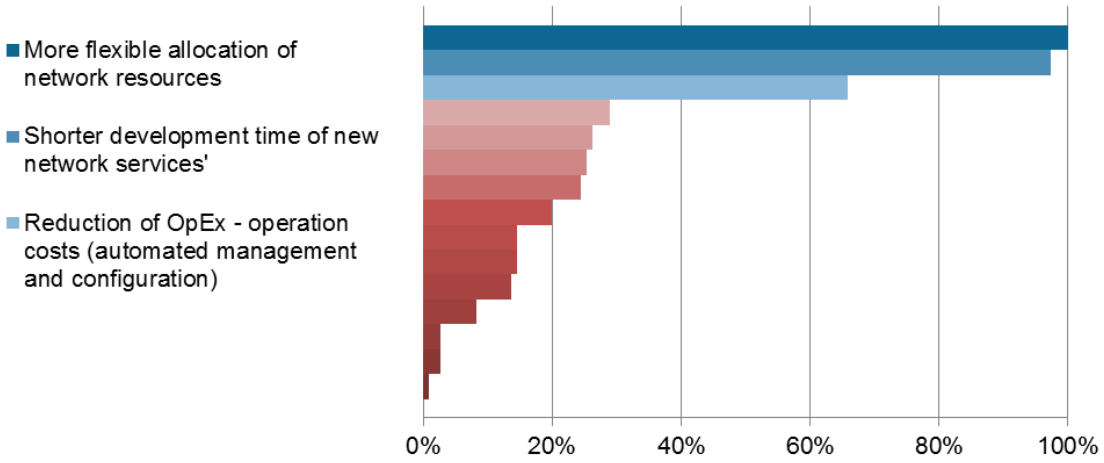
Currently, 3GPP is not dealing with these interfaces yet. Technology wise, 3GPP SA5 is working on NFV relation solutions, which are expected to be used as enabling technology for SA2 architecture group.

5 Business Potential of SDN and NFV in the Telecommunications Landscape

SDN and NFV are expected to have an impact on the telecommunication value chain, costs in general, and to enable revenue opportunities. Independent of specific use cases, it can be said that thanks to the flexibility gained and the ability to move from dedicated and proprietary hardware on to common and standard based equipment, SDN and NFV can reduce costs. The dynamic allocation of network resources can bring down CapEx.

As regards the question what the top 3 benefits of SDN and NFV in general are, the experts agreed on the following in the second Delphi round. Figure 5-1 shows the weighted ranking of the top 3 benefits relative to the highest ranked benefit (which was assigned 100%).

Figure 5-1: Top 3 Benefits of SDN and NFV in general

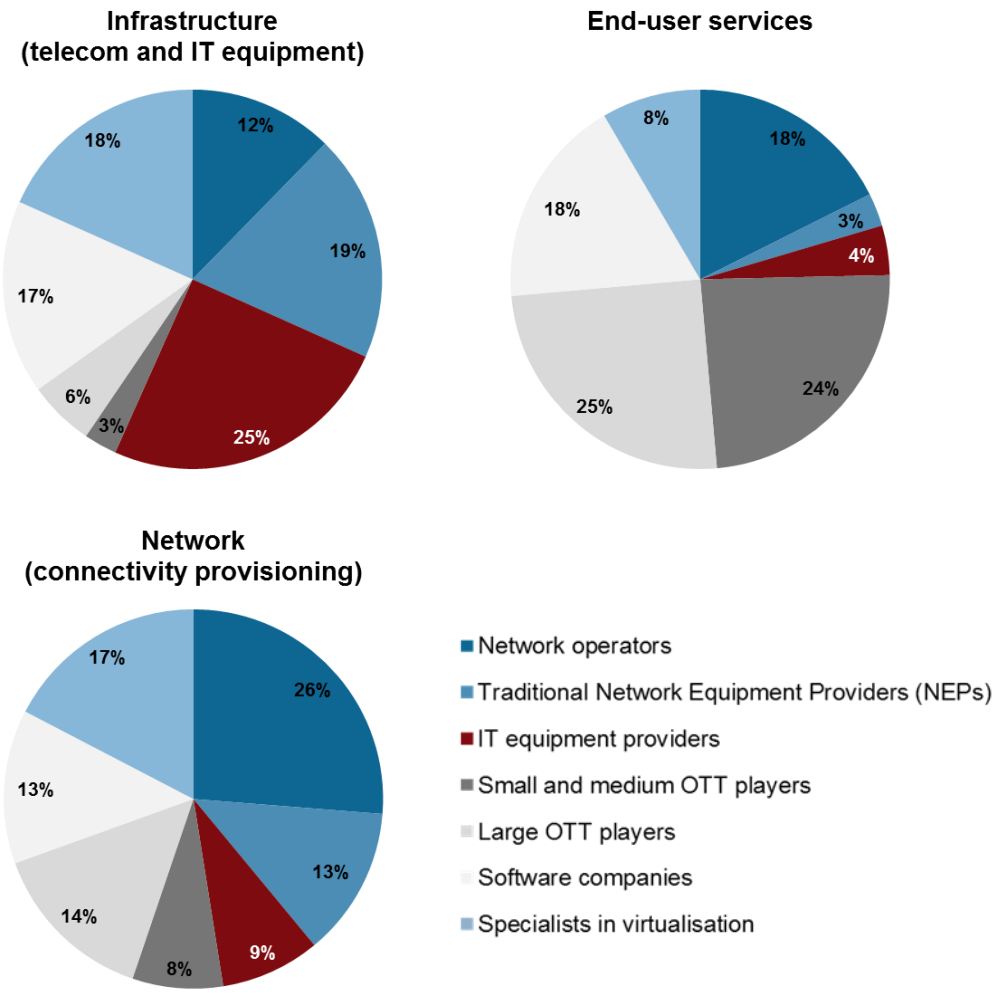


Source: Delphi-Questionnaire

SDN and NFV do not only bring cost reduction. Investments are also required to purchase standard industry equipment such as servers and licensed software.

In general, SDN and NFV with a software-based approach lower hurdles to market entry. This impacts the telecommunication value chain by new market entrants. Depending on the market the experts from the Delphi Panel assume IT equipment providers, network operators, or OTT players to gain the highest share of the considered market through SDN and NFV in the long term. Figure 5-2 shows the expected share of the players in the 3 considered markets: Infrastructure, End-user services, and Network.

Figure 5-2: Significant market share in the long term



Source: Delphi-Questionnaire

5.1 Business Potential of Virtualisation of Content Delivery Network

The CDN market developed numerous years before the introduction of SDN/NFV. It is already a market of around 4 billion EUR,[24] growing close to 25% per year.

Historically, CDNs have been primarily used for video traffic and transmitting large files for cloud-computing solutions, as this type of content is the simplest to distribute from a technical standpoint, and does not require low latency. Over the long term, we expect to see non-video content account for a growing percentage of the CDN market.

24 Only sales to third parties are taken into account (internal CDN is not valued); includes connectivity and third-party services.

Key players in the CDN industry include pure CDN players like Akamai or Limelight and large OTT players developing their own internal CDN (Google, Amazon, Netflix), some of them opening it to third parties. Most of those players are using cache servers at the edge of telecommunication providers' networks (collocation or equivalent), saving on backbone costs. Large telecommunication providers are also active in this market with telecommunication provider CDN solutions, but so far with a very limited impact on the market.

An operator or telecommunication provider CDN is a CDN that a telecom carrier deploys within its own infrastructure. One of its main purposes is to allow the operator to optimise the traffic being transmitted over its network, for both the distribution of its own services, such as IPTV, and for managing OTT (i.e. Internet) traffic in a more cost-effective way.

In theory, a telecommunication provider CDN (like a traditional CDN) can be used for any type of services, including:

- Video (large files, often now split into small files, with "progressive" delivery of packets, one packet at a time; generally, this will be heavy traffic that requires some strong capacity in edge storage and bandwidth)
- Distributing small files like web objects (including a large number of small items to display at the same time, therefore more complex to handle)
- Site-acceleration solutions for certain services where latency is critical, such as secured services on e-commerce sites

Operators' global strategies are relatively similar when it comes to rolling out a telecommunication provider CDN. All of the major telecommunication providers in Europe, North America and Asia – most of which are incumbent carriers – have deployed telecommunication provider CDN solutions. Their solutions cover only fixed networks. For cellular systems, operators have contented themselves with interconnecting their dedicated fixed CDN and the mobile core network to serve their mobile users. But there is a desire to develop solutions for the mobile market.

Table 5-1: Different approaches to the telecommunication provider CDN

Approach	Underlying principles	Examples
In-house technology	Operators develop their own CDN using technologies developed in-house	Telefónica
Distribution partnership/resale agreement	Operators resell pure-player CDN companies' solutions, possibly as white label products They do not integrate any CDN equipment into their own networks	DT
Managed CDN	Operators implement a CDN within their IP infrastructures, based on a pure-player CDN supplier's technology The CDN's management is then outsourced to that pure-player CDN supplier	KPN with Jet-Stream
CDN license	Operators deploy their own CDN infrastructures within their network, but using an outside party's technology, which they license from CDN suppliers (either a CDN specialist or a traditional equipment manufacturer)	Orange with Akamai
Federation	Operator CDN and traditional CDN are interconnected. Content can then be distributed to all users thanks to this federated network.	Trials underway for CDN-I (CDN Interconnection)

Source: IDATE, report on Telco CDN, April 2014 (updated with relevant examples)

One of the key issues for telecommunication provider CDNs is the footprint addressed by the solution (and therefore the associated traffic), addressing only one network, whereas traditional CDNs are generally global. A potential solution is therefore a federation of telecommunication providers (and also pure players) for CDN activities, initially around the CDN-I (CDN Interconnection) initiative. The purpose of CDN federation is not only to provide customers with the right level of quality of service, but also to simplify the sales process by interconnecting pure-player CDNs with CDNs from telecommunication providers and certain content providers as a way to resolve certain QoS issues.

CDN federation is thus a key ingredient in the future developments of the telecommunication provider CDN market, which cannot really take off until CDN-I solutions have been developed. From a technical standpoint, however, we expect to see a great deal of work to be done on standardising the various equipment involved, to ensure their interoperability.

A major limit to take into consideration is the legal framework of digital content and as a consequence the real ratio of traffic being cached. Indeed, in Europe, caching content requires some agreement with the rights holder. To determine which content should be stored on cache servers, traffic is analysed and the most popular content is cached. But unless the rights holders give their consent (as with a CDN), content can be stored only temporarily, at least in Europe. The notion of what constitutes "temporarily" is vague, and opens ISPs up to possible complaints from rights holders.

Otherwise, telecommunication providers could turn to transparent caching. Transparent caching is based on the same technical principles as a telecommunication provider CDN, with cache servers deployed close to end users. It involves operators intercepting, caching, and distributing unmanaged content. Transparent caching also constitutes an alternative solution for reducing traffic overload problems. Unlike a telecommunication provider CDN, however, with transparent caching there are no commercial agreements with content providers. This means that operators do not have to engage in any commercial transaction, which reduces sales costs, and creates a fundamental difference to a CDN solution. Operators do not earn any revenue from the use transparent caching.

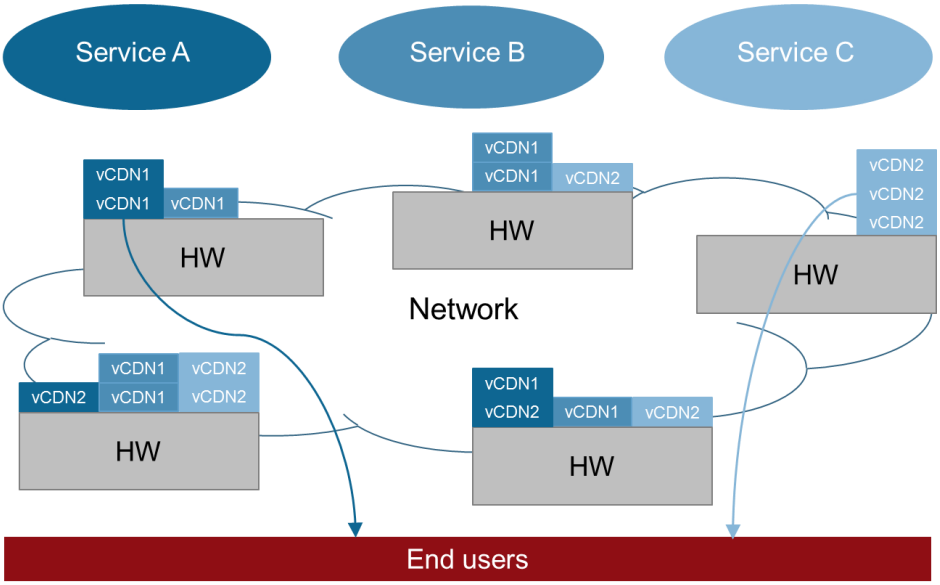
Impact on telecommunication provider cost model

Before getting any further, it is important to remember that some of the vCDN benefits for the telecom industry can already be captured with telecommunication provider CDN solutions without virtualisation. The same can be said for MEC around for instance small cells solutions (e.g. local based content delivery, local based network and services). Nonetheless, SDN/NFV should contribute to accelerate the concrete adoption of those solutions by providing a more cost-effective approach to deploy them and software-based approaches allowing for better integration.

Compared with other CDN implementations without it, a potential specific improvement from SDN/NFV technologies (essentially NFV) would come from the better capacity for deeper integration and interworking between all types of CDN players (traditional, OTT and telecommunication provider). The traditional federation approach is about cooperation of CDNs and tries to standardise the interfaces between different CDN technologies but having only one CDN technology (and associated servers) within the access network of a telecommunication provider, while thanks to virtualisation, VMs of vCDN platforms can be hosted and managed in telecommunication access networks on the same infrastructure. Somehow, all CDNs would virtually have their nodes into the telecommunication network, without requiring standardisation of interfaces, therefore indirectly solving the fragmentation issue and acting as a single CDN.

Thanks to virtualisation, shared hardware can be used by different third-party CDNs (and also by the telecommunication provider itself at least for its managed content) without the need to create complex interconnection mechanisms. vCDN decouples the software that controls and routes traffic on a network from the physical infrastructure that provides computing and storage resources. As a consequence, virtualisation would bring benefits to the cost model of CDN. Additionally, telecommunication providers will be able to use standardised/open-source SDN/NFV technologies, lowering the cost of servers, reducing upfront costs, and vendor tie-ins.

Figure 5-3: Principle of different vCDN cache nodes deployment in Virtualised environment



Source: ETSI (https://docbox.etsi.org/ISG/NFV/Open/Published/gs_NFV001v010101p%20-%20Use%20Cases.pdf)

Cost savings are likely to be concentrated on OpEx aspects, with less traffic going through the network. Impacts on CapEx are less obvious. Indeed, impacts in terms of CapEx are unknown, as virtualisation will reduce the need in terms of nodes or servers, but the number of nodes will increase significantly compared with today's architectures, generally using central storage resources.

Nonetheless, less space will be required to host the infrastructure, less traffic will go through the network (therefore fewer servers) and fewer switch ports and cables will be involved and savings specific to the video industry are also expected, as dedicated/specialised non-commodity hardware will become less necessary (generic high-performance servers can be used instead to allow scaling and sharing with other platforms).

These CapEx considerations may be partly solved if (physical) resources are deployed with new networks like 5G, as expected for instance by Nokia, and are reused. But this does shift the investment questions to the 5G networks. Also, resources in general developed for other use cases may be reused thanks to the sharing features of SDN/NFV.

OpEx savings can become very tangible according to HPE, with lower power consumption (more efficient cooling), less specialised and smaller admin and operations staff. OpEx savings can also come from peering/transit traffic reduction.

A few academics have started some simulations on the cost impacts. For instance, a mixed physical-vCDN infrastructure can provide benefits of 16% to 43% savings, according to various vCDN pricings, compared with physical-only CDN solutions (LRI, 2014).[25]

In addition to infrastructure cost savings, it will also improve speed of operations (installation, reboot, maintenance, scaling along the way, disaster recovery, etc.), which may represent indirect cost savings.

With a more software-based and open approach, traditional CDN features (like delivery) can interact with value-added services, which are intrinsically more software-oriented (nPVR, CMS, packaging, playout, analytics, etc.) and can also be deployed on VMs. Hardware resources for connectivity will even be shared with hardware resources for other features like encoding.

In addition, IT providers like HPE tend to develop vCDN as one of their products as part of a bigger portfolio of solutions that can use virtualisation and NFV resources and that are targeting their media and entertainment customers. vCDN will therefore benefit from the transformation of the media industry adopting progressively more virtualisation.

With MEC, more focused on the edge of the mobile networks (even potentially in base stations), this market could grow quite significantly, by targeting more local applications and services, leveraging the proximity features.

MEC is expected to bring higher efficiency of the network, and therefore some associated cost savings. But MEC is not so much about cost savings in general, but more about the possibility to enable new use cases (with reduced latency and better customer experience) and therefore new revenues (see next section).

MEC brings the usual capabilities and economic benefits of cloud computing at the edge of the network (RAN or mobile base stations), that could transform into savings.

Key savings expected with MEC

As identified by ETSI MEC Working group, main resources that can be optimised/saved include:

- Processing restricted to local information stored at the edge (e.g. augmented reality)
- Acceleration of videos taking into account local context (network conditions from radio analytics) to assist TCP control congestion mechanisms and usage of radio downlink

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25 http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6980395&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D6980395

- Reducing the round trip of data to the core or the cloud by storing some data locally (e.g. for connected cars, by leveraging roadside sensors and local information from other cars, or more generally for IoT applications). Less signaling in the core network is offloaded directly to the edge. Costs savings could become significant in the RAN's backhaul.

Among these optimisations, according to Intel, content caching has the potential to reduce backhaul capacity requirements by 35% and reduce download time by 20%.[26] Similar efficiency on hardware cost (30% to 40%) has been identified for CDN around the IPTV platform by Slovak Telecom during the workshop.

But all those optimisations should remain quite local, and therefore have an overall limited impact on the network if only deployed on a few cells. MEC is more positioned as an enabler for new business activities rather than as a cost-saving solution (apart from directly leveraging NFV features). MEC is nonetheless raising business concerns, due to significant CapEx investments to provide more capacities at a very local level (where capacities are today quite limited – indeed caches are generally today within the core network or even outside).

MEC will mostly allow extending applications and services that would normally reside at the core or data centres to the very edge of the network, in close proximity of the end users and connected objects. Many of the use cases for MEC can already be implemented non-locally (cloud level) but with more limited performances, or locally with small cells solutions (indoor or outdoor), but their implementation will be technically easier (software-based integration, too complex analysis at the core level to enable real-time due to an analysis encompassing too much data) and less expensive (virtualisation benefits) by leveraging some of the existing infrastructure and MEC, in combination with SDN/NFV and small cells.

High-level impacts

vCDN should allow for the realising of savings on the cost structure of telecommunication providers essentially for video/multimedia delivery, a significant part of the CDN market, and of the traffic being transported today in fixed and wireless networks (close to 78% in 2018 according to Cisco VNI tools, with similar orders of magnitude mentioned by telecommunication providers or other network vendors).

Other types of traffic (with for instance MEC) are less likely to have a significant impact on the cost model, as caching is often not involved and/or is essentially involving brand new and quite niche applications (at least from a volume of traffic perspective), not

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26 Cells revolutionalize service delivery. Intel Corp. http://www.intel.co.uk/content/dam/www/public/us/en/documents/white-papers/smart-cells-revolutionize-

handled today by networks. Most MEC applications are today at the proof-of-concept stage or even less advanced.

The real level of traffic that will be impacted will depend on the interaction with large OTT players, using their own CDN and not necessarily willing to pay for access to CDN capabilities from third parties (even with virtualisation) and the interaction with large CDN players, capturing most of the traffic of other OTT players, not willing to bother handling plenty of providers for their video delivery. Real network performances and pricing of vCDN compared with CapEx investments will obviously influence choices and therefore traffic really saved. Nonetheless, vCDN can be used also for internal traffic of telecommunication providers (managed traffic), supporting also a lot of traffic with SVoD, catch-up platforms and live delivery, and with players with whom they would find agreements. CapEx savings are also to be considered and can be amplified by hardware independence.

Cost impact range

By applying the IDATE cost model of telecommunication provider, overall savings for this use case may range from 5% to 9 % of the total cost of telecommunication providers. The average scenario leads to savings of close to 6.5% in total, essentially from network costs (or 10.5% of network and IT costs).

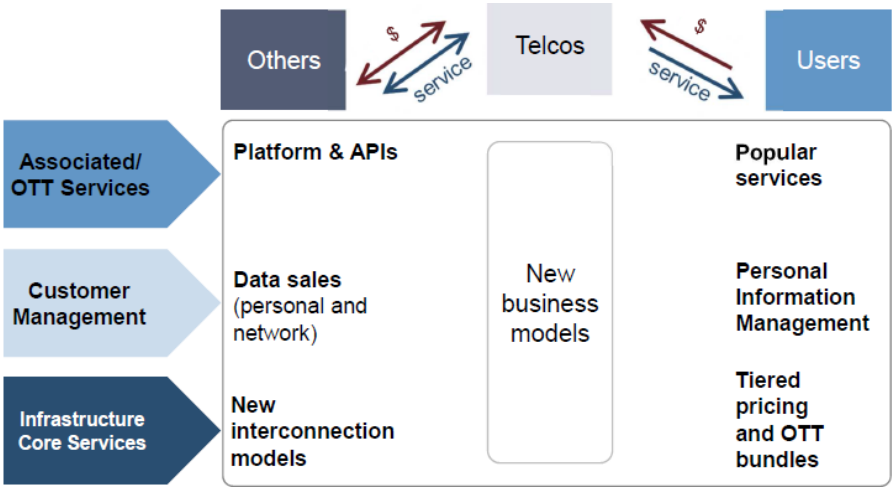
The average scenario would include up to 30% of savings for core and backhaul and up to 20% of savings on operations, maintenance, and network staff. Other improvements would come from IT savings (but more limited as already partly softwarised) and energy. Access costs would likely increase, but the increase would remain limited as the deployment in the access should remain very localised.

Impact on revenues and new business models

For years, CDN has been seen as a natural candidate for an evolution of the business models, with a two-sided market approach, in which telecommunication providers would bypass transit providers (and even if necessary CDN providers) and provide CDN features themselves to content providers, while still selling bandwidth (metered or unmetered) to consumers.

Indeed, new wholesale models can be imagined leveraging all network and also non-network assets, while still developing new retail pricing models, to offer capacities (volume) and/or guarantee of service (though SLAs).

Figure 5-4: Two-sided models for network and non-network assets



Source: IDATE, 2014

On the retail side, additional pricing models may be developed at the same time to provide extra QoS/QoE. Previous similar initiatives (without virtualisation) were already tested in the past (turbo boost, better latency for gamers), but have not really been successful commercially on the consumer markets. In a 2013 survey from Alcatel-Lucent, respondents who were interested in premium services showed an overwhelming preference for the premium subscription option (better speed all of the time). These consumers are looking for a boost that applies to every service, application, and location. The premium subscription was the most popular choice in all surveyed countries.

While retail solutions on the consumer markets are unlikely to develop much broader than packages and speed-based tiering, similar solutions could be developed on the professional/business/corporate markets with large accounts. There are indeed numerous advanced requirements.

Wholesale

Similarly, vCDN and MEC enable new wholesale models in numerous verticals, as spare NFV substrate capacities can be leased. Such capacities may include bandwidth, storage, computing, or personal data. In addition, new monetisation opportunities will arise due to the ability to test innovative services due to shorter innovation cycles.

vCDN revenues are likely to be generated with a similar approach such as CDN or telecommunication provider CDN. Typical pricing of vCDN is indeed reflecting traditional pricing of CDN. Pricing is generally based on the amount of traffic delivered, regardless of caching storage used. Like traditional CDN players, CDN pricing may also include

value-added services like transcoding, reporting, advertising, or analytics, sold to third parties generally based also on volume.

According to LABRI, vCDN will become necessary to handle the evolution of video traffic with 4K or 8K (premium video quality). Current CDN technologies (strongly dependent on DNS redirection) may not offer the relevant performances. These could allow a stronger shift from CDN market to vCDN.

MEC specific developments

MEC is characterised by potential benefits around:

- Low latency: many applications may leverage such features
- Proximity and location awareness: more local-specific information/content may be used at the local level, especially for analytics. Location data can also be provided through networks/small cells for indoor, even if GPS coverage is not available. This could therefore boost LBS markets, with personalised offerings.
- Edge: isolation with the rest of the network can be provided, especially to provide more security and resilience
- High bandwidth/computing/storage: strong capacities can be provided for certain location with more density
- Real-time insight of the network: additional local information can be contextualised (nonetheless by default, information available is limited to cell congestion, subscriber locations and movement directions)

Most of those features are not really available for third parties without MEC but can be leveraged through APIs or equivalent solutions thanks to MEC. Many applications, including mission-critical and enterprise-focused applications (more likely to develop first than retail-focused applications), can be deployed with it.

There is still a big mismatch between the targets for deployment of MEC and targets for revenues by MNOs, as shown in a survey by Rethink Technology Research. Key areas for MEC are related to video, augmented reality, retail experience and promotions, while revenues are mostly expected in general from enterprise telecommunication services, IoT/M2M, and video. In addition, MNOs consider that most features necessary to develop are not enabled by MEC, except for video and to a lesser extent analytics.

Most of these markets already exist in some form of equivalent market. But vCDN/MEC could allow an acceleration of these markets by introducing more premium features and also more capacity to compete for telecommunication providers (and therefore increase market share).

Table 5-2: Key markets for telecommunication providers

Markets	Differentiating features for telecommunication providers (with SDN/NFV)	Market volume	Assessment of capacity of telecommunication providers to capture new market share
Video CDN & enhanced video services	Mobile delivery Performances in 4K/8K environment? Local delivery (stadiums)	Small (around 2 billion EUR in 2015, source: IDATE & Frost & Sullivan)	Moderate on fixed markets (majority of the market) Significant on mobile and local markets
Location- based services (include active detection)	Local POI Stronger precision? Metadata	Moderate (5 to 8 billion EUR, but more than half in APAC, source: IDATE)	Very small (most solutions can be handled with alternative local solutions)
Augmented reality	Local content and processing	Very small (a few hundred million EUR)	Small (processing can be handled remotely and centrally in many cases and/or with powerful handsets)
Extra QoS and associated SLAs	Local bandwidth and resources	Small (around 1 billion EUR in 2015, source: IDATE)	High, especially in mobile environments
Analytics and Advertising	Local data and metadata (hyper targeting)	Large for online advertising (around 105 billion EUR, source: IDATE, of which 22% for mobile)	Small (numerous alternative solutions, rarely requiring a very detailed local approach)
Mission-critical IoT services	Capacity to provide SLA and low latency Additional metadata	Moderate (around 10 billion EUR in 2015, including basic connectivity, source: IDATE)	Moderate (some strong alternative for less critical solutions)
Integrated enterprise services (voice and data)	Capacity to provide SLA and low latency	Moderate	Marginal improvement (strong competition from IT vendors, no clear need for edge computing; but telecommunication providers may capture a part of this market without this use case)

Source: IDATE

By crossing market share potential for telecommunication providers and market potential size, it is clear that prime targets in terms of revenue opportunities for telecommunication providers are enhanced video services, extra QoS, analytics and advertising, and IoT. Other markets are not assessed in the following.

IDATE has already conducted some assessment of the revenues that telecommunication providers could capture from diversification into digital markets by

2018, with a potential of 103 billion EUR, mostly from financial intermediation, cloud, connectivity for additional devices, digital content sales and (traditional) IT services, plus to a lesser extent IoT/M2M.

In general, vCDN and MEC will imply more collaboration between the value-chain stakeholders, as solutions are more complex (despite automation) and require engaging different building blocks from different providers. These technologies will also lower the barriers to entry, by leveraging standardisation and third-party capabilities/technologies, leading to increased competition.

As for SDN in general and telecommunication provider CDN, traditional equipment vendors are being challenged more and more by IT vendors, putting pressure on prices. The capacity of IT vendors to be real contenders for vCDN/MEC is nonetheless less obvious, as it still involves at some point the use of physical edge hardware (sometimes taken for granted by some stakeholders).

The move towards NFV implies a reorganisation of the hardware mainly located in the core network so far, shifting progressively towards to the edge. Such transition could be very costly if not done correctly. HPE suggests to first develop the edge of the network to share resources between different applications and then use a NFV director to orchestrate the virtualised network functions to optimise the video delivery. Also, players can initially opt for managed services approach (servers are internal, but not staff) to limit risks before committing with in-house solutions.

A common NFV infrastructure can host multiple vCDN technologies that can coexist, enabling the content to select the own preferred CDN technology without conflicts. While CDN-I was about "competition" of multiple CDN providers (agreements between CDNs that are also in competition), vCDN will avoid competition issues between players, thanks to isolation of the different network functions. Smaller players are therefore more likely to participate along the value chain (smaller CDNs, smaller telecommunication providers, etc.), due to fewer barriers to entry.

A new breed of VNOs/VNEs (especially on mobile) may emerge, positioned as brokers with skills in terms of management of intelligent network and dynamic IT services in a context-aware manner. The brokering aspect is essential to address smaller customers that need to have an access with a global footprint approach, without the possibility to interact directly with each telco.

CDN players may also try to extend their telecommunication provider CDN solutions (managed or licenses) with a vCDN approach. Indeed, many CDN players have been developing their solutions in competition with equipment providers and have often been successful. But they are less likely to reiterate with vCDN, as it will essentially use virtualisation and generic hardware, developed for projects with a much larger scope than CDN/MEC.

5.2 Business Potential of Virtual Network Platform as a Service

A platform as a service provides client companies an environment to develop and run applications. The platform is accessed by developers over the web while the service providers are responsible for purchasing, configuring, and maintaining hardware and software to build applications. In this model the physical infrastructure (networking, storage, servers), virtualisation, the operating system, middleware, and runtime are delivered in the form of a platform. This includes an execution environment as well as tools that facilitate the application development.

In general the cloud-computing market is expected to grow about 20% annually. IDATE forecasts it to climb from 72 to 180 billion EUR between 2015 and 2020. This may result from businesses gradually moving their infrastructures to the cloud and growing trust in these kind of solutions.

Most telecommunication providers identified cloud computing as a major priority going forward. It has already been a key area for some of the telecommunication providers for several years. Telecommunication providers benefit from some major competitive advantages when sparring against Internet and IT heavyweights that will enable them to increase their market share little by little, thanks in particular to:

- Their end-to-end control of the connection between the customer and the cloud service, and so of the quality of service throughout (SLAs for availability both in the data centre and over the network)
- Data centres located near customers
- An existing relationship with customers

VNPaaS functions are very similar to those of traditional PaaS. In particular, the capability of orchestrating virtual infrastructures spans a range of virtual and physical network functions, compute storage, servers as well as an operating system along with a development environment that can be accessed by developers over the web.

According to IJARCCE, VNPaaS is "certain to replace traditional PaaS" in the future as implementation challenges (access control, security, management interface protection among others) will be resolved.

Cost savings

Limitation of upfront CapEx and improved network asset utilisation is the major advantage as regards the telecommunication providers cost model. SDN and reduce the expenses dedicated to network functions thanks to the ability to move from dedicated and proprietary hardware on to common and standard based equipment and also thanks to the high gained flexibility. Options other than investing can increase capacity. This is due to the VNFs hosted in VMs and the efficient share of available resources.

SDN and NFV enable the dynamic allocation of resources. In the VNPaaS scenario this means that network managers can create new VMs or use an existing VM. There is no need to invest in new hardware devices as the necessary capacity can be provided through software. This leads to an increase of the network utilisation from current 25%–30% to 90% thanks to virtualisation technologies. In the VNPaaS model, it is also possible to connect with VNPaaS from other service providers, a form of federation of VNPaaS. SDN and NFV bring flexibility in the management structure and scalability with the ability to manage VMs according to business need or network service requirements. Telecommunication providers do not need to over-invest in capacity anymore.

The key benefit of VNPaaS is the ability for the operator to provide services with the actual resources consumed by the end users that makes a low cost model.

The OpEx savings realised through VNPaaS can be compared with those realised through traditional PaaS, like scalability of deployed software with failover and load balancing. In the VNPaaS model, VNFs on VMs decrease the infrastructure management costs as follows:

- Smaller number of dedicated hardware appliances to deploy and to manage
- Reduction of the process to purchase hardware equipment, and no heavy procedures of installing proprietary network equipment
- Less on-site maintenance intervention

Moving away from traditional PaaS also means a common sever centralisation, which supports reliability, scalability, and management of each service requirement.

A platform with distributed hardware resources hosted on VNFs (data centres in different areas) and logical integration enables faster system recovery in the event of natural disaster. This was demonstrated in a proof-of-concept realised by NTT Labs, Alcatel-Lucent CloudBand (now Nokia) and Fujitsu.[27] VNPaaS provides reliability and offers auto recovery in events of the redundant system in case of failure. In this demonstration from NTT, vSIP has been the tested VNF.

Scaling the whole network, OpEx reduction could generate significant savings in terms of time and support related costs.

The results of an experiment suggest that a VNF approach provides a more than fourfold reduction of operation costs of the network.[28] However, difficulties lie in the

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27 Fujitsu (2014): Server Platform Technology that supports reliability and scalability functions for service applications approved as a Proof of Concept by ETSI, Press Release, 01.05.2014. Available online: http://www.fujitsu.com/global/about/resources/news/press-releases/2014/0501-01.html

28 Bari, F.; Chowdhury, S. R.; Ahmed, R. and Boutaba, R. (2015): On Orchestrating Virtual Network Functions in NFV, CNSM '15 Proceedings of the 2015 11th International Conference on Network and Service Management, IEEE Computer Society Washington, DC, USA, p. 50-56. Available online: https://arxiv.org/abs/1503.06377

assessment of the number of VNFs and their location to optimise network utilisation. Another study conducted by Juniper and ACG Research[29] shows how using VMs could drastically decrease total cost of ownership. The example shows how virtualisation brings down support costs. Typically, cloud CPE and virtual firewalls reduce installation and support costs by 72% and 86% respectively compared with a physical solution.

Overall savings for VNPaaS usage scenario could be up to 7.1% in total telecommunication provider costs.

Revenue opportunities

Next to cost savings the VNPaaS scenario also offers revenue opportunities as a key enabler for the acceleration of services and applications. This is especially the case because of the 5G standards for which the networks will be transformed into intelligent orchestration platforms. Telecommunication providers can therefore offer a better proposition to end users, taking advantage of the current massive and flourishing services.

Indeed, VNPaaS will enable telecommunication providers to capture more revenues compared with traditional PaaS from multiple sources:

- Extended target end users thanks to the large variety of functions abstracted (one VNF or a combination of VNFs). Operators can be one of the tenants along with enterprise customers that can develop and run broad applications and services built on VNPaaS. Clearly, the innovation with VNPaaS stands in the larger scale of network services that can be provided by the operator. Thus, the VNPaaS can be seen as an enabler for the development of applications.
- Higher level of customisation. In VNPaaS, each tenant can also introduce and deploy their own VNF instances that offer additional services or that suit the specific requirements beyond using existing VNFs.

Nonetheless VNPaaS implementation is facing challenges driven by the shared resources with third parties:

- Access control to API
- Mechanisms to separate workloads between tenants and limitation of resource usage
- A protection of the management interfaces provided to enterprises

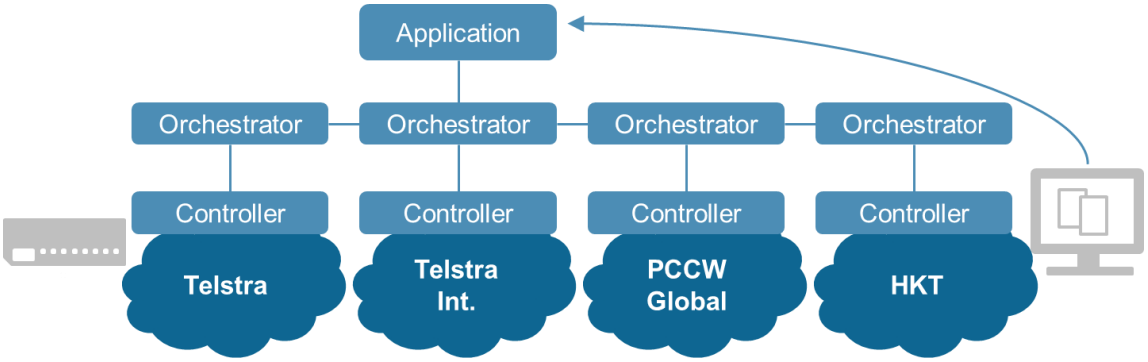
29 ACG Research (2014): Business Case for NFV/SDN Programmable Networks, ACG Research Study. Available online: http://fr.slideshare.net/junipernetworks/acg-research-paper

Federation

As VNPaaS from different service providers can be interconnected, this use case could be the basis of new business model for telecommunication providers. A specific improvement from the use of SDN and NFV is the ability to reach global footprint, especially to link multiple enterprise locations.

Some telecommunication providers are already working on a form of federation using SDN and NFV, such as PCCW and Telstra as shown in Figure 5-5.

Figure 5-5: Federation, service providers' perspective



Source: PCCW

Deutsche Telekom is also one of the telecom operators involved in covering several markets while centralising production. In its Pan-European IP project, Deutsche Telekom is moving away from a model where they apply separate production capabilities dedicated to each market to a model where the operator is active using SDN and NFV technologies.

One typical example can be the offering of VPN service as a VNF based on VNPaaS architecture model, as confirmed during different expert interviews and during the third workshop. Such service allows customers to self-serve and to take control around the VPN offer.

Deutsche Telekom and Vodafone have both announced plans for a deployment of VPN services across several markets based on the use of SDN and NFV technologies, with the aim of simplifying operational process. New concepts mean the typical time to market can be reduced from several weeks to 15 minutes to set up a VPN, according to Deutsche Telekom.

High-level market sizing from telecommunication provider perspective

According to IDATE, the PaaS market is the smallest cloud service, estimated at 3.6 billion EUR in 2015 and expected to reach 9 billion EUR by 2020. Telecommunication providers generally make up 10% of the cloud market. By extrapolation, and assuming an annual PaaS market growth of 18%, telecommunication providers could expect new revenues of 0.89 billion EUR from VNPaaS by 2020.

From the service perspective, VNPaaS applications are quite unlimited, with the opportunity to monetise on connectivity and data centres. We assess here the example of security services encompassing VPN and value-added services such as firewalls, SSL VPNs, intrusion detection, and parental controls. In 2015, the security market was estimated at 58 billion EUR by IDATE. 10% of this market is currently captured by telecommunication providers, the largest remaining part is the share of IT players. Not only coming from VNPaaS, new revenues from security could reach over 13 billion EUR by 2020.

Specifically, in the VNPaaS, as network functions can be supplied in the form of software moving away from proprietary appliances, that could have an impact on the hardware business activities of the Ericsson, Nokia, and Huawei. They will be in competition with virtualisation software providers that can be open-source based and easy to integrate in multi-vendor platform. However, they are positioned by moving up in the value chain by providing virtualisation solutions. Developed by former Alcatel-Lucent, Nokia CloudBand has an NFV platform that orchestrates, automates, and optimises resources across distributed clouds and networks that have been used by NTT for its VNPaaS demonstration.

Lastly, traditional equipment vendors who have a long relationship with network operators can also leverage their network-related service offerings. In fact, they have already moved up in the value chain by providing more and more services. Typically, Ericsson which is the market leader in telecom services, has expanded its services portfolio, especially in IT. The Swedish infrastructure provider has already made significant contracts, such as with Telefonica, where Ericsson has been selected as a preferred integrator in its virtualisation programme transformation. The opportunity for traditional equipment vendors will be their capacity to take the role of integrator in a software-based multi-vendor environment.

Impact on telecommunication providers

In a VNPaaS model, telecommunication providers act as the VNPaaS provider and are in competition with PaaS providers, typically cloud players such as Salesforce. Telecommunication providers have competitive intrinsic advantages by providing their network functions along with a large variety of services such as security. According to VMWare, telecommunication providers need to work differently than for legacy business

to take the opportunity of the PaaS/VNPaaS market, and have a platform approach such as IT players than network approach.

Telecommunication providers would have several opportunities to move in the value chain with VNPaaS. They would have the responsibility of integrating, managing, and orchestrating the entire VNPaaS infrastructure. So, concretely, telecommunication providers need to do more and more integration as well as acting as hosting service providers if the different VNFs are to take the opportunity of the market.

The VNPaaS usage scenario could strengthen the position of telecommunication providers in the IT area.

New players in the telecommunication value chain

VNPaaS involves a new role in the value chain and opportunities for new players to enter the market as follows:

- Integrators already active in the traditional cloud market and also IT players who have extended their traditional activities such as Microsoft, Cisco, Dell and HP
- Virtualisation providers including suppliers of NFV infrastructure, VNF, VNF manager, SDN controllers. Typical virtualisation specialists include VMware, Big Switch, Affirmed Networks. Software vendors who want to develop VNFs, MANO, SDN controllers could also jump in the bandwagon.
- Hosting companies to host VMs such as OVH, Microsoft, Rackspace

5.3 Business Potential of Virtualisation of Mobile Core Network

Virtualisation of the mobile core network usage scenario can be considered as a specific case of VNPaaS where elements that composed the mobile core network are exposed through different VNFs in the virtual platform.

The current Mobile Core Network is EPC in line with 3GPP LTE, an all-IP mobile core network. This usage scenario in particular has emerged as one of the more tangible examples of the application of SDN/NFV in carrier networks transformation. The virtualisation of the EPC can be considered as part of the network function layer in the 5G architecture where network functions are abstracted thanks to SDN and NFV and network functionalities offered to users.

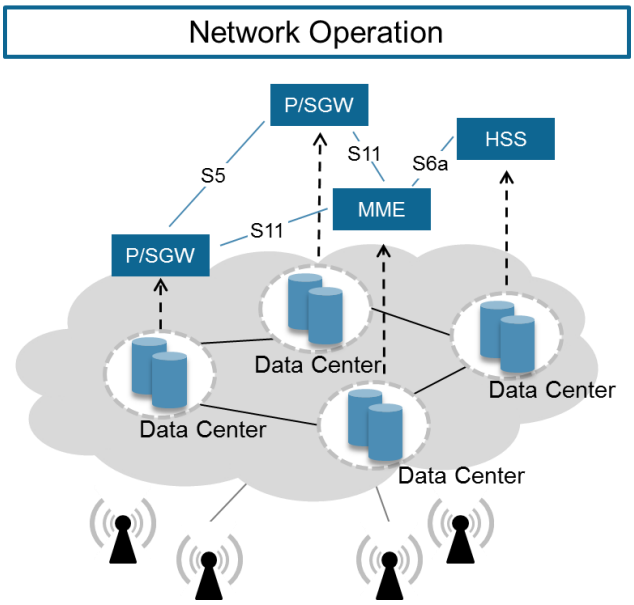
According to Vodafone, EPC elements are not easy to virtualise due to the highly fluctuating traffic and flows.

Many mobile core functions have been identified for virtualisation that should operate at the same performance or better than conventional mobile core network. Alcatel-Lucent

has tested capacity and performance of a virtualised mobility management entity (vMME). Supporting up to millions of simultaneous attached users and hundreds of thousands of eNodeBs and small cells, the vMME has equivalent performance to hardware platforms. Also, virtualised serving and packet gateways (vSGW/vPGW) have shown better performance in terms of speed and increased capacity.

In terms of deployment, the entire EPC or only specific part of mobile core network functions can be virtualised. Indeed, telecommunication providers can fully virtualise EPC components or start with gateways leveraging distributed infrastructure. A possible view of vEPC has been introduced by ETSI with the typical EPC functions comprising S/P GW, MME, HSS, as shown in Figure 5-6.

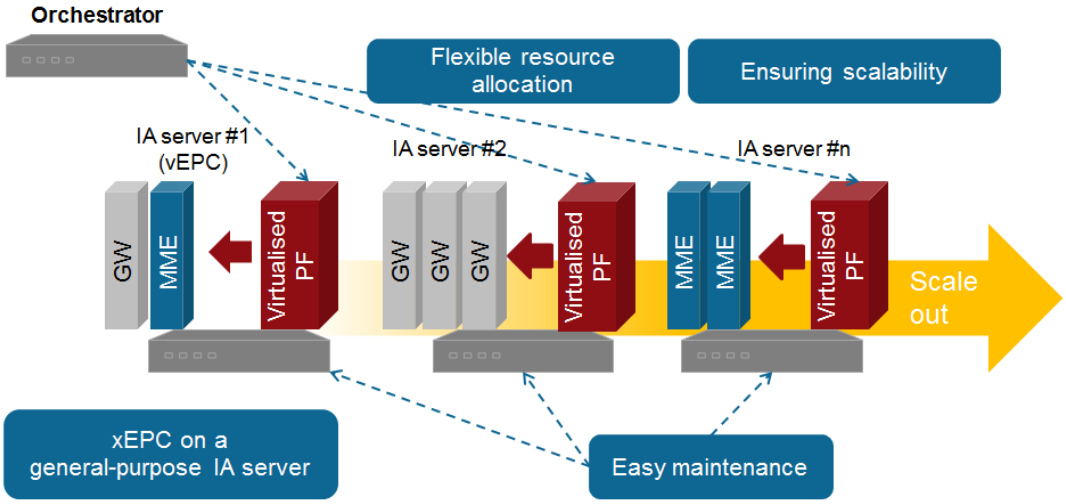
Figure 5-6: vEPC architecture



Source: ETSI

Benefits from vEPC are globally generic to SDN/NFV. By running each network function of the EPC on VNFs running on standard servers instead of dedicated appliance, the industry expects a reduction in terms of OpEx and CapEx along with operational benefits. Indeed, vEPC should bring flexibility and dynamic scalability, especially on resources demand peak. Figure 5-7 shows these expected benefits as well as the vEPC concept as a whole.

Figure 5-7: vEPC concept and expected benefit



Source: NEC

Cost reduction

vEPC clearly brings down network costs for telecommunication providers thanks to the capacity to scale – up/down and in/out – independently according to network traffic demand and also to the use of common servers. That allows telecommunication providers to improve the network assets' utilisation.

As the EPC is characterised by a large number of nodes, NFV allows a reduction deployment of physical nodes by replicating nodes under the form of software, along with a decrease of dedicated physical hardware.

The reduction of infrastructure deployment costs is also linked to the modular architecture brought by the virtualisation, allowing throughput, transaction, and session capacity to be added independently. Indeed, virtual functions can be scaled independently. Some functions related to data plane may require an increase of resources, not necessarily increasing resources dedicated for other functions.

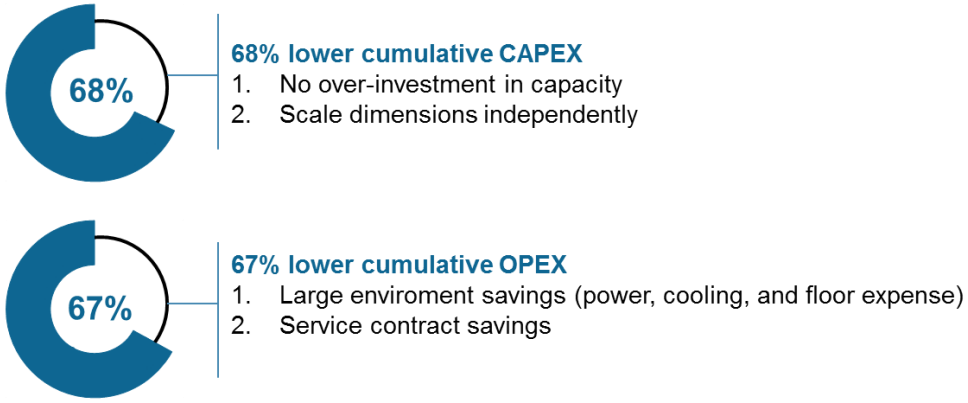
CapEx can be reduced by the reduction of platforms. ACG Research demonstrated the reduction of platforms and that virtualisation enables a change of the network architecture to move from three distinct hardware appliances to manage to the use of a single platform. By running vEPC on x86 servers, the Total Cost of Ownership (TCO) of any size of mobile core platform and EPC can be reduced. Indeed, the different elements of EPC can be consolidated on industry standard servers. The cost of hardware for the mobile core platform and software required for the different appliances functions is reduced. Sources of cost reduction are mainly linked to the use of standard

servers than proprietary blade systems, the higher infrastructure utilisation, and related operational expenses.

The virtualisation of mobile core solution to keep up with traffic demand is 68% lower than the traditional solution in terms of CapEx, and a reduction of 67% as regards to OpEx.

Another example of deployment of vEPC is dedicated to M2M, which differs in terms of network requirements shows different cost gain. The comparison between virtual and traditional approach show TCO savings of 50% for CapEx and 60% for OpEx.

Figure 5-8: CapEx and OpEx reduction linked to vEPC



Source: ACG Research

Also from a cost perspective, like all usage scenarios using SDN and NFV, investments are required to purchase standard industry equipment such as servers but also licensed software. Here for the vEPC case, investment payback in 3 years can be expected for mobile network operators moving to vEPC.

Directly tied to hardware, environmental expenses are reduced with vEPC due to the effect of equipment consolidation. Indeed, power, cooling, and equipment housing are naturally reduced as vEPC implies less equipment and less related spaces. Environmental costs can be reduced by 90% in the case of a virtualisation of mobile core network.

In addition to infrastructure financial benefits, vEPC will also bring scaling benefits, improved speed of operations, and reduced maintenance.

Time to market acceleration

The process of service creation can be potentially accelerated with SDN and NFV. In the case of EPC, the time taken for lab tests and establishing site phases can be

divided in half as settings and fine tunings can be done through software, meaning fewer manual processes and reduction of on-site intervention. That would be a clear advantage to introduce new services, getting close to OTT process time. Time savings for service creation can be reduced from 15 to 6 months.

Scaling is another intangible saving from virtualisation, especially when adapted to traffic and capacity variations:

- Elasticity, scalability from the launch VMs to handle traffic spikes
- Improve network usage efficiency in day-to-day network operations thanks to the optimisation of the allocation of resources
- Granular scalability preventing over provisioning
- Increases business agility through on-demand scalability
- Ability to start at any size and grow at market speed

Operations and maintenance reduction

Seen as typical SDN/NFV impact, maintenance costs are reduced thanks to the automation and programmable aspects allowed by the new concepts. Several gains can be obtained by deploying vEPC, such as:

- Consolidation of the different mobile core elements on common server
- Reduction of complexity and operational issues of a mobile core network
- Fewer on-site operations
- Short and easy upgrade cycles
- Quick provisioning
- Easier to integrate other functions such as IMS and DPI

Cost impact range

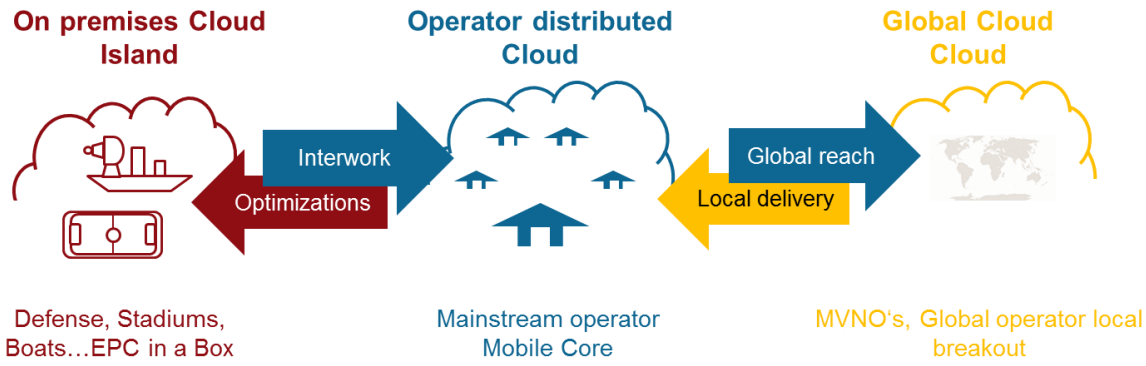
Overall savings for the vEPC use case are limited as it is focused mainly on core network functions. Indeed, the application of 50% to 60% of savings thanks to vEPC on core network costs remain marginal, as this part of the network weights for only 1.20% of the total costs. The majority of the savings come from the reduction of operation and maintenance and energy linked to core functions and also from roaming fees.

By application of the IDATE cost model of telco, savings may range from 3.7% to 5.0% of the total costs of telecommunication providers.

New revenues come mainly from the ability of vEPC to slice and separate traffic, and run multiple concurrent instances of mobile data core network with different profiles, and also from leveraging cloud capabilities that provide global reach. Virtualised mobile

core's strength is its capacity to cost-effectively scale services. Today, the virtualisation of mass market consumer EPC is not the focus of the industry looking on use cases delivering a fast return.

Figure 5-9: Opportunities with virtual mobile core



Source: Ericsson

vEPC can be used as the core for the deployment of broadband wireless access. Alternatively to fixed-line broadband services, such solutions can be deployed in sparsely populated areas where telecommunication providers have difficulty building broadband connections due to issues of ROI.

SDN/NFV also have the potential to breathe new life into old business models, notably by giving MVNOs the opportunity to differentiate their services with a low cost operational model. In the current form, MVNOs are limited in their ability to understand subscriber behaviour and control the services they provide.

Virtualised mobile packet core allows the creation of network slices in line with IoT traffic profiles. Indeed, the sub elements of vEPC can be used in different combinations, meeting the specificity of IoT applications. It also gives operators the ability to cost-effectively customise their networks, addressing individual customers, industries, and applications.

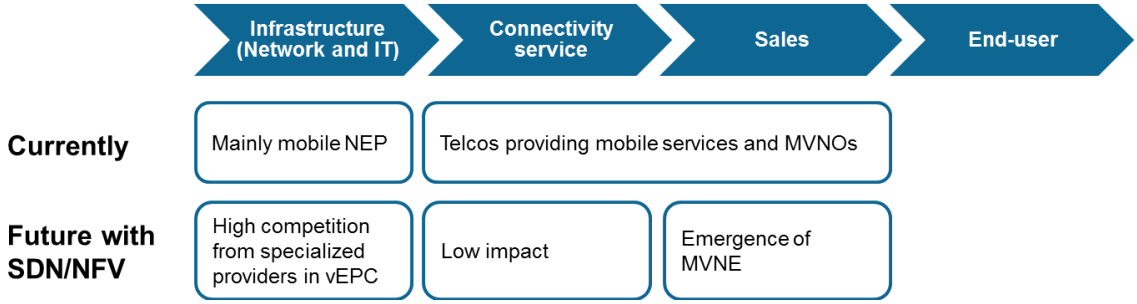
As far as IoT will grow, the network is going to be subjected to much more variability depending upon the requirements that the IoT users have. However, few operators are jumping on the vEPC bandwagon for IoT, because so far the amount of IoT traffic in the networks has been fairly small.

Also, by leveraging vEPC and more generally SDN/NFV, IoT players can become somewhat virtual operators with global reach.

As already mentioned, vEPC cannot be considered as a market but as an enabler. vEPC is used mainly for telecommunication providers as a support for existing services over a cost-effective network. Consequently, vEPC does not itself directly generate new revenues for telecommunication providers.

In the case of vEPC, virtualisation opens up the development of mobile network platforms to a broader range of infrastructure vendors. Figure 5-10 shows the impact of SDN and NFV as regards vEPC on the telecommunication value chain.

Figure 5-10: Value chain impacts of the vEPC use case



Source: IDATE

Increasingly, leading mobile packet core vendors are faced with new players, specialists in virtualisation that increases price pressure and reduce the vendors' margin. Though beyond this new competition, the impact on large equipment manufacturers is relative. They have the advantages of long-established relationships with telecommunication providers, managing the complexity of the network and associated integration.

6 Economic Potential of SDN and NFV beyond the Telecommunications Landscape

SDN/NFV is essentially a toolkit and an enabling technology. To measure its direct economic effects beyond the telecommunications landscape is difficult at this early stage of deployment when there is still a substantial degree of uncertainty about the services and products that will emerge. Consequently, this chapter provides a high-level overview of relevant trends that are likely to be enabled and/or further supported by the three usage scenarios that are considered in this study.

6.1 Economic Potential of Virtualisation of Content Delivery Network

A particularly data hungry but also economically relevant category of innovative services is augmented and virtual reality. A study by Deloitte, Fraunhofer, and Bitkom indicates that, for Germany alone, companies will invest more than EUR 840 million in virtual, augmented, or mixed reality from now until 2020.[30] This will include EUR 753 million for software-based solutions concerning implementation, updates, and new releases. According to MarketsandMarkets, the global augmented reality market is predicted to be USD 117.40 billion and the global virtual reality market is predicted to be worth USD 33.90 billion by 2022.[31]

From an economic perspective, the potentials that can be lifted in terms of new opportunities enabled by technologies such as virtual reality (e.g. OculusRift) and augmented reality (e.g. MagicLeap, HoloLens) can be observed, e.g. in the following sectors:

- Education
- Health
- Logistics
- Transport
- Travel
- Gaming
- Entertainment

Virtual reality is going to empower the gaming and entertainment sectors. Enabling new ways to experience online games and movies in more dimensions and enhanced

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30 Deloitte, Fraunhofer and Bitkom (2016): Head Mounted Displays in deutschen Unternehmen – Ein Virtual, Augmented und Mixed Reality Check. Report, May 2016.

31 MarketsandMarkets (2016): Augmented Reality and Virtual Reality Market by Device Type (HMD, HUD, Handheld Device, Gesture Tracking, Projector and Display Wall), Component (Sensor, Display, Camera, and Software), Vertical, and Geography - Global Forecast to 2022, Report.

realities will boost these industries within the next years. Augmented reality has significant potential in education, health, logistics, transport, and travel. Education can be enriched by more intensive courses providing more insights from different perspectives and featuring for instance visual and even tactile feedback. Logistics and transport will profit from more precision and increased efficiency in tasks such as postal delivery being independent from the individual's familiarity with the location, and assemblymen and warehouse workers being more reliable and flexible. The travel sector can profit from new experiences related to sight-seeing activities, etc.

6.2 Business Potential of Virtual Network Platform as a Service

At this point, it is difficult to foresee if and how such virtual network functions will be adopted by clients from other lines of industry as well as which specific cost savings they will entail for them. Consequently, it is also difficult to foresee the economic impact of functions enabled by VNPaaS. While many of these functions are likely to be used only by a small group of highly sophisticated commercial users, there are also functions that are likely to gain widespread usage across Europe. A particular relevant example is the virtualisation of email servers in the network.[32] Essentially, an email VNPaaS offers the same functions as a traditional email server. However, the client may choose to also integrate other VNF instances. For instance, this may enable them to implement advanced use cases such as filters and security features.[33]

According to Forrester,[34] the savings that in particular multinational companies can achieve by unified communications are very substantial. They expect a full payback within 14 months of installing the solution and a ROI of 79%. In absolute terms, a study by Unicomm estimates the potential savings by introducing unified communications to be EUR 5 million per 1000 employees annually.[35] As this estimate does not apply to SMEs, one can only apply it to large enterprises in Europe. According to Eurostat,[36] 33% of all persons employed in Europe (excl. the financial sector) are employed in large enterprises (250 employees and more). In total, this is just over 44m employees. Assuming that the estimated savings represent a sufficiently good estimate of the average savings, the full deployment of unified communications enabled (partly) by VNPaaS would translate into EUR 221 billion saved annually across Europe.[37]

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32 ETSI (2013): Network Functions Virtualization (NFV): Use cases. ETSI GS NFV 001 v1.1.1. Available online: http://www.etsi.org/deliver/etsi_gs/NFV/001_099/001/01.01.01_60/gs_NFV001v010101p.pdf

33 Chowdhury, N. M.; Mosharaf, K. and Boutaba, R.(2010): A survey of network virtualization, Computer Networks, 54 (5), p. 862-876.

34 Forrester (2014): The Total Economic Impact of Microsoft Lync 2013, Unified Communications Platform.

35 Parker, M. and van Doren, D. (2009): Achieving Cost and Resource Savings with Unified Communications, Unicomm and Microsoft.

36 Eurostat (2015): 9 out of 10 enterprises in the EU employed fewer than 10 persons, Press Release for SME Week 2015.

37 This is only a rough estimate of the actual effect.

One example beyond the telecommunication sector that will benefit from VNPaaS is the healthcare sector. Through the connection of different devices over a virtual platform healthcare IT departments can monitor the connected devices, operating systems, and applications running on them more easily. Controls using automation and analytics can be deployed.[38]

6.3 Business Potential of Virtualisation of Mobile Core Network

Typically, vEPC will enable the allocation of a hardware resource pool in the case of non-anticipative increased demand for specific services. ETSI[39] gives the example of a large-scale natural disaster such as the great east Japan earthquake,[40] where mobile networks were faced with a massive number of call attempts for voice communications as people tried to reach their relatives. With vEPC, it will be possible to allocate resources for voice services more easily.

Given the Internet's relevance, the total economic effects will be huge. A report from IBM predicted that, by 2025, consumer-driven mobility will extend far beyond car-centric services controlled by the automotive industry and will offer opportunities for both traditional and new industries.[41] According to a report by MarketsandMarkets, the global market potential for connected cars is estimated to be USD 46,69 billion by 2020.[42] A study by Strategy& suggests that worldwide sales of connected-car products will increase almost fourfold between 2015 and 2020, adding more than EUR 110 billion in revenues in the passenger car segment alone.[43] As a study by Gartner estimated last year, about 250 million cars will be equipped with wireless connectivity by 2020.[44]

The increasing capacity needs are coming from – amongst others – different systems that will be implemented in connected cars and driverless cars. Improving the performance of cars, systems that autonomously steer the car such as parking assistant systems and cruise control systems will ensure consumer convenience. Moreover, systems enabling drivers to save time due to efficient reach of destinations will also increase security by technologies showing warnings in case of external dangers and autonomous accident protection. In addition, new interfaces and Internet access with Wi-Fi hot spots will enhance entertainment possibilities. This will go along with

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38 For further information on the impact of SDN on the healthcare sector read: http://www.networkcomputing.com/data-centers/digital-transformation-healthcare-industry/690236276

39 www.etsi.org/deliver/etsi_gs/nfv/001_099/001/01.01.../gs_nfv001v010101p.pdf

40 Actually, it could be also the case of server failure or attack on a specific server.

41 IBM Institute for Business Value (2015): Automotive 2025: Industry without borders: Engage with consumers, embrace mobility and exploit the ecosystem. Available online: https://public.dhe.ibm.com/common/ssi/ecm/gb/en/gbe03640usen/GBE03640USEN.PDF

42 MarketsandMarkets (2015): Connected Car Market by Connectivity Form Factor (Embedded, Tethered, Integrated), Connectivity Technology (LTE, 3G, HSPA+, Wi-Fi, Bluetooth), Application (Navigation, Telematics, Infotainment) and Geography - Trends & Forecast 2014 – 2020, report

43 Strategy&. (2015): In the Fast Lane - The bright Future of Connected Cars. Available online: http://www.strategyand.pwc.com/media/file/Strategyand_In-the-Fast-Lane.pdf

44 Gartner (2015): Newsroom. Available online: http://www.gartner.com/newsroom/id/2970017

increasing ease of use by on-board information about car conditions and service scheduling as well as updates of relevant software. Such systems and other digital solutions can help to reduce or even to avoid car accidents. In a report for the Global e-Sustainability Initiative, Accenture estimates that, until 2030, connected cars could save 720,000 human lives annually from road accidents worldwide.[45]

In general, there are several positive welfare gains of connected cars (passenger vehicles) in terms of saving potentials globally per year, as predicted by Cisco Systems:[46]

- Eight million traffic accidents that cost 1.3 million lives and injure more than seven million people
- 90 billion hours in traffic jams, generating 220 million metric tons of carbon equivalent
- USD 1 trillion due to traffic congestion, or two per cent of GDP

Moreover, there are several improvements for the society to gain from universal vehicle-to-vehicle and vehicle-to-infrastructure communications. On the one hand, users of cars can save an estimated USD 550 in operating expenses each year; on the other hand, roughly USD 420 per vehicle per year can be saved by reducing the cost of crashes and traffic congestion.

45 Accenture (2016): Global e-Sustainability Initiative System Transformation Report. Available online: http://systemtransformation-sdg.gesi.org/160608_GeSI_SystemTransformation.pdf

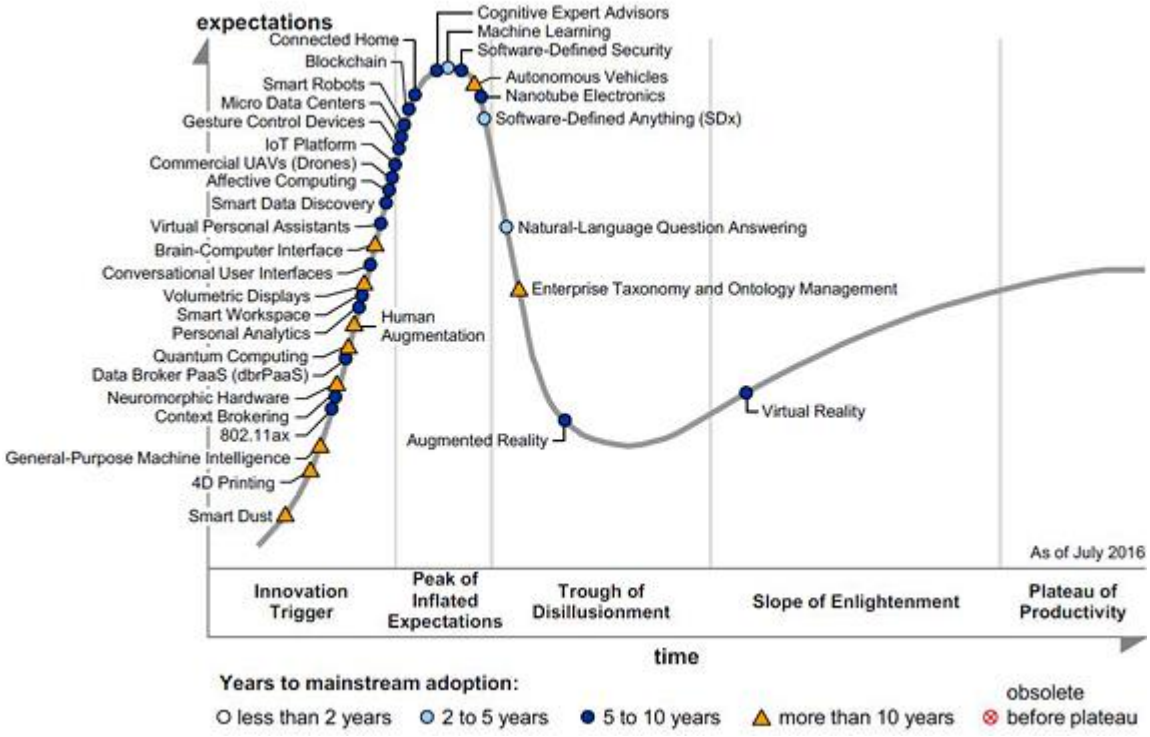
46 Cisco Systems (2016): Website: http://www.cisco.com/c/en/us/solutions/industries/transportation/passenger.html

7 Implications of SDN and NFV for European Policy

7.1 SWOT Analysis: Overarching policy implications for facilitating SDN and NFV development and deployment

SDN and NFV represent technologies that are still at an early stage of their development and deployment. Over recent years, there have been various assertions about their potentially revolutionary impact on the telecommunications landscape as well as other lines of industry. The results of the present report show that at least some of these expectations were inflated. This general finding is in line with the results of a recent study commissioned by the Dutch government.[47] The latest Gartner hype-cycle underscores this insight. It puts Software-Defined Anything (SDx) just at the beginning of the trough of disillusionment and after the peak of inflated expectations.

Figure 7-1: Gartner 2016 Hype-Cycle



Source: Gartner

47 Van der Vorst, T.; Naudts, B.; de Bijl, P.; Verbrugge, s. & Brennenraedts, R. (2016): The impact of network virtualisation on the Dutch telecommunications ecosystem: An exploratory study. A study commissioned by the Dutch Ministry of Economic Affairs. Project 2016.024. Utrecht: Radican Economics, iMinds, dialogic.

Nonetheless, the findings of this study also support that SDN and NFV have positive effects on the cost structure of connectivity provision, and may unlock additional technological potential that will at least support the development of novel services with significant economic and societal impact. Equally, SDN- and NFV-enabled technologies such as MEC will significantly improve the QoE for consumers and businesses alike.

In light of these benefits, significant deployment of SDN and NFV is likely to happen within the next 4 to 6 years according to the results of the Delphi expert panel conducted for this study. Specific decisions to deploy SDN and NFV will however depend on the individual business case and the risks perceived by telecommunications operators. Consequently, there is a minor role for European policy to play in the foreseeable future. To support network-related innovation e.g. by SDN and NFV deployment by setting the right framework conditions nonetheless appears to be able to capture significant potential for Europe. In order to analyse the current state of policy and regulation in relation to this policy objective, a SWOT[48] analysis is conducted here. One of its key features is that it adds clarity to the evaluation of complex subjects such as policy and regulatory framework conditions. Furthermore, it is a forward-looking tool that fits the purpose of the study well. In a SWOT analysis, the Strengths and Opportunities are positive, while the Weaknesses and Threats are negative. In SWOT analyses, the Strengths and Weaknesses are internal, while the Opportunities and Threats are external. The SWOT analysis explicitly looks at the wider frame of European policy areas, since e.g. innovation policy contributes critically to the success of novel technologies such as SDN and NFV. The following figure summarises the strengths, weaknesses, opportunities, and threats that can be identified from the findings of this study. In the following, each bullet point will be discussed.

Table 7-1: SWOT Analysis of the policy and regulatory framework

Strengths	**Weaknesses**
• Early and substantial support for technological innovation e.g. in Horizon2020 • European Commission's efforts in facilitating the development of 5G • General pro-investment direction of European telecommunications regulatory framework • Digital Single Market as an important framework for new cross-border digital services	• Regulatory framework may be too static for accelerating technological development
Opportunities	**Threats**
• Side-by-side development of open-source and industry standards • Digitisation economic and societal potential	• Resistance from legacy actors • Challenges in terms of change management • Uncertainty about the effects, impact, and implications of SDN and NFV

48 Strengths, Weaknesses, Opportunities, Threats.

Strengths

Early and substantial support for technological innovation

The European Commission has long focused on driving innovation in Europe. Given its cross-cutting relevance, the Commission has established DG Research & Innovation as the central unit to define and implement European Research and Innovation policy. In particular with the Framework Programmes and the following Horizon2020 programme, the Commission has been supporting technological innovation in Europe strongly. Projects typically address early stage research and develop key technological enablers.

Given the early stage of SDN/NFV deployment that can be observed right now, innovation policy can play an important role to foster SDN/NFV development and take-up in Europe. The European Commission has recognised this. For instance, the FP7 call 11 emphasised SDN/NFV projects. Equally, the current Horizon2020 programme by the European Commission features various SDN/NFV projects ranging from fundamental technological research to the development of use cases and applications of SDN/NFV in practice. In addition to these projects, there are various projects funded (partly) by the European Commission that either develop relevant building blocks for major drivers of SDN and NFV deployment such as 5G, or seek to exploit the technological potential of SDN and NFV.

In summary, European innovation policy strongly supports innovative network technologies and within that SDN and NFV. This support is critical in order to keep up with other regions of the world that also put significant effort and investment into novel network technologies.

European Commission's efforts in facilitating the development of 5G

Besides the support that 5G and surrounding technologies receive in European innovations policy, the European Commission has taken important steps to accelerate the development of 5G in Europe. The European push towards this critical technology involves a landmark agreement with the "5G infrastructure Association" in 2013 to establish a Public Private Partnership on 5G (5G PPP). For this flagship project funding of EUR 700 million has been put into the Horizon2020 programme. In total, the European Commission expects the investment stimulated by this funding to reach EUR 3 billion.

The 5G manifesto published in July 2016 further underscores the strong support that DG Connect and the major telecommunications operators in Europe give to this technology. The plans described in the manifesto include cross-sector hubs for experiments, trials, and large-scale pilot programmes. The Commission is further considering the harmonisation of regulation in verticals to set the best possible framework conditions for a quick adoption of 5G and accompanying technologies e.g. in health, energy, or transport. European operators on the other hand have committed themselves to roll out 5G in at least one city in each Member State.

This strong support for 5G is clearly a strength of the current European telecommunications policy. It is likely to facilitate the development and deployment of SDN and NFV.

General pro-investment direction of European telecommunications regulatory framework

Overall, the European Commission is urging NRAs to secure the long-term benefits of digitisation. To achieve this, they should as far as possible adopt regulatory approaches that facilitate investment into new and innovative infrastructures. The European Commission has proposed in Article 74 and Annex IV of its Draft European Electronic Communications Code[49] that coinvestment models are exempted from cost-oriented pricing under certain cumulative conditions; as long as the access conditions are transparent and non-discriminating for third parties, it considers high capacity network elements and that competition conditions do not become worse. Furthermore, the Commission has proposed to exempt wholesale-only operators from price regulation as well, even when these possess significant market power. It is important that wholesale-only operators can focus on the roll-out of fibre infrastructure and the related wholesale offers for third parties. This pushes on the one hand the fibre roll-out and on the other hand the competition on the retail level, as can be observed in Scandinavian countries. The absence of price regulation ensures that the investments will deliver their expected returns over time.

Another possibility to steer investment in broadband infrastructures, especially with a view towards low density areas, is coverage obligations used and enforced as part of spectrum auctions. This is also foreseen in the Draft European Electronic Communications Code[50] in Article 47, where competent authorities receive the right the attach conditions to individual rights to use radio spectrum.

A regulatory approach that favours the deployment of new broadband infrastructure is likely to have a positive effect on the deployment of SDN and NFV. Although technology-neutral, it may be expected that any new deployment is likely to include (at least some aspects of) SDN and NFV. Consequently, the pro-investment approach that reflects in the revised telecommunications regulatory framework as shown in the examples above can be considered a driver for SDN and NFV deployment.

Weaknesses

Current regulatory framework perceived as being too static

One main benefit of SDN and NFV that has been highlighted throughout the present study is the potential to substantially shorten the time that is needed to develop new

49 European Commission (2016): Proposal for a Directive of the European Parliament and of the Council establishing the European Electronic Communications Code. COM(2016) 590 final.
50 Ibid.

services. The reason behind this is that these services are being defined in a virtual environment and there is no new infrastructure that has to be deployed. Participants at the workshops of this project have consistently stated their perception that the current regulatory is too static to allow for quick innovation in Europe. This assertion is reflected in academic publications[51] that highlight a potentially adverse effect of a mainly ex-ante (asymmetric) regulatory environment on especially large and SMP actors. It is however also argued that such a framework provide certainty to all market actors as it tends to be more prescriptive and specific. The current regulatory framework has a relatively strong focus on ex-ante regulation as compared with the upcoming Electronic Communications Code. Notably, hard quantitative or causal linkages between regulatory frameworks and innovation action are difficult to establish. Nonetheless, if a framework is perceived as being too static this perception alone may curb the intrinsic motivation to innovate.

Opportunities

Side-by-side development of open-source and industry standards

The main insight of many decades of innovation research is that innovation is neither a linear nor easy-to-monitor process. It is now commonly understood that innovation happens within a complex system of framework conditions, different actors, and economic incentives to name only a few potential parts of an innovation system. However, another common understanding is that competition among different streams of innovative activity is likely to foster innovation and improve the final outcome of the innovation process.

The ongoing innovation process of SDN and NFV is led by both open-source and typical standardisation work. This side-by-side development is likely to be advantageous for the final outcome of the process and thus can be understood as an opportunity for policy makers to facilitate the development of SDN and NFV.

Digitisation economic and societal potential

There is almost no area of economic and societal activity that is not influenced by digitisation in one way or another. The demand for high-performance networks is increasing rapidly. Recent studies into consumer behaviour show that consumers' willingness-to-pay for Internet access actually increases with their usage intensity of OTT services.[52] Although this is unlikely to fully solve the issues of broadband

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51 Pelkmans, J., & Renda, A. (2014). Doess EU regulation hinder or stimulate innovation? In. Brussels: Centre for European Policy Studies.; Bourreau, M., & Doğan, P. (2001). Regulation and innovation in the telecommunications industry. Telecommunications Policy, 25, 167-184.

52 Arnold, R. C. G., & Schneider, A. (2016a). OTT Services and Consumer Communication Behaviour in Germany. In. Bad Honnef, Cologne: WIK and Fresenius University of Applied Sciences
Arnold, R. C. G., & Schneider, A. (2016b). OTT Streaming Services in Germany. In. Bad Honnef, Cologne: WIK and Fresenius University of Applied Sciences.

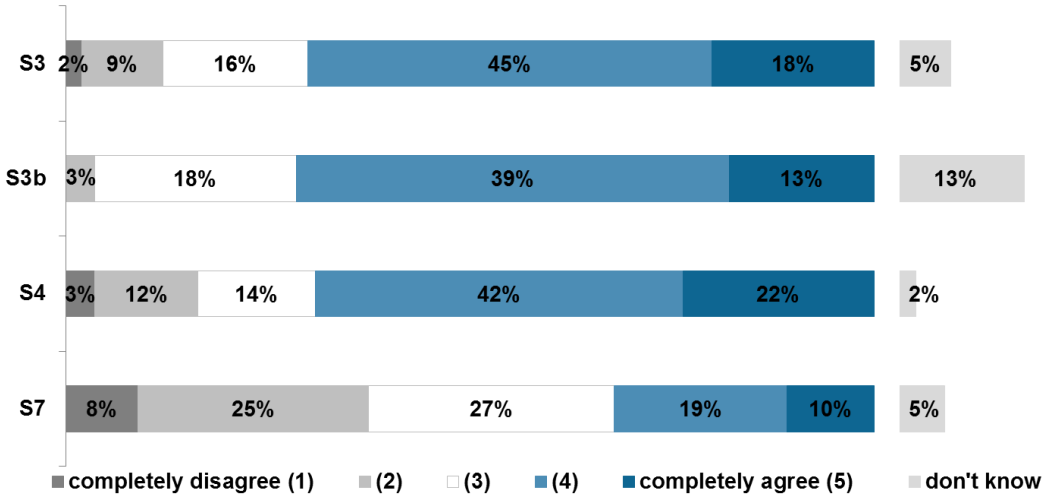
deployment in low density (rural) areas, it is a positive signal for both policy makers and telecommunications operators, who may profit from the trend to more intensive usage of OTT services. As such digitisation is a strong opportunity that policy makers can use to facilitate further SDN and NFV development and deployment, which is likely to play a part of most newly deployed networks.

Threats

Resistance from legacy actors

The Delphi study conducted for the present study shows that there are potentially significant challenges in the transition from legacy infrastructures to virtual networks. Experts on the panel see these challenges to be particularly pronounced with the transition of Mobile Core Networks (S4). For this usage scenario, more than half of the experts who responded to both rounds of the Delphi study expect significant transition challenges, with 22% of them agreeing strongly. For VNPaaS (S3/b), a similar effect is foreseen by the experts on the panel. Fewer transitional challenges are expected for vCDN (S7).

Figure 7-2: Transition Challenges



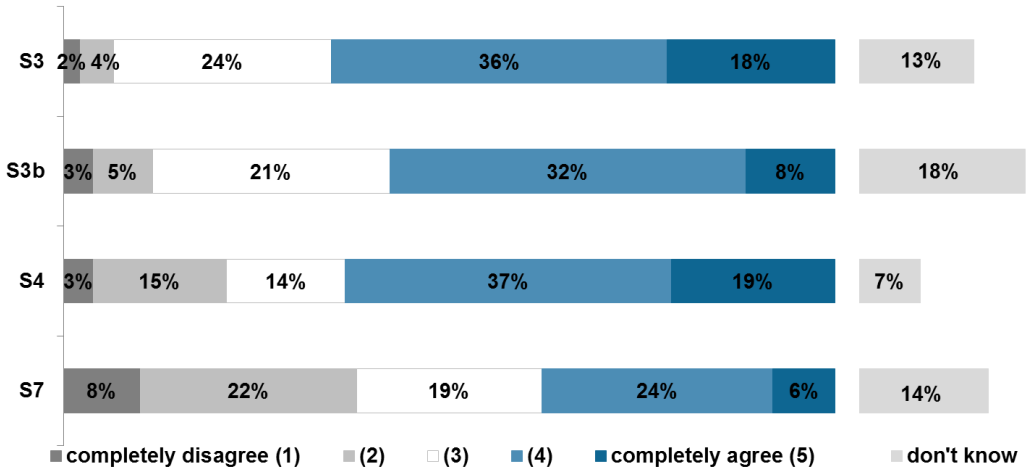
Source: Delphi Questionnaire

Such challenges may include resistance from legacy infrastructure owners or technical issues such as interoperability between legacy and virtual networks. To facilitate the development and deployment of SDN and NFV, policy makers should closely monitor the transition process and potentially intervene when they identify issues that may constitute market failure.

Challenges in terms of change management

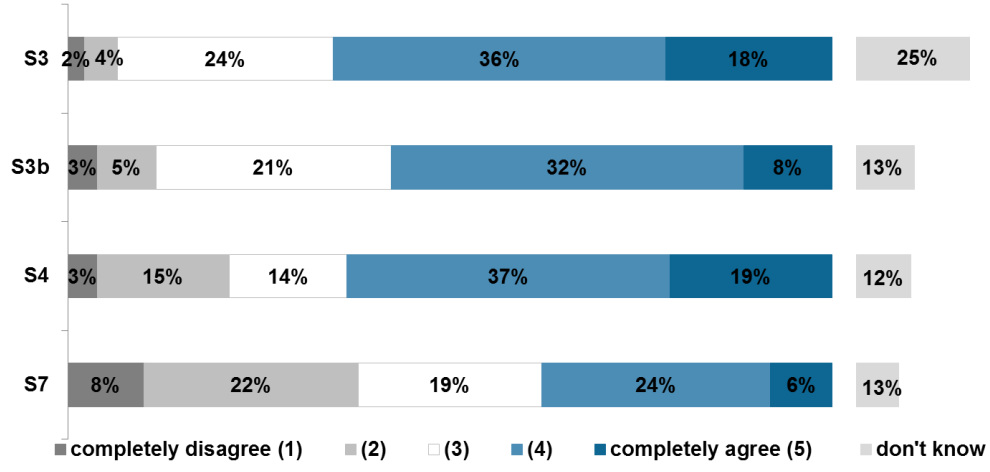
In a similar vein, the experts on the Delphi panel foresee internal management challenges and challenges referring the rearrangement of organisational structures in telecommunications operators in the deployment of the usage scenarios analysed in the present study. The challenges for internal management are rated similarly by experts for vNPaaS (S3/b) and vMCN (S4). For vCDN (S7), fewer experts foresee significant internal management challenges. The requirement for organisational changes is rated similarly by experts.

Figure 7-3: Internal Management Challenges



Source: Delphi Questionnaire

Figure 7-4: Organisational Challenges



Source: Delphi Questionnaire

Uncertainty about the effects, impact, and implications of SDN and NFV

Throughout the project, it transpired from the workshops and the expert interviews that there is still substantial uncertainty as regards the specific effects of SDN and NFV. As the Gartner hype-cycle presented at the beginning of this chapter shows, it is likely that various inflated expectations may not be fulfilled in the actual deployment of SDN and NFV. Thus, the results from the Delphi study and the workshops conducted as part of this study should be interpreted with some care and may have to be reviewed as soon as the effects of SDN/NFV deployment have become more visible.

Implications for policy makers

The implications for policy makers that emerge from the SWOT analysis have been discussed in light of the Draft Electronic Communications Code,[53] which already addresses various issues mentioned in the above. Article 3 lists the objectives of the Electronic Communications Code:

- Promotion of take-up of of very high capacity data connectivity
- Promotion of competition in the provision of electronic communications networks including efficient infrastructure-base competition
- Development of the internal market by developing common rules and predictable regulatory approaches
- Promotion of the interests of citizens of the Union

Within these objectives, the upcoming framework explicitly factors in SDN/NFV roll-out as it is likely to pose new challenges for the existing rules.[54] Given the current market development and take-up of SDN/NFV technology by various market actors, there seems to be relatively little need for policy action with the aim of reaping the benefits of SDN/NFV deployment in Europe e.g. more cost efficient provision of ECS. Beyond efficiency gains, SDN/NFV is also a driver for innovative services. The support that is already provided by the European Commission to promote innovation in network technologies has been highlighted as a strength in the SWOT analysis. Continued support, e.g. through the Horizon2020 and related programmes, is likely to play an important role in developing essential network technologies in Europe. A pro-investment regulatory like the upcoming one further supports innovation by creating incentives for new infrastructure deployments. Fiscal policy that reduces the cost of R&D is also likely to have a positive effect on innovation and GDP in the long term.[55] In fact, network technologies are likely to have a disproportionately large effect on GDP given their importance for various innovative services in health, transport, or energy.

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53 European Commission (2016): Proposal for a Directive of the European Parliament and of the Council establishing the European Electronic Communications Code. COM(2016) 590 final.
54 These potential challenges are discussed in more depth in the following sections.
55 IMF (2016): Fiscal Monitor.

The current relatively static regulatory framework has been mentioned in particular by workshop participants as a weakness of the European policy framework. The Draft Electronic Communications Code considers that while the key principles of the framework remain valid, significant adjustments are necessary to provide necessary incentives for both incumbents and competitors to make economically viable investments or co-investments in future networks that are in principle capable of providing very high capacity connectivity to every citizen and business in Europe. Specifically, SDN and NFV have been factored into the review process.[56] The Code offers more long-term legal certainty for market actors since its review period has been extended from three to five years. Also the Open Internet Regulation that has sometimes been discussed critically during the workshops in this project provides no obvious obstacles to offering innovative service based on SDN/NFV. Most notably, the regulation and the accompanying guidelines explicitly do not require an ex-ante authorisation of any specialised service. This is an example where ex-post evaluation and potential sanctions in case of any harm to the open Internet is identified opens room for innovation both by established and new actors in the market.

As opportunities and threats are external factors, the immediate influence of policy makers and regulators over them is naturally limited. However, they can react to them and steer the framework conditions that they have influence over in a way that allows them to seize the opportunities that are there and to avoid the threats as far as possible. Within that, it is naturally essential to adhere to fundamental principles of regulation and policy making, such as technology neutrality.

As regards opportunities, the side-by-side development of open-source and typical standardisation in line with the findings of innovation research is likely to improve the overall outcome of the SDN and NFV innovation process. Furthermore, this side-by-side development process is likely to keep the process open for both small and large stakeholders. Thus, it is likely to stimulate open competition. However, it should be noted that during the workshops of this project, there were also raised concerns about the co-existence of open-source and standardisation processes. Concerns revolved mainly around the uncertainty and potential liability issues that open-source codes may bring. For standardisation processes, experts were concerned about actors deliberately holding back such processes to safeguard their established business models and their legacy infrastructures. Consequently, policy makers and regulators should closely monitor both processes and their (incremental) outcomes.

The overarching opportunity of digitisation has most certainly been recognised by policy makers. With the Digital Single Market and adjoining initiatives, the Commission is already using this opportunity. Most Member States have put in place their own digital

56 European Commission (2016): Proposal for a Directive of the European Parliament and of the Council establishing the European Electronic Communications Code. COM(2016) 590 final (Explanatory Memorandum).

agendas. Essentially, the harmonisation of regulation, rules, and policies across Member States will be an essential precursor for multinational service provisioning across different networks e.g. for multinational companies. While SDN and NFV will facilitate the development of such services significantly, the Commission provides important support by setting the right framework conditions for such services to actually become available in the market.

As regards the threats identified in the above, policy makers and regulators should continuously gather information and closely monitor the deployment process. Sufficient information about the internal and external challenges to deployment will enable them to anticipate potential market failure or similar issues that may necessitate policy action. Given the uncertainty in the market and the fact that smaller businesses are unlikely to be familiar with the technology and its possibilities at all, it may be advisable to share the knowledge, e.g. R&D insights created in Horizon2020 projects that the Commission gathers. It is already well-equipped to multiply such information using its substantial outreach online and offline.

Besides these overarching policy implications, SDN and NFV may potentially affect telecommunications regulation. Given that SDN and NFV are at such an early stage of deployment, it is however difficult to foresee the specific effects. This is also reflected in the BEREC input paper on potential regulatory implications of SDN and NFV.[57] Nonetheless, some indications for potential implications of SDN and NFV for telecommunications regulation can be drawn from desk research, expert interviews, and the Delphi expert panel conducted as part of this study. Notably, the findings of this study are by and large in line with the findings presented in the BEREC input paper.

7.2 Regulatory Implications of SDN and NFV

7.2.1 Introduction

In light of this uncertainty, this section deliberates some fundamental principles of when and how regulation ought to come into play. While such a discussion naturally concentrates on overarching issues such as ensuring healthy competition, it seeks to position SDN/NFV and services that this technology is likely to enable within this

57 BEREC (2016): Input paper on Potential Regulatory Implications of Software-Defined Networking and Network Functions Virtualisation. BoR (16) 97. This input paper is based on a fact-finding process that BEREC has set up to anticipate the regulatory implications of SDN/NFV. A first expert workshop took place in January 2016. This workshop showed that SDN/NFV may functionally replace some traditional access products and facilitate new forms of network interconnection. Equally, however, the participants in this workshop concurred that there is significant uncertainty as regards the diffusion of SDN/NFV in networks for the foreseeable future, the emerging market structures as well as the emergence of actors with significant market power. Consequently, no recommendations for or against any specific regulatory action emerged from the workshop. It is obvious nonetheless that BEREC will further observe the development towards the virtualization of network functionalities as well as any emerging regulatory implications.

discussion. The findings from desk research, discussion with BEREC representatives, additional expert interviews, and the results of the Delphi expert panel are used throughout the section to reflect and discuss the current state of the discussion. Given the innovative momentum of SDN/NFV, this section will also draw on general insights on innovation policy and technology diffusion to provide an overarching evaluation of whether there is a need for regulatory action in the foreseeable future, referring to the way that networks and services are delivered to users, when using SDN/NFV or related technologies. While the fundamental results of the present study do not differ significantly from the insights presented by BEREC in their Input Paper on SDN and NFV,[58] the discussion in this report adds empirical insights from the Delphi expert panel, an international view of NRAs' publicly visible activities in this area as well as an in-depth discussion of potential network neutrality implications in light of the BEREC Guidelines that had not been published at the time when BEREC Input Paper was written.

In the questionnaire of the Delphi panel, the experts gave their expectations as regards the need for regulatory intervention linked to eight specific usage scenarios (in the first round) and the selected three usage scenarios (in the second round). Notably, their expectations as regards the necessity for regulatory intervention rarely differ significantly across usage scenarios, clear trends emerge however, as regards the specific areas of regulation. On average there is an indication towards less need of regulatory intervention in future partly due to SDN/NFV.

Overall, this section attempts to position SDN/NFV in the current telecommunications regulation framework. Again, the uncertainty as regards the creation of relevant services, their actual diffusion, emerging market structures, and emerging actors with significant market power makes this a difficult task.[59] Additionally, it is important to point out that while SDN/NFV may offer the same functionality as some existing access and interconnection products, the physical infrastructure, to which most telecommunication regulation applies, remains unchanged.[60] Essentially, this mirrors the debate around substitution of Over-The-Top (OTT) communication services for traditional Electronic Communication Services (ECS) to some extent. In this case, there is arguably some functional substitution, but traditional telecommunication regulation does not apply. Notably, the proposed European Electronic Communications Code redefines the term 'electronic communications service' (ECS) based on a functional approach. It contains three types of service categories: (i) internet access service, (ii) interpersonal

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58 BEREC. (2016). Input paper on Potential Regulatory Implications of Software-Defined Networking and Network Functions Virtualisation - BoR (16) 97. In. Riga: Body of European Regulators for Electronic Communications.

59 ETNO in its response to BEREC's work programme 2016 cautions against premature regulatory actions in the field of SDN/NFV fearing that innovation may be stifled (p. 4).

60 ECTA's response to BEREC's work programme 2016 supports this understanding: "In ECTA's view, such technological developments do not seem prima facie to affect the physical network layer and thus would not affect the need to retain regulation in market 3a. The same is likely the case for Layer 2 transport as such, and hence it would not affect the need to retain regulation in markets 3b and 4." (p.19).

communications service (ICS), distinguishing between number-based and number-independent ICS, and (iii) services consisting wholly or mainly of the conveyance of signals, such as transmission services used for M2M communications and for broadcasting signals.

The final section of this chapter will mostly draw on the results of the Delphi expert panel and the discussion of the preceding sections to discuss where the current regulatory telecommunications framework may affect the diffusion of SDN/NFV and if there are any foreseeable effects of SDN/NFV that are missed at the moment.

7.2.2 NRAs' (public) view on SDN and NFV

Apart from BEREC's efforts on the topic, there is little visible activity from NRAs around the world in this topic at all. In light of the early stage of SDN/NFV's development, this is not surprising. A systematic review of the websites of 46 NRAs[61] revealed that only 12 of them showed any public activity on SDN/NFV. Even if there is some activity, at this point the publicly available documents refer almost entirely to initial fact-finding exercises undertaken by NRAs. Commonly, NRAs interact directly with industry stakeholders in these exercises. Notably, the angle from which SDN/NFV is approached differs somewhat across NRAs.

While AGCOM,[62] IDA,[63] MCMC,[64] and Ofcom look at SDN/NFV's general technical capabilities, ACMA,[65] ANACOM,[66] and FICORA[67] focus on its role in 5G developments. ARCEP,[68] MCA, and NKOM[69] approach the topic mainly from a

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61 **Europe:** ACM – Netherlands, AGCOM – Italy, AKAS – Slovenia, ANACOM – Portugal, ANCON – Romania, ARCEP – France, BAKOM – Switzerland, BEREC – European Union, BIT – Belgium, Beta – Germany, COMIC –Spain, Coreg – Ireland, CAR – Bosnia, CRC – Bulgaria, CTA – Turkey, CUT – Czech Republic, DBA – Denmark, ECA – Estonia, EETT – Greece, ESD – Latvia, FICORA – Finland, HAKOM – Croatia, ILR – Luxemburg, MCA – Malta, NKOM – Norway, NMHH – Hungary, Ofcom – United Kingdom, PTS – Sweden, RATL – Serbia, RRT – Lithuania, RTR – Austria, Teleoff – Slovak Republic, UKE – Poland, **North America:** CRTC – Canada, FCC - USA, IFT – Mexico, **South America:** ANATEL – Brasil, **Asia-Pacific:** ACMA - Australia, CFCA – Hong Kong, ComCom – New Zealand, IDA – Singapore, KCC – South Korea, MCMC – Malaysia, MOC – Israel, SOUMU – Japan, TRAI – India, **Africa:** ICASA – South Africa.

62 AGCOM commissioned a study into convergence scenarios, enablers and new services in future Internet developments that also describes the characteristics of SDN/NFV in some detail, concentrating on their effects on network resiliency. See: Menduni, E. et al. (2014): Future Internet: scenari di convergenza, fattori abilitanti e nuovi servizi. Report commissioned by AGCOM as part of the research programme "Servizi e contenuti per le reti di nuova generazione – SCREEN".

63 IDA looks at SDN/NFV developments from an IPv6 diffusion perspective. Exploring the fundamental technological capabilities of SDN/NFV are in the focus rather than regulatory implications. Information comes from industry actors.

64 MCMC notes SDN/NFV as part of Malaysia's evolution to a smart (digitised) nation.

65 ACMA explored some characteristics of SDN/NFV as part of 5G developments in mobile networks.

66 ANACOM has held a conference on future Internet technologies where SDN/NFV was discussed as part of 5G development.

67 FICORA is framing SDN/NFV in the discussion around 5G developments retrieving mostly technical information from industry stakeholders and referring to Tekes' work programme for 2015 to 2019 as a major future source of information.

68 ARCEP invited two representatives from the industry to discuss the business implications of SDN/NFV in their newsletter. See Maulay, V. (2014): Un impact économique encore incertain, mais prometteur

business angle. While ARCEP and NKOM do not mention any further need for action, MCA announces in its 2016 Annual Plan[70] to monitor the SDN/NFV developments closely and participate in BEREC's efforts to understand SDN/NFV's potential regulatory implications. They expect that SDN/NFV deployment "should facilitate the emergence of new and innovative pan-European electronic communication services."[71]

Similarly, NMIAH recognises the trend towards SDN/NFV. They expect a fundamental change in the cost structures for the introduction of new services by the deployment of SDN/NFV. In their view, this will likely have significant regulatory implications, In particular, they raise concerns over resulting market competition anomalies. Consequently, NMIAH announced in 2015 to analyse possible ways of regulatory intervention.[72] However, no further indication of this has been published on their website.

The FCC has discussed the implications of securing SDN/NFV extensively in a White Paper in its Cybersecurity Working Group.[73] This is however only the first step in a broader assessment of SDN/NFV's regulatory implications foreseen in the work programme for FCC's Technological Advisory Council (TAC)[74] in 2016.

Ofcom commissioned Fujitsu with a study into SDN/NFV published in 2014[75] that also elaborates regulatory implications as regards regulatory markets design, mobile networks regulation, net neutrality, security, and privacy, as well as potential competition issues. It was discussed among other venues in the Ofcom Spectrum Advisory Board (OSAB). While highlighting its potential for cost saving and new business cases, the OSAB highlighted likely barriers for SDN/NFV deployment in diverging national regulations with regards to taxation and data protection as well as the resulting need to build some level of regulatory control into the system in order to mitigate these issues.[76]

In fact, questions concerning the emerging competitive landscape ought to be at the heart of NRAs' interest.

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pour les opérateurs. And Fiocco, A. (2014): La virtualization ou la revolution des réseaux. Both articles published in ARCEP (2014): Les cahiers de l'ARCEP. No. 11 – Octobre 2014.

69 NKOM notes SDN/NFV as part of their considerations of cloud technology. They see it an opportunity for new business models, but do not mention any regulatory implications.

70 MCA (2016): Annual Plan 2016. Malta: Malta Communications Authority.

71 Ibid. p. 51.

72 NMIAH (2015): ORSZÁGGYŰLÉSI BESZÁMOLÓ. A NEMZETI MÉDIA - ÉS HÍRKÖZLÉSI HATÓSÁG ELEKTRONIKUS HÍRKÖZLÉSSEL ÖSSZEFÜGGŐ TEVÉKENYSÉGÉRŐL. B/2740. Budapest: National Media and Infocommunications Authority

73 FCC TAC Cybersecurity Working Group – Securing SDN NFV Sub-Working Group (2016): White Paper: Consideration for Securing SDN/NFV. Washington, DC: Federal Communications Commission.

74 Roberson, D. (2016): Technological Advisory Council. Presentation Work Programme Recommendations 2016

75 Fujitsu (2014): Carrier Software Defined Networking (SDN) – Technical Report. A study commissioned by Ofcom. Birmingham: Fujitsu.

76 Ofcom (2014): Minutes of "Ofcom Spectrum Advisory Board held on 13 October 2014 at Riverside House, 2a Southwark Bridge Road, London.

Although SDN/NFV may functionally substitute some products and services that currently fall under telecommunications regulation, the technology as such does not imply a call for any regulatory action. Consequently, (emerging) competition issues are the most important impetus for any potential regulatory action. Fujitsu's report commissioned by Ofcom concludes that "SDN and NFV technologies are unlikely to change the nature of interconnect between carriers, so existing interfaces and processes will remain relevant. […] SDN and NFV are unlikely to have a fundamental impact on regulatory markets […]".[77]

7.2.3 SDN/NFV and competition in the telecommunications landscape

As shown in this report, SDN/NFV can have a significant effect on the current telecommunications competitive landscape depending on some scenarios. At this point, emerging market structures are difficult to foresee. Generally, SDN/NFV are expected to lower typical entry barriers, such as investments in infrastructure or complex interconnection arrangements, rather than increase them.[78] Also, the systematic review of NRAs' publications on SDN/NFV did not reveal any indication of specific actors being able to make unfair use of their current market position. Equally, there are no obvious signs of (emerging) market actors with significant market power (SMP) in the envisaged scenarios. Nonetheless, some competition issues may require closer observation from NRAs.

Infrastructure providers are likely to remain in a position to be able to unreasonably discriminate specific service providers by foreclosure of some functions enabled by the API of the network[79] for some service providers, but not for others. Equally, infrastructure owners may unreasonably limit the degree of service and network integration permitted to e.g. OTT actors. Small carriers may be disadvantaged if northbound API applications become an integral part of large OTT actors' service delivery, which hence may require individually developed northbound APIs provided by carriers. While large carriers have the resources and the critical mass of users, smaller carriers may have difficulty making attractive offers to such large OTT actors. Hence, QoE of their customers may reduce and give these customers an incentive to switch to a larger carrier. This draws the attention of regulators to national and international standardisation efforts. While these may mitigate some competitive issues, large OTT actors may still refrain from the efforts of negotiating legal agreements with smaller carriers that cannot deliver a critical mass of consumers. Notably, SDN/NFV do not trigger such economies of scale effects. Nonetheless, they merit further observation.[80]

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77 Fujitsu (2014): Carrier Software Defined Networking (SDN) – Technical Report. A study commissioned by Ofcom. Birmingham: Fujitsu. P.41.

78 Portal, J. et al. (2015): Reshaping the future with NFV and SDN. The impact of new technologies on carriers and their networks. Arthur D. Little study for Bell Labs Alcatel-Lucent.

79 The so-called northbound API.

80 Fujitsu (2014): Carrier Software Defined Networking (SDN) – Technical Report. A study commissioned by Ofcom. Birmingham: Fujitsu.

The issue of vertical integration is naturally closely related to the previously discussed implications around competition. The efficiency rationale of vertical integration can be traced back to Coase.[81] Over the decades, it has received substantial empirical support.[82] The specificity of asset investments has been identified as the most important rationale for vertical integration. In the telecommunications sector, this rationale applies directly to the infrastructure investments necessary to provide electronic communications services (ECS).[83] If the envisioned SDN/NFV usage scenarios revolving around the idea of a more flexible use of physical resources come true, they will mitigate asset specificity to some extent. In turn, incentives for vertical integration may be reduced somewhat. This, however, rests on the premise that issues around access discussed in the above are resolved.

On the other hand, fully integrated carriers that are able to offer end-to-end solutions cross-cutting access network, metro network, mobile networks, and cloud-computing networks may be able to leverage SDN/NFV's potential better than carriers owning only a portion of the assets necessary. Concretely, integrated carriers may be able to offer a superior quality of service to its customers, as they can monitor and manage performance end-to-end. With access and standardised interfaces, this may also be technically possible for smaller carriers as well; however, costs of implementing such functions may be prohibitive. Even if costs of implementation are low, the complexity of multi-domain implementation is likely to slow down deployment, resulting in a competitive disadvantage.[84]

As it is expected that the deployment of SDN/NFV will open the competition for more actors such as equipment manufacturers, software companies, or OTT service providers, limiting one's view on carriers and operators as regards vertical integration is probably myopic. Although the specific incentives for vertical integration are difficult to foresee at the moment, regulators should broaden their market observation as regards SDN/NFV. Interestingly, Telefonica and China Unicom even imply in their White Paper[85] that a clear separation of software and hardware is advisable and that effective independence of the two should be ensured. To avoid lock-in effects, portability of software appliances of an SDN/NFV scenario, for instance network functions, should also be guaranteed. Again, this can be an area where revisions and additions to current regulatory frameworks may be necessary. In particular, the regulatory status of such new entrants has to be assessed.[86]

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81 Coase, R. H. (1937): The Nature of the Firm. Economica 4(16): 386-405.

82 For an overview see: Lafontaine, F. & Slade, M. (2007): Vertical Integration and Firm Boundaries: The Evidence. Journal of Economic Literature 45(3): 629-685.

83 Schneider, v. (1991): The Governance of Large Technical Systems: The Case of Telecommunications. La Porte, T. R. (ed.): Social Responses to Large Technical Systems. Control or Anticipation. Dordrecht: Springer Netherlands. P. 19-41.

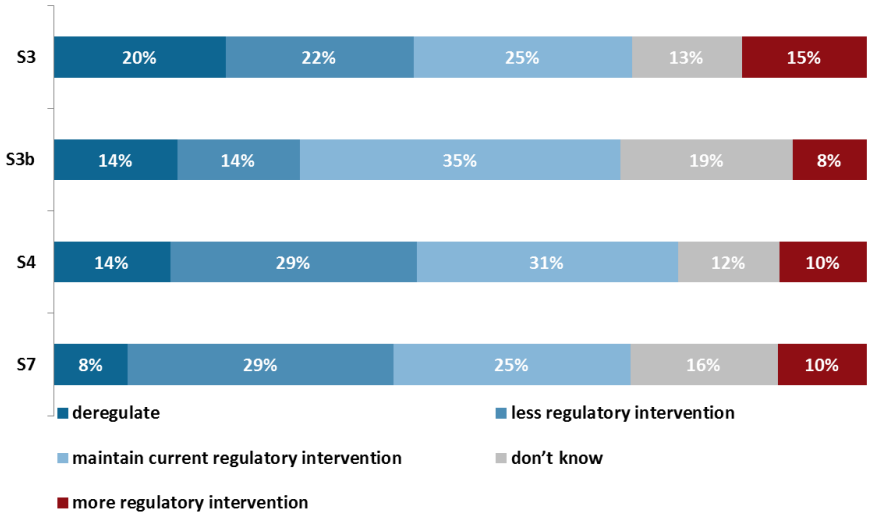
84 Fujitsu (2014): Carrier Software Defined Networking (SDN) – Technical Report. A study commissioned by Ofcom. Birmingham: Fujitsu.

85 Telefonica and China Unicom (2013): A joint Vision on Network Virtualization. White Paper presented at the "SDN and OpenFlow World Congress" in Bad Homburg, Germany.

86 Schramm, W. (2016): Regulatory Perspective on SDN and NFV. Keynote Presentation at the workshop on SDN/NFV regulatory impact as part of the present project (SMART 2015/0011) on 13th April 2016.

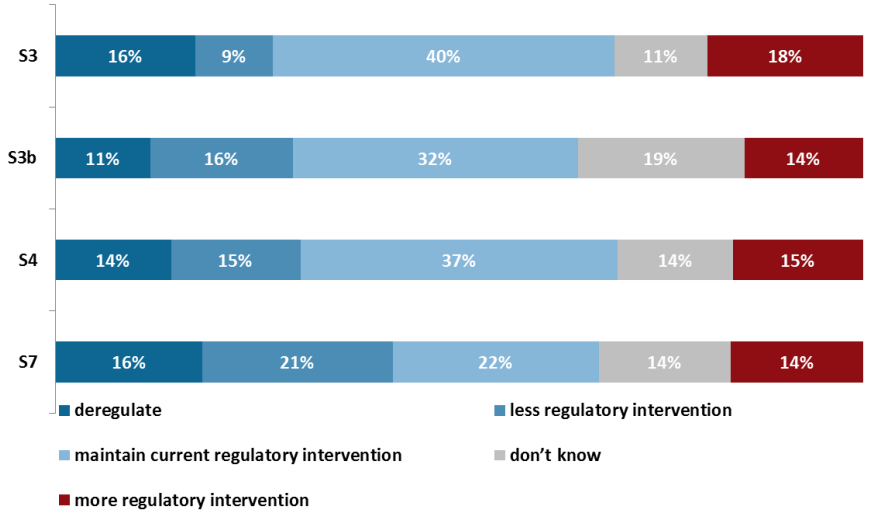
The results of the Delphi expert panel by and large reflect these deliberations taken from the literature. The vast majority of experts do not see any need for additional regulatory intervention as regards vertical integration. In fact, many experts in line with the idea that virtual networks may make it easier for new entrants to enter the market expect that more use of SDN/NFV will reduce existing constraints in competition, hence reducing the need for regulation as regards vertical integration.

Figure 7-5: Regulation on vertical integration/disintegration with services (upward integration)



Source: Delphi-Questionnaire

Figure 7-6: Regulation on vertical integration/disintegration physical infrastructure (downward integration)



Source: Delphi-Questionnaire

Participants at the workshop questioned the presumption that SDN/NFV are the or even one of the most important drivers of blurring boundaries between network operators and OTT players. They also expected less interest of OTTs to gain more control over the networks than they have already. First of all, participants concurred that such a move would contradict OTTs' objective to quickly roll out lean and highly standardised solutions globally. Secondly, it was noted that OTTs appear to have even less motivation to vertically integrate towards physical infrastructures apart from infrastructures they require internally, because this does not fit their business model.

However, it was mentioned at the workshop that completely new entrants may emerge based on the functionalities SDN/NFV offers. Such actors could be for example large enterprises that require control over network functions for new services they want to implement for instance autonomous driving.

7.2.4 SDN/NFV's potential implications on access and spectrum regulation

Besides competition-related issues, other areas of regulatory intervention merit further observation by NRAs as regards SDN/NFV's implications. The two topics that emerged from the analysis in this study as the most relevant ones are (1) Access to virtual networks and (2) SDN/NFV's influence on spectrum regulation.

SDN is expected to leverage the full potential of sharing a common physical infrastructure across many virtual network operators (VNOs).[87] As these VNOs will also need some degree of control over their virtual networks, there is a need for the infrastructure owner to provide an interface that allows both monitoring and managing of data traffic possibly even across networks of different owners. Offering such a level of control would be unprecedented in current agreements for VNOs and one may doubt that infrastructure owners would offer such capabilities to VNOs voluntarily. If it was the case and it could not be resolved by industry-led initiatives or standardisation efforts, regulators might need to intervene either by offering coordination or by revising the framework for access. Also, such interfaces might turn into a new form of market power for owners of substantial infrastructures. Current developments of OTT actors can be taken as a point in case here. For instance, if Google decides to change its mapping APIs this will likely put pressure on smaller actors who depend on this service and have aligned their internal processes with it.

The experts on our Delphi panel also highlighted this in their expectations as regards access to virtual networks. This was the only item, for which a substantial share of experts foresee a need for more regulation. A particularly high share of experts holds this view as regards VNPaaS (incl. the sub-scenario multi-tenancy VNPaaS) (S3/b).

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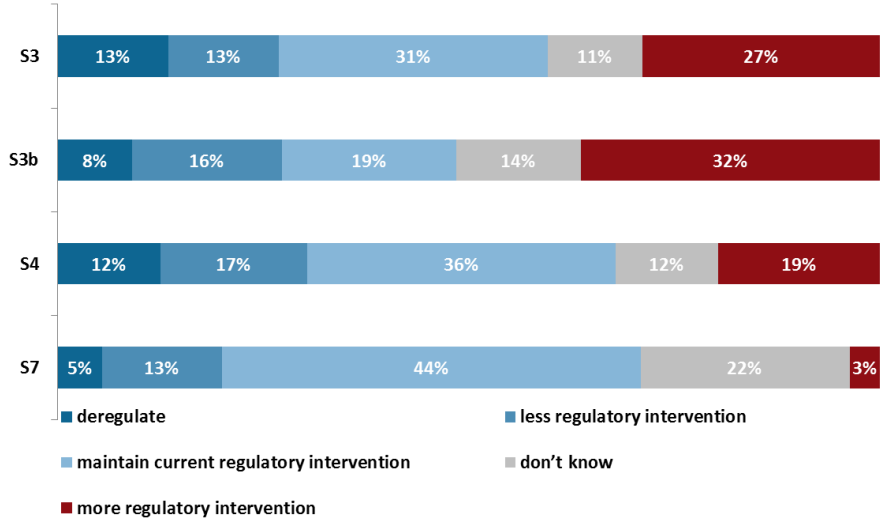
87 FTTH Council Europe (2016): FTTH Business Guide. Creating a brighter future. Edition 5. Brussels: Fibre to the Home Council Europe.

Figure 7-7: Implications for Access to virtual networks regulation



Source: Delphi-Questionnaire

Workshop participants did not see any need for access regulation to change in the light of SDN/NFV. The main argument was the SDN/NFV constitutes only a new (and still evolving) toolkit that enables the curation of network functions that have been used for a long time and have been scrutinised by regulators already. Given that these regulatory measures adhere to the technology neutrality principle, they ought to be fit to cope with SDN/NFV in the eyes of workshop participants.

Participants however noted that SDN/NFV may blur the retail point where access is granted. It was further noted that this may have some implications for regulation, which may have to be moved up or down the layers in order to be uniformly applicable. A downward movement implies that regulators would have to get much more involved in the technicalities of networks than they are right now. The implications of an upward movement were not discussed.

The Fujitsu report on SDN/NFV's regulatory implications commissioned by Ofcom provides further insights into this area of regulatory intervention. As regards wholesale local access it concludes that some LLU operators may use x86 servers to provide additional networking capability. Such a development may make it necessary to observe the impact on existing hosting product sets. The market for mass market and business grade wholesale central access is likely to have more significant regulatory implications due to SDN/NFV utilisation. For instance, regulators may have to control and potentially penalise discriminatory access to internal and external SDN/NFV services offered by the wholesale network operator. Refusal to support SDN/NFV capability in the network could be equally problematic for fair competition in this market. Although there is little commercial incentive for the wholesale operator to behave in

such ways, regulators ought to monitor these developments closely. For SDN/NFV products that would effectively substitute leased-line services such as Ethernet connections, regulators ought to take care not to inadvertently penalise SDN/NFV solutions by legacy regulation.[88]

The EU FP7 funded project DISCUS[89] suggests that a shared wavelengths access model, in which wavelengths for bandwidth management are shared across service providers and carry all service types, is the most efficient solution as regards capacity utilisation and assignment flexibility. In this model, which relies heavily on SDN, resources and user demands can be matched dynamically. Furthermore, capacity can be freely assigned between users and providers. A critical prerequisite of such a model is, however, an (incumbent) operator, who owns and controls the active and passive physical infrastructure. To arrive at such a model, it is suggested to initiate participation of virtual network operators through a standardised sharing interface, which can provide raw access to the management layer and offer monitoring and diagnostic functionalities. Hence, to install new hardware capable of resource virtualisation, while the network access may still be managed through the preceding system. Implementation of SDN would only be the third and final step.[90]

Essentially, a move to the SDN/NFV paradigm of network management brings similar benefits for mobile networks as for fixed networks. Thus, it is not surprising that the industry promises a significant reduction of operation and management costs.[91]

Most commonly, SDN/NFV are mentioned with regards to mobile networks in the evolution towards the 5G. Within that virtualisation technologies enable better resource allocation and mobility.[92] It is also stipulated that SDN/NFV will enable utilising MM-wave bands for front- and backhaul.[93] While these characteristics may be commercially relevant, their regulatory implications are very limited. However, SDN/NFV's expected capability of decoupling infrastructure, spectrum, and services[94] holds very significant implications for telecommunications regulation.

If this capability comes into play, a separation of spectrum owner and operators will become possible. Thus, capacity may be offered by spectrum owners to operators. This

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88 Fujitsu (2014): Carrier Software Defined Networking (SDN) – Technical Report. A study commissioned by Ofcom. Birmingham: Fujitsu.
89 FP7 – ICT – GA 318137.
90 DISCUS (2016): Final report on regulation, policy and multi-business model usage. Ref. Ares(2016)522690. Deliverable 3.7 of the Project DISCUS under FP7.
91 See for instance: Huawei (2016): From Today to Tomorrow – Huawei microwave & MM-wave Whitepaper.
92 Tullberg, H. et al. (2015): METIS System Concept: The Shape of 5G to Come. IEEE Communications Magazine.
93 METIS II (2015): Preliminary spectrum scenarios and justification for WRC Agenda Item for 5G bands above 6 GHz. Report R3.1 of the METIS II project funded under FP7.
94 For an in-depth discussion of this issue and current research challenges, see Mijumbi, R. et al. (2016): Network function virtualization: State-of-the-art and research challenges, IEEE Communications Surveys Tutorials, vol. 18, no. 1, pp.236–262, Firstquarter 2016.

gives new impetus to a concept dating back to the 1990s: Cognitive Radio (CR).[95,96] With more flexible (real-time) spectrum allocation, there is also the possibility of real-time brokerage of spectrum under a "use it or lose it" regime. The "use it or lose it" principle for spectrum usage would be a fundamental change from the current telecommunications regulatory approach. It dictates that spectrum owners may lose portions of their spectrum if they are not using it for a certain period of time in a given geographic location.

Masonta and Ngwenya[97] offer a cloud-based spectrum manager (CBSM) as potential solution for regulators to enable real-time spectrum brokerage and discuss its regulatory implications. The CBSM enables regulators to automate RF spectrum management.

The CBSM consists of five components, mirroring five central regulatory requirements:

- The *Core Spectrum Manager Decision Engine* handles spectrum administration including billing, security, and authorisation.
- The *Radio Frequency Monitoring and Enforcement Manager Decision* Engine polices spectrum usage among the licensees and other spectrum users. This entails processes of conflict resolution addressing, for instance, technical issues, or public safety.
- The *Spectrum Brokerage Manager* facilitates the process of assigning (leasing) spectrum among the stakeholders. It also controls that interference is kept below the regulatory limits. This could, for instance, be handled by a real-time auctioning system similar to Google AdWords.
- The *Spectrum Licensing Manager* interfaces with the stakeholders. It also manages the type approval process and provides all licensing administration. Furthermore, it can feature a graphic user interface for the regulator providing a detailed overview of spectrum usage in real-time.

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95 "An ideal CR is expected to be intelligent, self-aware, useraware, and machine learning in order to change its transceiver parameters based on interaction with its external environment. CR is attractive due to its frequency agility which promises to address the inefficiency and scarcity of RF spectrum problems. The frequency agile CR allows DSA by secondary users to coexist with licensed users without causing interference. Practically, CR builds on the SDR architecture with added intelligence to learn from its operating environment and adapt to statistical variations in the input stimuli for efficient resource utilization. Furthermore, CR is expected to be RF aware for improved quality of service (QoS) and quality of information (QoI) which promises to bring a paradigm shift in spectrum management. The ultimate goal of CR was to transform the radios from "blind executions" of predefined protocols to "radio-domain-aware" intelligent agents capable of delivering appropriate services." quoted from Masonta, M. T. & Ngwenya, D. W. (2015): Cloud Based spectrum Manager for Future Wireless Regulatory Environment. ITU (ed.): ITU Kaleidoscope 2015 - Trust in the Information Society. Barcelona, Spain, 9-11 December 2015: 124. See also: Mitola, J. (2009): Cognitive Radio Architecture Evolution. Proceedings of the IEEE 97(4): 626-641.

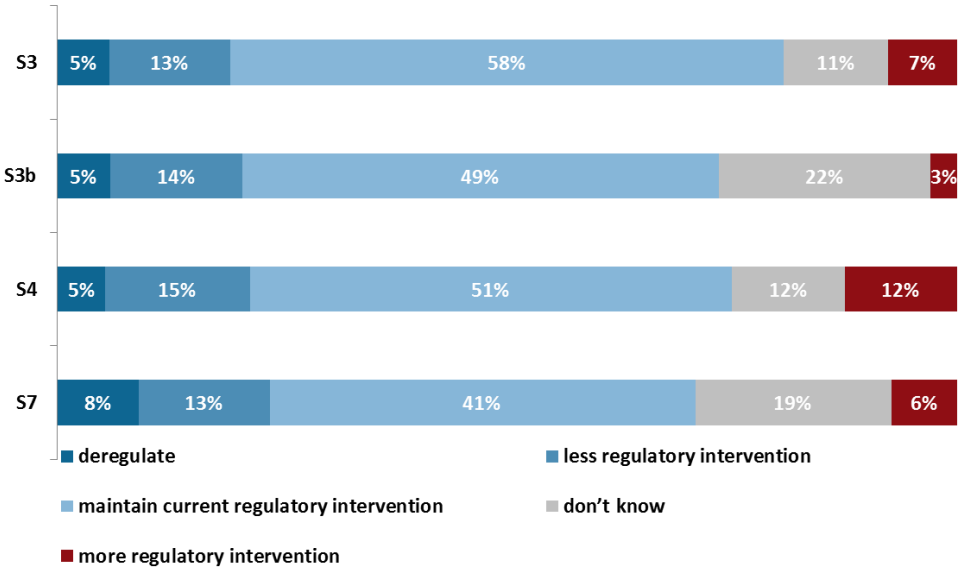
96 Andrews, J. G. et al. (2014): What Will 5G Be? IEEE Journal on Selected Areas in Communications Special Issue on 5G Wireless Communication Systems: 1-17.

97 Masonta, M. T. & Ngwenya, D. W. (2015): Cloud Based spectrum Manager for Future Wireless Regulatory Environment. ITU (ed.): ITU Kaleidoscope 2015 - Trust in the Information Society. Barcelona, spain, 9-11 December 2015: 121-128.

- The *Spectrum Planning Workflow* would automate spectrum allocation to a degree where there is little if any human interaction required.[98]

Experts on the Delphi panel predominantly expect spectrum regulation to remain untouched or reduced in light of the move towards SDN and NFV. There are no substantial differences in this regards for the usage scenarios tested in both rounds of the Delphi study.

Figure 7-8: Implications for spectrum regulation



Source: Delphi-Questionnaire

At the workshop, it was highlighted that real-time spectrum sharing may in theory be very sensible. In practice, various problems are likely to occur. Demand may be difficult to predict and therefore allocation of spectrum can hardly happen on a use it or lose it principle. Network operators would run the risk of losing customers due to service failure. Consequently, they are likely to refrain from such ideas. It was mentioned that big data predictive analytics algorithms may be able to mitigate this problem in the future. If this were the case, the economic benefits could be significant.

In summary, the fundamental logic of regulatory control and intervention in spectrum may not change by the utilisation of SDN/NFV-based technologies in mobile networks. However, the trend towards virtualisation is likely to alter NRAs' operation significantly as regards the licensing, allocation, and supervision of spectrum usage. Ultimately, regulators may even consider to outsource the operational part of their spectrum

98 Ibid. P. 126.

activities to a third-party provider that may be able to provide the service more efficiently, and instead concentrate on the supervision of spectrum allocation and conflict resolution.

7.2.5 SDN/NFV's implications for further areas of regulatory intervention

Beyond these two core regulatory areas, there are, for instance, various open questions with respect to the security of networks, APIs, and controllers. At the moment, there is a lack of standards that can safeguard SDN/NFV networks from unauthorised control of the communication over the API or the exchanged data itself. These unresolved issues that are not yet covered by established best common practices may require further coordination by NRAs just as well as standardisation bodies.[99]

While such threats to network security may pose a risk to the reliability and resilience of SDN/NFV-enabled networks, virtualisation in itself is likely to improve continuity of network performance even under difficult (disaster) conditions. To this end, ETSI has introduced a corresponding specification on resiliency requirements[100] that defines resiliency objectives as regards service continuity, automated recovery from failures, failure location in the network, resiliency in multi-vendor environments, and hybrid infrastructures. ACMA expects SDN/NFV to have a positive effect on mobile network resiliency as this technology enables a quick and continuous relocation of network functions in the network in disaster situations. For instance, damaged base stations functions could be relocated in the network to ensure reliable communications.[101] A report commissioned by AGCOM supports this point across all types of SDN/NFV-enabled networks.[102] Equally, the experts at the BEREC workshop on regulatory implications of SDN/NFV concurred with this position, at least in the long term.[103]

On the individual level, SDN/NFV may also have implications on data privacy that merit further observation by NRAs. The handover point from customer premises equipment (CPE) to the Internet service provider's network can be used for traffic snooping using an OpenFlow switch. This can, however, be done with currently deployed technologies, too. Second, the service chaining and content optimisation in an SDN/NFV-enabled

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99 FCC TAC Cybersecurity Working Group – Securing SDN NFV Sub-Working Group (2016): White Paper: Consideration for Securing SDN/NFV. Washington, DC: Federal Communications Commission.

100 ETSI ISG (2015): ETSI GS NFV-REL 001 V1.1.1: Network Functions Virtualisation (NFV) Resiliency Requirements. Sophia Antipolis Cede: ETSI.

101 ACMA (2016): 5G and mobile network developments – Emerging issues. Occasional paper. Canberra, Melbourne, Sydney: Australian Communications and Market Authority. The commercial viability of redundancy in mobile networks depends strongly on the requirements of the client. If the client requires a fully redundant network, e.g. banks or hospitals, then there is also a sufficient commercial incentive to provide such a network.

102 Menduni, E. et al. (2014): Future Internet: scenari di convergenza, fattori abilitanti e nuovi servizi. Report commissioned by AGCOM as part of the research programme "Servizi e contenuti per le reti di nuova generazione – SCREEN".

103 Schramm, W. (2016): Regulatory Perspective on SDN and NFV. Keynote Presentation at the workshop on SDN/NFV regulatory impact as part of the present project (SMART 2015/0011) on 13th April 2016.

network builds on an increased use of Deep Packet Inspection (DPI). Thus, deployment of virtual networks may have some privacy implications. While technology may make it somewhat easier to access personal information, the current regulatory framework safeguarding privacy is still applicable and there is no foreseeable need for further regulatory action.[104] Notably, the Regulation on the Open Internet[105] and the accompanying BEREC Guidelines[106] limit the processing of personal data in any traffic management measure to the degree that is necessary and proportionate to achieve the objectives. Traffic management measures have to be compliant with Directive 95/46/EC and Directive 2002/58/EC.

Finally, since SDN/NFV-based services address a global audience, national legislation and regulation may impede a rapid diffusion. In particular, small entrants into the market face great uncertainty as regards their services' compliance with national and local rules. Often they do not have the means to employ external consultancy, nor do they necessarily have the means to individualise their offers across various countries.[107] Notably, the virtualisation of networks makes it easier to comply with local rules and regulations, as they can be lodged into the software.

On this backdrop, it appears particularly relevant to understand first of all the concept of reasonable traffic management[108] as it is defined in the Regulation. This concept rests on the premise that reasonable traffic management shall not be motivated by commercial considerations, meaning that negative discrimination shall be avoided. Naturally, this general principle holds in the light of SDN/NFV utilisation.

SDN/NFV may have particularly positive effects on the management of congestion on the network as they offer to flexibly assign capacity where it is required. The most positive effects of using SDN/NFV can be expected to emerge from a continuous use of this technology. The way SDN/NFV is used could, however, be in conflict with the Regulation in some instances, in particular with regard to the use of traffic management measures that go beyond reasonable traffic management measures, such as throttling of traffic. Article 3(3) second sub-paragraph allows the implementation of reasonable traffic management measures, which “shall not be maintained for longer than necessary”. BEREC’s Guidelines interpret a trigger function for such a reasonable traffic management that is consistently installed not to be in conflict with the Regulation[109]. Article 3(3) third

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104 Fujitsu (2014): Carrier Software Defined Networking (SDN) – Technical Report. A study commissioned by Ofcom. Birmingham: Fujitsu.

105 Regulation (EU) 2015/2120.

106 BEREC. (2016). BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules. In. Riga: Body of European Regulators for Electronic Communications.

107 Gittik, Y. (2014): Distributed Network Functions Virtualization – An Introduction to D-NFV. White Paper. Tel Aviv: RAD.

108 The Code under Commitment 2, the Regulation primarily in Article 3(3).

109 Specifically, Guideline 73 states: “This does not prevent, per se, a trigger function to be implemented and in place (but with the traffic management measure not yet effective) on an ongoing basis inasmuch as the traffic management measure only becomes effective in times of necessity. Necessity can materialise several times, or even regularly, over a given period of time. However, where traffic management measures are in effect on a permanent or recurring basis, their necessity might be

sub-paragraph on the other hand prohibits non-reasonable traffic management measures such as blocking or throttling of traffic, with a limited number of exceptions, one of which is the prevention of impending network congestion and the mitigatation of the effects of exceptional or temporary network congestion, provided that equivalent categories of traffic are treated equally. Recital 15 on traffic management measures that go beyond reasonable traffic management measures is very elaborate in explaining the applicable conditions of temporary and exceptional congestion, and in explaining that "[r]ecurrent more long-lasting network congestion which is neither exceptional nor temporary should not benefit from that exception but should rather be tackled through expansion of network capacity". The Recital leaves no doubt that traffic management measures that go beyond reasonable traffic management for purposes of managing congestion are allowed as long as "[…] congestion occurs only temporarily or in exceptional circumstances".[110]

If SDN/NFV is used in supporting the delivery of specialised services this is possible under the Regulation, whose Article 3(5) allows the provision of such services provided a number of conditions are met[111]. The use of SDN/NFV can also be possible in traffic management measures that go beyond reasonable traffic management measures in order to "safeguarding the security and integrity of its network": this practice is compliant with the Regulation under the provisions of Article 3(3)(b) and Recital 14.

It is, however, important to note that the Regulation[112] applies to Internet access services (IAS), while it allows the provisionof specialized services subject to a number of conditions[113]. Article 2(2) further defines conditions to be considered in the decision whether a service qualifies as an IAS. There are two conditions to be considered. The first condition determines that neither the network technology nor the terminal equipment used shall play a role in determining what an IAS entails. The second condition determines the aspects that shall have an impact on the assessment. It comprises "a publicly available electronic communications service that provides access to the Internet, and thereby connectivity to virtually all end points of the Internet […]".[114]

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questionable and NRAs should, in such scenarios, consider whether the traffic management measures can still be qualified as reasonable within the meaning of Article 3(3) second subparagraph."

110 Recital 15 acknowledges that "[…] congestion might occur especially in mobile networks, which are subject to more variable conditions […]", but it is important to realise that this refers to temporary congestion only. In case it is "[…] predictable that such temporary congestion might occur from time to time at certain points in the network […]", the Regulation qualifies such predictable temporary congestions as non-exceptional ones – and it concludes for these cases "[…] that a capacity expansion would be economically justified".

111 These are services which are optimised for specific content, applications or services, or a combination thereof, where the optimisation is necessary in order to meet requirements of the content, applications or services for a specific level of quality. Such services can be provided only if the network capacity is sufficient to provide them in addition to any internet access services provided; they shall not be usable or offered as a replacement for internet access services, and shall not be to the detriment of the availability or general quality of internet access services for end-users.

112 Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015.

113 See footnote 119.

114 See also Recital 4.

The BEREC Guidelines clarify the scope of "publicly available ECS" as put forward in the Regulation: (1) it applies to providers of publicly available ECS and does not cover services or networks that are not publicly available; (2) technical limitations such as non-reachable endpoints due to failure or application of rules beyond the ISP's influence i.e. in other networks or the issues linked to addressing schemes (IPv4 and IPv6) do not preclude the definition of an IAS; (3) sub-internet services i.e. services that restrict acces to services or applications or allow access to only a pre-defined part of the Internet are recognised as a potential way for ISPs to circumvent the Regulation, consequently BEREC requires NRAs to consider such sub-Internet services as IAS in the sense of the Regulation, and an infringement of Articles 3.1, 3.2 and 3.3 of the Regulationand (4) services where the number of reachable end-points is limited by the nature of the terminal equipment used with such services are considered to be outside the scope of the Regulation unless they are used to circumvent this Regulation. Notably, if any of these services uses the IAS or are a SpS the connectivity service is subject to the rules of the Regulation.[115]

Thus, the key question to assess the above scenario is to what extent a product would have to differ from IAS and/or specialised services as understood in the TSM Regulation and guidelines in order to qualify as a product outside or inside of the Regulation's scope. This decision appears to be in the hands of individual NRAs which have to take utmost account of the guidelines. Consequently, some uncertainty remains for actors who want to offer SDN/NFV-based services as regards the interpretation of individual NRAs.

The aspect of being a potential replacement[116] for IASs refers to the Regulation's take on managed services as outlined in Article 3(5). Although it is important to reiterate that alternative products are not necessarily managed services, it is obvious that managed services are likely to play a role in some alternative products. If that is the case, it is essential for the overall alternative product's compliance to consider the Regulation's requirements for managed services in addition to the connectivity aspect discussed in the above.

The Regulation might not call them specialised services, but it obviously means (what is in the BEREC Guidelines referred to as) specialised services when it refers in Article 3(5) to "[…] services other than Internet access services which are optimised for specific content, applications or services, or a combination thereof […]". The Regulation clearly allows providers to offer specialised services. Given that the Regulation is technology-neutral, SDN/NFV could be used to realise such services.

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115 BEREC (2016): BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules. BoR (16) 127. (pp. 6-7.

116 It may in general be advisable for the Code to replace "alternative product" with "different product", or similar, in order to avoid any misleading signal that might emerge in terms of these products being alternatives – in the sense of possible replacements or substitutes – for Internet access.

Concretely, the Regulation characterises such services as "optimised" services in response to "requirements of the content, applications or services for a specific level of quality". It goes on to define that such services have the potential to "guarantee a certain level of performance", and refers to a corresponding "quality of service arrangement". Quality of service arrangements using slicing of the network may be an example of SDN/NFV utilisation, where further clarification is needed, provided that the Regulation addresses contractual agreements between providers and end users in Article 3(2) and Recital 7.[117]

It should be noted that the Regulation imposes prerequisites for specialised services. Providers of such services need to be able to demonstrate that the respective optimisation is necessary. Recital 16 demands that "[n]ational regulatory authorities should verify whether and to what extent such optimisation is objectively necessary to ensure one or more specific and key features of the content, applications or services and to enable a corresponding quality assurance to be given to end users, rather than simply granting general priority over comparable content, applications or services available via the Internet access service and thereby circumventing the provisions regarding traffic management measures applicable to the Internet access services." Further prerequisites introduced by the Regulation in Article 3(5)[118] embrace that managed services may only be offered if there is sufficient network capacity,[119] that they may not be a replacement for Internet access and that they "shall not be to the detriment of the availability or general quality of Internet access services for end users". Articles 4 and 5 lay down the corresponding contractual information as well as monitoring and reporting duties.[120]

7.2.6 Conclusion on SDN/NFV regulatory implications

Across all areas of regulatory intervention where SDN/NFV may have some implications that were considered in this chapter, it can be concluded that full assessment of the impact of SDN/NFV as such and usage scenarios enabled by SDN/NFV is not yet possible. There is too much uncertainty in regard to the possible future network functions, how they operate and which markets they might affect.

In line with this conclusion, it also seems premature to aim for immediate reflection of (potential) effects of SDN/NFV deployment in the upcoming regulatory framework for

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117 It should be noted in this context that the European Commission's Fact Sheet mentions "[…] that there can be no paid prioritisation of traffic in the Internet access service". See http://europa.eu/rapid/press-release_MEMO-15-5275_de.htm

118 See also Recital 17.

119 Note that the Code also refers to the relation between managed services and Internet access services, but it does so by recognising "[…] the importance of best efforts Internet access being a viable choice for consumers alongside any managed services that might be developed and offered".

120 This section draws on Waldburger, M. & Arnold, R. (2015): Review of the Open Internet Codes. A Study for the Broadband Stakeholder Group. Bad Honnef: Wissenschaftliches Institut für Infrastruktur und Kommunikationsdienste.

electronic communications networks and services by the European Commission. As exemplified in particular by questions 49 through 52 in the questionnaire for the public consultation on the review of the regulatory framework, it is however relevant to understand the foreseeable implications of SDN/NFV better. Since SDN/NFV is an underlying technology, first and foremost, it is imperative that any revision of the regulatory framework adheres to the principle of technology neutrality. In many cases it may be difficult to isolate SDN/NFV in specific areas of regulatory intervention. Secondly, it is important to keep in mind the timeframes indicated by the Delphi expert panel for the tested usage scenarios. Based on these insights, it is quite clear that SDN/NFV will not reach significant diffusion before the next review of the regulatory framework has to be approached. There is probably little need to address SDN/NFV specifically in the present one beyond the way the technology is already factored in. Finally, given the overall uncertainty, a soft hands-off regulatory approach appears to be sensible if the objective is to have both a positive position of European players that offer SDN/NFV solutions as well as a sufficient take-up of services enabled by this technology. Premature regulatory intervention may harm European actors' innovation.

Overall, workshop participants were convinced that the existing regulatory instruments suffice to handle the foreseeable effects of SDN/NFV usage scenarios. On the other hand, it was questioned whether the Significant Market Power framework is still valid, given that full scope of potential effects is difficult to predict. Consequently, monitoring of SDN/NFV's effects appears to be necessary. Generally, participants asked for a deeper understanding of the technology by regulators, which they felt is not yet apparent.

Most notably, it was highlighted by participants that SDN/NFV is actually only a "toolset" that enables the curation of network functions that have been existing in the market for a long time now, and have therefore already been the object of scrutiny by regulators for many years. Consequently, there were doubts whether SDN/NFV as such should be the focal point of regulatory attention at all.

Although SDN/NFV may facilitate a more international approach of network resources, that leads to e.g. subscriber data may be moved across national boundaries within the EU, workshop participants did not see this as an issue. First of all, compliance with national rules can more easily be integrated into the software. Thus, virtual networks can be aware of the regulatory framework in different locations and behave accordingly. Furthermore, many participants were under the impression that the existing legal and regulatory frameworks do not stand in the way of establishing international solutions. Some participants felt, however, that the rules may require more clarification.

Finally, it should be noted that the results as regards the regulatory implications of SDN/NFV across the various usage scenarios from the Delphi expert panel have to be interpreted with some care. For instance, it may be argued that each expert was already predisposed for or against regulation in general and this may have influenced the

responses. While it is only natural that any respondent does not enter any questionnaire in a *tabula rasa* state – in fact the Delphi method builds on the existing expertise – the differences across different areas of regulatory intervention as well as across some usage scenarios show that experts' predispositions did not unduly bias their expectations. Furthermore, it is important to emphasise that the questionnaire did not ask the experts to state whether more regulation was required or whether they wished for more or less regulation, but aimed at their expectations as regards whether more or less regulatory action was likely.

8 Annex

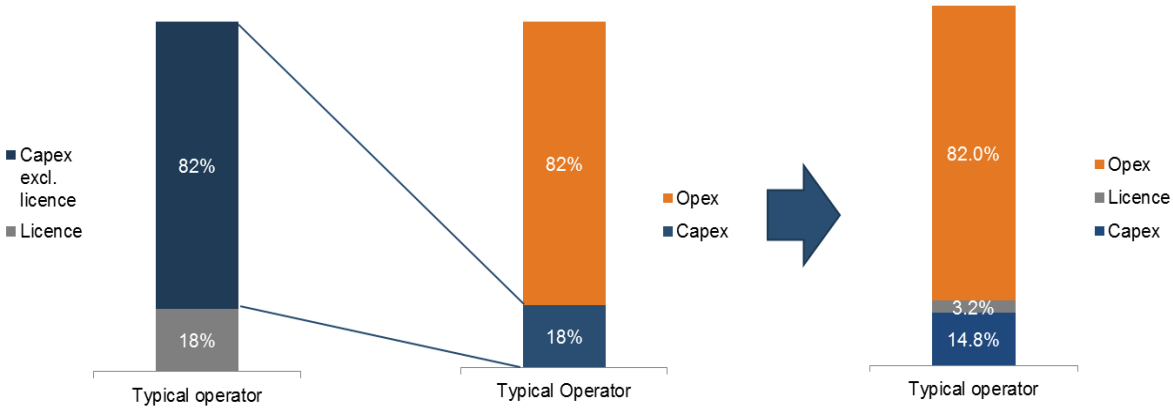
8.1 Concept of the IDATE telecommunications cost model

This cost model framework has been built mainly in the 2013-2014 period, but it still applies with the same order of magnitude. It was established by benchmark P&L reports from major telcos in Europe and USA[121], essentially incumbents with integrated activities (i.e. both fixed and wireless) and strong domestic footprint plus often multi-country activities, including those from smaller countries (Belgium, Switzerland, Austria, Scandinavian countries). It is also built on third party analyst (CapGemini, Deloitte, AT Kearney, Analysis Mason) guidelines for cost model.

8.2 Principles of the IDATE telecommunications cost model

Some calculations have been nonetheless necessary to integrate both CapEx (which generally does not include spectrum license fees in financial statements) and OpEx (which does not include depreciation and amortisation, which are considered in the US financial statements) in the same cost model. Additional calculations have also been necessary to reconcile spectrum costs (generally included into cash flows).

A first breakdown of costs was therefore to calculate the cost of licences compared to CapEx. A second operation was to compare OpEx (not taking into account amortisation and depreciation to avoid double counting CapEx) and CapEx. As a conclusion, we get the first following breakdown of costs.



121 A few non-European telcos were also considered, with incumbents in Japan, China and Russia.

CapEx can then be broken down by taking into account investments per type of part of the network considered (access, backhaul, core) and other non-network spending (like IT costs and civil works). Such information is provided by some of the telcos or equipment vendors analyzed.

OpEx is generally presented through various breakdown by telcos, depending on their financial statement approach. US players distinguish sales, network and G&A while European have a generally more detailed approach, but with some of the data provided being spread over the three cost categories mentioned above. The table below summarizes the typical European cost breakdown.

Cost breakdown	Type of cost
Staff/Labour costs	Network, Sales and G&A
Interconnection/payment to other operators	Network
Advertising/Marketing	Sales
Sales/Commissions	Sales
Energy	Network, Sales and G&A
Land&properties	Network, Sales and G&A
Various network costs (outsourcing, maintenance/repairs, etc…)	Network
Devices/Raw materials	Sales
Other (taxes, consulting,debt, etc…)	G&A
Depreciation, amotizment	N/A

A deep dive into all those categories on some specific telcos providing more information has allowed providing more detailed breakdown.

8.3 Key results

The cost model is detailed below, with network costs in the first table and sales, general and administrative costs in the second table.

Type of costs	Breakdown	% of total cost (CapEx + OpEx)
Network Infrastructure	Access/Radio	6.40%
	Backhaul/transmission	3.10%
	Core network	1.20%
	Licences/Spectrum	3.20%
IT (including datacentres)	Software+Hardware+Datacentre	2.30%
Operations	Operations and maintenance (incl Managed services)	15.10%
	Payment to operators (roaming, interconnection, etc..)	18%
Other network-related costs	Staff (Network & IT only)	6.10%
	Building, land, properties	1%
	Energy/Utilities	3%

Type of costs	Breakdown	% of total cost (CapEx + OpEx)
Sales	Sales internal staff	5.10%
	Distribution commissions (when using third parties)	2.90%
	Devices/CPEs (subsidies and internal specifications)	9%
Marketing/ Advertising	Advertising supplies	2.50%
	Marketing staff	0.90%
Customer Care	Customer care internal staff	2.70%
	Customer care supplies (e.g.third party call centres)	2.10%
Other sales-type	Building, land, properties	1.30%
	Energy/Utilities	0.30%
	IT for sales and customer care	1.30%
G&A	G&A Staff	3.20%
	Building, land, properties (G&A)	0.40%
	Energy/Utilities	0.10%
	Other (supplies, taxes)	8.80%

8.4 Documentation of Delphi Study

8.4.1 Questionnaire

Welcome to the SDN/NFV expert panel

Dear Expert,

first and foremost, we would like to thank you for your participation in the second round of our Delphi Study on behalf of the project team and the European Commission. The insights gathered in this foresight study will critically inform the European Commission's perspective on the subject of SDN/NFV deployment and corresponding use cases.

For the second round, the questionnaire focusses on the three usage scenarios that were selected to be carried forward for final phase of the study. You will find the average responses for the questions on these three usage scenarios in the first part of the questionnaire. If you have participated in the first round, you will be able to see your responses as well.

We ask you to consider your responses in light of the average results from the first round. If you want to revise your responses based on this new insights, please do so. If you decide to maintain a response that is far from the average please provide us with a short explanation, why you think that your response better represents the expectable development.

The next opportunity to discuss the results of the Delphi panel is the final workshop in this project on 30th June 2016 in Brussels. However, you do not have to join the workshop to stay up to date. You can access all information via our website http://sdn.wik-consult.com/. We look forward to a lively discussion with you.

Information regarding the survey:

- If you do not want to answer a question, you can skip it by clicking the "Next" button twice (a message informing you that you have not answered the question appears after the first click, the second click enables you to jump to the next question).
- It is also possible to navigate within the questionnaire using the "Next" and "Previous" buttons (please do not use the browser for navigation).
- Use the "Stop" button if you want to take a break from the survey and complete it later.

To access the survey later, simply log on using the link in the e-mail you received and carry on from where you left off before.

In case of questions concerning the general content of the questionnaire, please contact:
rene.arnold@wik.org

In case of technical problems with viewing, entering or taking the survey, please contact:
Umfragezentrum Bonn - Prof. Rudinger GmbH (uzbonn GmbH)
info@uzbonn.de

Questionnaire

"For the quality of our results, it is important that you feel comfortable answering our questions and have the right expertise. Thus, we would kindly like to ask you to indicate your field of expertise below. This will make sure that you only receive questions that you can relate to."

Question 1: Please indicate your field(s) of expertise as regards SDN / NFV.	
Please select all that apply.	
Technology	☐
Business strategy / Economic impact	☐
Policy / Regulation	☐
I cannot comment on any of the three fields mentioned above	☐

Question 2: Please indicate the type of organisation you are mainly working for.		
Please select all that apply.		
Telecommunications operator		☐
Equipment manufacturer/vendor		☐
Over-The-Top Service Provider		☐
Research institution		☐
Software Provider		☐
National Regulatory Authority		☐
Other	[Please specify]	

"First of all, we would like to ask you some general questions relating to your expectations as regards the general benefits and business impact of SDN / NFV. Please answer spontaneously based on your own expertise and expectations."

Question 3: In your opinion, what are the **top 3 benefits** of SDN and NFV in general?	
Please select three items from the left hand side and rank them from top 1 to top 3 in descending order on the right hand side.	
Reduction of CapEx - virtualised infrastructure equipment	TOP 3 RANKING EXERCISE
Infrastructure services – support for network slicing	
Reduction of OpEx - reduced time to repair'	
Reduction of OpEx - operation costs (automated management and configuration)	
Reduction of OpEx - energy consumption	
Automated provisioning	
Customer experience improvement - provision of custom services	
New revenue streams	
Independence from traditional network equipment providers	
Granular reporting for traffic management/monitoring	
Innovative service offers to end-consumers	
Innovative service offers to business customers	
Shorter development time of new network services'	
More flexible allocation of network resources	
Application services – New opportunities for providing network services to verticals	

Question 4: Please use the text box below to indicate any further benefits that you feel are missing from the list in the question above.
Please use the text box below. Please separate each benefit by a semi-colon.
[OPEN TEXT BOX – 2,000 characters maximum]

Question 5: Can you think of any policy action that would stimulate innovation of network services related to SDN and NFV in Europe? For instance, is there any legislation or regulation that currently hinders such innovation and that needs to be removed? Or is there a specific support measures that would be useful?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 6: How will the telecom value chain be affected by SDN and NFV **in the long-term**?				
Please indicate the players who will gain a significant share of the listed markets. Select any that apply.				
		Markets		
		Infrastructure – telecom and IT equipment	Network – connectivity provisioning	End-user services
Players	Network operators	☐	☐	☐
	Traditional Network Equipment Providers (NEPs)	☐	☐	☐
	IT equipment providers	☐	☐	☐
	Small and medium OTT players	☐	☐	☐
	Large OTT players	☐	☐	☐
	Software companies	☐	☐	☐
	Specialists in virtualisation	☐	☐	☐

“Thank you very much for entering your expectations as regards the general benefits and business impact of SDN / NFV. Your input is very important to the European Commission as well as our project and we look forward to discussing the results with you at the workshops in the second week of April 2016.

As part of the project, we would also like to hear your opinion on how SDN and NFV are going to be deployed. In the first workshop in Brussels, it discussed how deployment scenarios depend on the specific operator’s situation and its migration strategy. During workshop two possible deployment scenarios were presented as examples:

- **Waterfall model**, where complexity of deployment is controlled by changing just one aspect of the network at one moment. For example: moving from manual control of the network to agile (automated) control of the network / resources and locations of VNFs, and when that transition is done, start the movement from a centralised data centre to a distributed data centre, and so on.
- **Dynamic / agile deployment**, where an operator is introducing changes in all aspects (BSS/OSS, migration from core to edge, from static to agile assigning of resources, single-domain to multi-domain) of its network, and actively managing the process.

Please keep these two ends of the continuum of potential ways to deploy SDN and NFV features in the network in mind when you respond to the following two questions that were added to the questionnaire in coordination with the European Commission.

Question 7: What are your expectations as regards the progress in automating deployment of network services using SDN and NFV management, orchestration and control. Please indicate the share of systems that will be managed predominately using each of the automation procedures below.			
Please fill in the share of systems in percent for the respective years indicated. The sum has been set to 100.			
Networks	2016	2020	2025
Manual configuration of SDN and NFV components (for example CLI or using scripts) (Question 7a)	ENTER %	ENTER %	ENTER %
Machine assisted configuration of SDN and NFV components (Question 7b)	ENTER %	ENTER %	ENTER %
Fully automated configuration of SDN and NFV components which is policy driven (Question 7c)	ENTER %	ENTER %	ENTER %

Question 8: What are your expectations as regards the progress in the process of real-time adaption of network service's resources and configuration based on user-demand using SDN and NFV orchestration and control, and reaction times for recovery in case of failures/outages: Please indicate the share of systems that will be managed predominately using each of the automation procedures below.			
Please fill in the share of systems in percent for the respective years indicated. The sum has been set to 100.			
Networks	2016	2020	2025
Manual configuration of network and adaptation of resources (Question 8a)	ENTER %	ENTER %	ENTER %
Machine assisted adaptation of resources (Question 8a)	ENTER %	ENTER %	ENTER %
Fully automated adaptation of resources (Question 8a)	ENTER %	ENTER %	ENTER %

Additional explanations:

"Machine assisted adaption":	Machine assisted adaptation of resources assets operators in creating necessary control signals for implementing changes in the network.
"Fully automated adaptation":	Fully automated adaptation of the resources means that the operator is defining a set of policies which is then implemented by the software.

"Thank you very much for entering your expectations as regards the deployment scenarios of SDN / NFV. Your input is very important to the European Commission as well as our project and we look forward to discussing the results with you at the workshops in the second week of April 2016.

This section of the Delphi Study questionnaire concentrates on usage scenarios based on the deployment of SDN / NFV. First of all, we would like to introduce to you the 3 usage scenarios that have been selected for further analysis in the study. Please take a moment to read the descriptions carefully, so you have got a good overview before you reply to the questions.

For each usage scenario, we will ask you exactly the same set of questions. Just like in the first round of this Delphi Study. This enables comparing usage scenarios at the workshops easier and greatly facilitates answering the questions for you. We acknowledge though that in some cases more specific questions may have had other advantages."

Overview of usage scenarios

Question 9: For each usage scenario, please indicate your expectation for its deployment potential in Europe.
Please select only one.

Virtual network platform as a service

Virtualised platform provided as a service:
Run your services on a platform that you do not own.

Question 9a	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don’t know	☐

Virtualisation of mobile core network

Flexible connectivity in the mobile core network:
Elasticity of connectivity in the mobile network can bring savings.

Question 9b [DROP DOWN MENU]	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don’t know	☐

Virtualisation of Content Delivery Networks (CDN)

Virtualised Content Delivery Network provided as a service:
Content delivery network flexibility – created and moved on demand, when and where needed.

Question 9c [DROP DOWN MENU]	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don’t know	☐

Virtual network platform as a service

Some companies want to keep full control over the services that run on their networks; in some cases they might even prefer to develop their own services. Service providers can offer these companies a Virtual Network Platform as a Service (VNPaaS). In that case the company can focus on running their services – now on a virtual network platform. By running services on a platform which is maintained and managed by a third party (the service provider), the company may realise savings.

Question 10: Can you please let us know, why you think that "Virtual network platform as a service" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 11: Can you think of any actions that policymakers could take in order to foster the success of "Virtual network platform as a service"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 12: For "Virtual network platform as a service" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
SME Business Networks (Question 12b)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Data Centre Networks (Question 12d)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Access Networks (Question 12e)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □

Question 13: When do you expect to see <u>significant</u> multi-domain deployment of "Virtual network platform as a service"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Additional Information

“multi-domain deployment”

The term *multi-domain* is used to indicate that a single (virtual) network service is deployed across multiple administrative operator domains. For the *VNPaaS* usage scenario, the platform on which third parties can define their network services extends for example over a Dutch, German and Danish telecommunication operator network. For the *vMobile Core Network* usage scenario, multi-domain means that the mobile network service extends over multiple operator networks (so there is no need for roaming!). For *vCDN using MEC* usage scenario, the content delivery network service extends over multiple operator domains using Mobile Edge Computing components in the access networks of different network operators. Towards the user, a multi-domain service appears as a single service. A requirement for realising multi-domain services is that management and orchestration entities from the different domains have to interact.

Question 14: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtual network platform as a service" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 15: Please let us know which hurdles or bottlenecks you see that might delay "Virtual network platform as a service".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 16: For "Virtual network platform as a service" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Virtual network platform as a service"…	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 17: For "Virtual network platform as a service" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 18: Please let us know if you have any further comments on "Virtual network platform as a service".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Virtualisation of mobile core network

NFV aims at the reduction of the network's complexity and thus wants to reduce operational costs by using standardised virtualisation technologies, and map them to high-volume hardware. By virtualising the mobile network core, network operators can assign available resources in a flexible manner and dynamically adapt to the current load of the network. This flexibility is important due to a high level of complexity in the mobile core network and fluctuating demand for network resources of end-users over time. Virtualising the mobile network core helps mobile network operators to save energy by activating the ‘sleep-mode’ for some of its base stations. Mobile core network resources can then be used for some other purpose until they are needed again.

Question 19: Can you please let us know, why you think that "Virtualisation of mobile core network" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 20: Can you think of any actions that policymakers could take in order to foster the success of "Virtualisation of mobile core network"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 21: For "Virtualisation of mobile core network" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
SME Business Networks (Question 12b)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Data Centre Networks (Question 12d)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Access Networks (Question 12e)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □

Question 22: When do you expect to see <u>significant</u> multi-domain deployment of "Virtualisation of mobile core network"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Additional Information
"multi-domain deployment"
The term *multi-domain* is used to indicate that a single (virtual) network service is deployed across multiple administrative operator domains. For the *VNPaaS* usage scenario, the platform on which third parties can define their network services extends for example over a Dutch, German and Danish telecommunication operator network. For the *vMobile Core Network* usage scenario, multi-domain means that the mobile network service extends over multiple operator networks (so there is no need for roaming!). For *vCDN using MEC* usage scenario, the content delivery network service extends over multiple operator domains using Mobile Edge Computing components in the access networks of different network operators. Towards the user, a multi-domain service appears as a single service. A requirement for realising multi-domain services is that management and orchestration entities from the different domains have to interact.

Question 23: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtualisation of mobile core network" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 24: Please let us know which hurdles or bottlenecks you see that might delay "Virtualisation of mobile core network".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 25: For "Virtualisation of mobile core network" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Virtualisation of mobile core network"…	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 26: For "Virtualisation of mobile core network" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 27: Please let us know if you have any further comments on "Virtualisation of mobile core network".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Virtualisation of Content Delivery Networks (CDN) using Mobile Edge Computing
Based on the comments received here an during the first two workshops, this scenario has been detailed to clarify which particular application we had in mind. Please refer to this description, when you consider your initial responses.

Mobile Edge Computing (MEC) is a technology in which cloud-computing capabilities are introduced at the edge of the mobile network, for example at the eNB or at another location in the RAN (e.g. collocated with CloudRAN). The scenario vCDN using MEC describes the situation in which a Content Delivery Network (CDN) provider uses MEC components of a network operator to deploy its CDN network functions, e.g. content caches. The edge locations are in this way part of the NFV Infrastructure. Pushing CDNs towards the operator edge can have advantages in terms of achieving lower latencies for content services, offloading the core and access networks and offloading end-user devices from computing and storage-intensive tasks.

Additional original description:
Streaming content is one of the fastest growing types of traffic in today's networks. This is mostly due to the rise smartphones, tablets and laptops – and the increased availability of content delivered over IP. This relates equally to linear (live) and non-linear (on-demand) content. Currently, CDNs are integrated into the operator's network and are typically distributed, in order to be as close as possible to the end-user. By basing CDNs on NFV, network operators may profit from higher flexibility in the network as they may assign resources dynamically (e.g. instantiating CDN servers on demand). This enables them to match the demand for content with its delivery efficiently.

Question 28: Can you please let us know, why you think that "Virtualisation of Content Delivery Networks" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 29: Can you think of any actions that policymakers could take in order to foster the success of "Virtualisation of Content Delivery Networks"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 30: For "Virtualisation of Content Delivery Networks" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
SME Business Networks (Question 12b)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Data Centre Networks (Question 12d)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Access Networks (Question 12e)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □

Question 31: When do you expect to see <u>significant</u> multi-domain deployment of "Virtualisation of Content Delivery Networks"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Question 32: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtualisation of Content Delivery Networks" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 33: Please let us know which hurdles or bottlenecks you see that might delay "Virtualisation of Content Delivery Networks".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 34: For "Virtualisation of Content Delivery Networks" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Virtualisation of Content Delivery Networks"…	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 35: For "Virtualisation of Content Delivery Networks" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 36: Please let us know if you have any further comments on "Virtualisation of Content Delivery Networks".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Optional Part

Thank you very much for your time and engagement. The remainder of the survey is optional. It shows the results of the remaining usage scenarios that will not be carried forward in the rest of the study.

Still, we would like to give you the opportunity to see how the other experts have responded to these usage scenarios. Of course, you can also revise and comment on your responses in this part of the survey.

Overview of usage scenarios

Question 37: For each usage scenario, please indicate your expectation for its deployment potential in Europe.
Please select only one.

Network Function Virtualisation Infrastructure as a Service (NFVIaaS)

Virtualised infrastructure provided as a service:
Use network infrastructure, don't own or maintain it.

Question 9a [DROP DOWN MENU]	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don't know	☐

Virtual network function as a service

Virtualised functions provided as a service:
Build a network from available building blocks, wherever they are.

Question 9b [DROP DOWN MENU]	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don't know	☐

Virtualisation of mobile base station

Base station on demand:
Make and break base stations when and where needed.

Question 9e [DROP DOWN MENU]	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don't know	☐

Virtualisation of home environment

Virtualised home network as a service:
Intelligence moves from home networks to the operator's domain.

Question 9f [DROP DOWN MENU]	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don't know	☐

Virtualisation of fixed access network functions

Virtualised fixed access network provided as a service:
Provision of fixed access to users with a few clicks – near-real-time.

Question 9h [DROP DOWN MENU]	
Please select only one.	
No deployment potential whatsoever	☐
Marginal	☐
Small	☐
Somewhat significant	☐
Significant	☐
Very significant	☐
Don't know	☐

Network Function Virtualisation Infrastructure as a Service (NFVIaaS)
All networks, large or small, require specialised hardware and cabling. A party providing connectivity via this network infrastructure is called network operator. A network operator does not need to own this network infrastructure to provide connectivity and the according services. With Network Function Virtualisation (NFV) most of the specialised network functions are run on general-purpose hardware (providing storage and computational power). NFVI (NFV Infrastructure) describes both, the set of virtualised network functions needed to provide connectivity as well as the processing and storage capabilities needed to run those virtualised network functions. Thanks to NFVI providers can either provide network services on their own infrastructure or alternatively via another service provider's NFVI. Therefore NFVI can be offered as a service to third parties which do not own their own infrastructure.

Question 38: Can you please let us know, why you think that "Network Function Virtualisation Infrastructure as a Service" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 39: Can you think of any actions that policymakers could take in order to foster the success of "Network Function Virtualisation Infrastructure as a Service"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 40: For "Network Function Virtualisation Infrastructure as a Service" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
SME Business Networks (Question 12b)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Data Centre Networks (Question 12d)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Access Networks (Question 12e)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □

Question 41: When do you expect to see significant multi-domain deployment of "Network Function Virtualisation Infrastructure as a Service"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Question 42: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Network Function Virtualisation Infrastructure as a Service" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 43: Please let us know which hurdles or bottlenecks you see that might delay "Network Function Virtualisation Infrastructure as a Service".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 44: For "Network Function Virtualisation Infrastructure as a Service" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Network Function Virtualisation Infrastructure as a Service" …	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 45: For "Network Function Virtualisation Infrastructure as a Service" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 46: Please let us know if you have any further comments on ""Network Function Virtualisation Infrastructure as a Service".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Virtual network function as a service

For most companies, providing communication services and applications within their own company is not their core business. Doing so means owning, maintaining and managing specialised network hardware and software. A company can achieve savings by moving network functionalities from purpose-built network elements to equivalent functionalities provided by NFVI (NFV Infrastructure) run by a service provider or a network operator. Functionalities of most network elements can be replaced by Virtualised Network Functions (VNF) – pieces of software, running on general-purpose processing and storage hardware. By running VNF on NFVI, companies may lower operational costs by outsourcing maintenance and management of the network to network operators or service providers. In such a way the company can gain increased flexibility in scaling (up and down) the needed networking capacity, and leaving the maintenance of the network to experts (network operators).

Question 47: Can you please let us know, why you think that "Virtual network function as a service" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 48: Can you think of any actions that policymakers could take in order to foster the success of "Virtual network function as a service"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 49: For "Virtual network function as a service" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
SME Business Networks (Question 12b)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Data Centre Networks (Question 12d)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Access Networks (Question 12e)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □

Question 50: When do you expect to see significant multi-domain deployment of "Virtual network function as a service"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Question 51: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtual network function as a service" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 52: Please let us know which hurdles or bottlenecks you see that might delay "Virtual network function as a service".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 53: For "Virtual network function as a service" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Virtual network function as a service"…	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 54: For "Virtual network function as a service" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 55: Please let us know if you have any further comments on "Virtual network function as a service"	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Virtualisation of mobile base station

Mobile networks provide not only voice but also data connectivity. Users expect to have internet access, and watch their favourite TV programs on their smartphones or tablets. A mobile network operator has to plan for its network to handle as many end-user requests as possible. For example, if the operator designs the network to handle all of the requests in the busy city centre during the day, a substantial share of the overall network capacity will be idling since there will be significantly less users. Virtualisation of mobile base stations helps locate and run the RAN (Radio Access Network) on standard IT servers, storage and switches. This approach is expected to provide savings in energy consumption, result in simpler maintenance and update of hardware, enable faster roll-out of new software releases to base stations, and make more efficient use of the available resources.

Question 56: Can you please let us know, why you think that "Virtualisation of mobile base station" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 57: Can you think of any actions that policymakers could take in order to foster the success of "Virtualisation of mobile base station"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 58: For "Virtualisation of mobile base station" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
SME Business Networks (Question 12b)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Data Centre Networks (Question 12d)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Access Networks (Question 12e)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □

Question 59: When do you expect to see significant multi-domain deployment of "Virtualisation of mobile base station"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Question 60: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtualisation of mobile base station" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 61: Please let us know which hurdles or bottlenecks you see that might delay "Virtualisation of mobile base station".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 62: For "Virtualisation of mobile base station" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Virtualisation of mobile base station"…	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 63: For "Virtualisation of mobile base station" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 64: Please let us know if you have any further comments on "Virtualisation of mobile base station".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Virtualisation of home environment

The home services currently offered by network operators are typically provided as a combination of services in the operator's network and dedicated Customer Premises Equipment (CPE), such as a Residential Gateway (RG) or a set-top box (STB). It is common for operators to make use of CPE from different vendors or multiple models of CPE from a single vendor. A heterogeneous CPE landscape implies a high level of complexity in managing the equipment. With the virtualisation of RGs and STBs devices at home will become simpler, cheaper and easier to manage since only basic functionality remains in the devices at home, whilst advanced functionality is moved into the network operator's domain. In addition to expected cost savings and simpler device management, software updates are assumed to roll out faster, new services can be deployed more easily, resulting in increased operational efficiency and customer satisfaction.

Question 65: Can you please let us know, why you think that "Virtualisation of home environment" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 66: Can you think of any actions that policymakers could take in order to foster the success of "Virtualisation of home environment"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 67: For "Virtualisation of home environment" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
SME Business Networks (Question 12b)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Data Centre Networks (Question 12d)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Access Networks (Question 12e)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never □	ENTER YEAR	Never □	ENTER YEAR	Never □

Question 68: When do you expect to see significant multi-domain deployment of "Virtualisation of home environment"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Question 69: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtualisation of home environment" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 70: Please let us know which hurdles or bottlenecks you see that might delay "Virtualisation of home environment".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 71: For "Virtualisation of home environment" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Virtualisation of home environment"…	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 72: For "Virtualisation of home environment" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 73: Please let us know if you have any further comments on "Virtualisation of home environment".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Virtualisation of fixed access network functions

Copper-based fixed network access is still the dominant method of connecting households to the internet. Their demand for data is continuously growing due to a rising amount of content (video, data), the move to delivering all types of content over IP, and the increase in quality of delivered content – for example moving from High Definition TV to Ultra High Definition TV. Matching higher demand for data was made possible thus far by using complex processing of signals and by shortening the 'last mile' part of the copper wire coming into homes. Currently, signal processing is happening in so-called 'street cabinets' which use dedicated pieces of hardware for this task. With the virtualisation of network functions, it is possible to use general-purpose hardware to process those signals. The use of virtualisation is expected to result in added flexibility, faster upgrades, faster provisioning, lower energy use and overall lower costs.

Question 74: Can you please let us know, why you think that "Virtualisation of fixed access network functions" will never [enter testing] / [be offered by some suppliers]?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 75: Can you think of any actions that policymakers could take in order to foster the success of "Virtualisation of fixed access network functions"?	
Please use the text box below to elaborate.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

OR

Question 76: For "Virtualisation of fixed access network functions" please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.						
Please fill in the year accordingly. Please keep in mind that some of the sites may already feature corresponding functionalities, while others may never feature them. Please indicate your personal expectation for each region.						
Networks	Europe		North America		Asia Pacific	
Home / SOHO Networks (Question 12a)	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐
SME Business Networks (Question 12b)	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐
Large Enterprise Business Networks (Question 12c)	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐
Data Centre Networks (Question 12d)	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐
Access Networks (Question 12e)	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐
Wide Area Networks (WAN) (Question 12f)	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐	ENTER YEAR	Never ☐

Question 77: When do you expect to see significant multi-domain deployment of "Virtualisation of fixed access network functions"?	
Please indicate the year, in which you expect to see significant multi-domain deployment.	
Year	[ENTER YEAR]

Question 78: When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtualisation of fixed access network functions" did you have in mind?	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 79: Please let us know which hurdles or bottlenecks you see that might delay "Virtualisation of fixed access network functions".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

Question 80: For "Virtualisation of fixed access network functions" please rate the following statements.						
Please indicate your approval from 1 = "completely disagree" to 5 "completely agree".						
"Virtualisation of fixed access network functions"…	1	2	3	4	5	Don't know
… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	o	o	o	o	o	o
… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	o	o	o	o	o	o
… will enable further new forms of network access or network sharing.	o	o	o	o	o	o
… will pose new challenges to interoperability across solutions from different suppliers.	o	o	o	o	o	o
… will lead to a strong information asymmetry among actors along the value chain.	o	o	o	o	o	o
… will lead to centralisation of control over critical network functions in the hands of a few actors.	o	o	o	o	o	o
… will pose significant challenges as regards the transitions from legacy to new processes.	o	o	o	o	o	o
… will pose significant challenges to the internal management of stakeholders.	o	o	o	o	o	o
The implementation of … will require significant organisational changes.	o	o	o	o	o	o
… faces a lot of resistance from established actors in the legacy ecosystem.	o	o	o	o	o	o

Question 81: For "Virtualisation of fixed access network functions" please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.	
Please indicate your personal expectation as regards future regulatory intervention using the drop down menu provided.	
Spectrum regulation (Question 17a)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Numbering regulation (Question 17b)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Other existing scarce resources regulation (Question 17c)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to SDN/NFV networks (Question 17d)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Access regulation to traditional networks (Question 17e)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Physical access topologies regulation (Question 17f)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Pricing regulation (Question 17g)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know

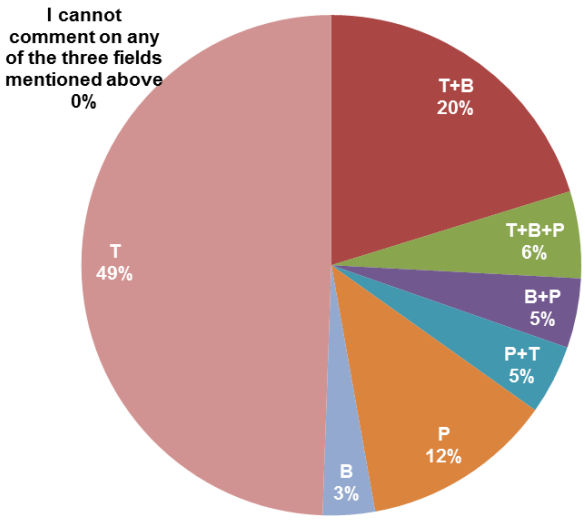
Regulation on vertical integration/disintegration with services (upward integration) (Question 17h)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
Regulation on vertical integration/disintegration physical infrastructure (downward integration) (Question 17i)	○ deregulate ○ less regulatory intervention ○ maintain current regulatory intervention ○ more regulatory intervention ○ don't know
New scarce resource regulation (please describe) (Question 17j)	Open text
Other (please describe) (Question 17k)	Open text

Question 82: Please let us know if you have any further comments on "Virtualisation of fixed access network functions".	
Please use the text box below to comment.	
Elaborate here:	[TEXT BOX 2,000 CHARACTERS]

8.4.2 Results

Please indicate your field(s) of expertise as regards SDN / NFV

Technology	Business strategy / Economic impact	Policy / Regulation	I cannot comment on any of the three fields mentioned above
71	30	24	0



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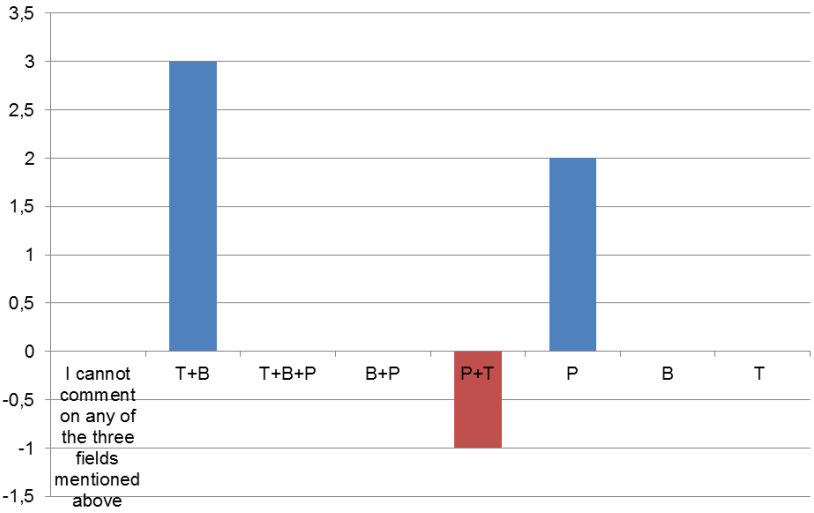
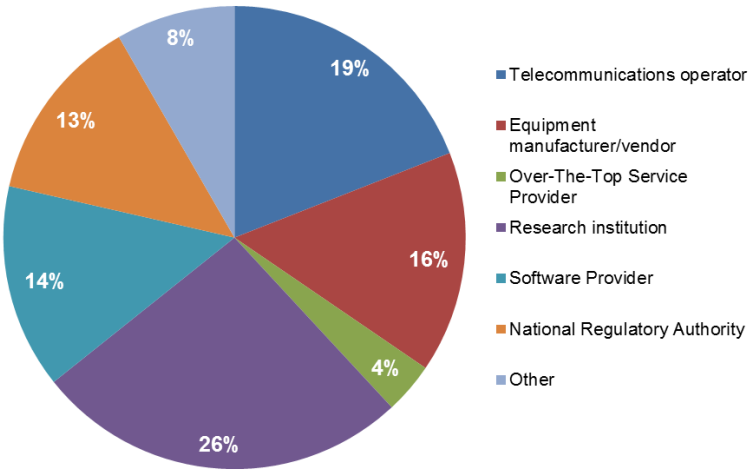


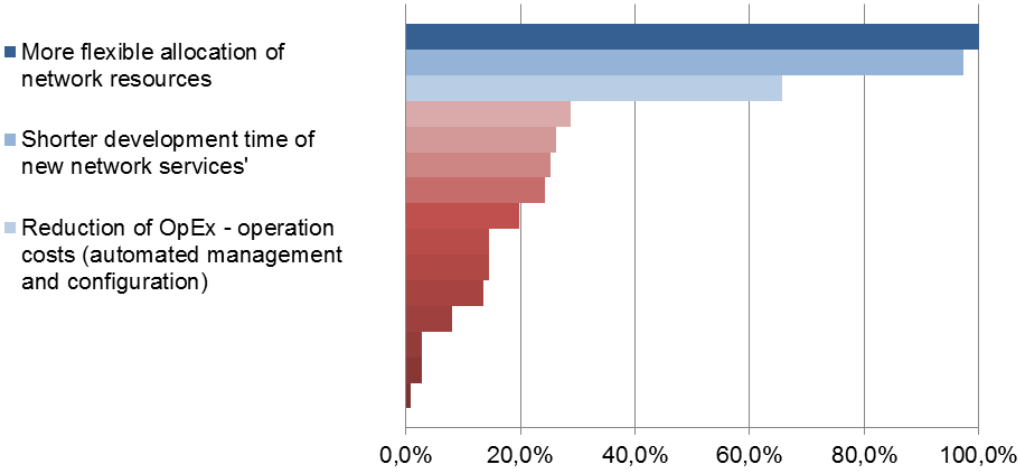
Please indicate the type of organisation you are mainly working for.

Telecommunications operator	Equipment manufacturer/ vendor	Over-The-Top Service Provider	Research institution	Software Provider	National Regulatory Authority	Other
16	13	3	22	12	11	7



In your opinion, what are the top 3 benefits of SDN and NFV in general?

	Ranking 1	Ranking 2	Ranking 3	No Rank	weighted
Reduction of CapEx - virtualised infrastructure equipment	4	5	0	80	22
Infrastructure services – support for network slicing	5	6	5	73	32
Reduction of OpEx - reduced time to repair'	1	0	0	88	3
Reduction of OpEx - operation costs (automated management and configuration)	9	15	16	49	73
Reduction of OpEx - energy consumption	0	0	1	88	1
Automated provisioning	3	4	11	71	28
Customer experience improvement - provision of custom services	3	2	3	81	16
New revenue streams	2	2	5	80	15
Independence from traditional network equipment providers	3	5	8	73	27
Granular reporting for traffic management/monitoring	0	1	1	87	3
Innovative service offers to end-consumers	1	1	4	83	9
Innovative service offers to business customers	4	7	3	75	29
Shorter development time of new network services'	19	19	13	38	108
More flexible allocation of network resources	23	16	10	40	111
Application services – New opportunities for providing network services to verticals	4	1	2	82	16
other	2	0	2	85	8



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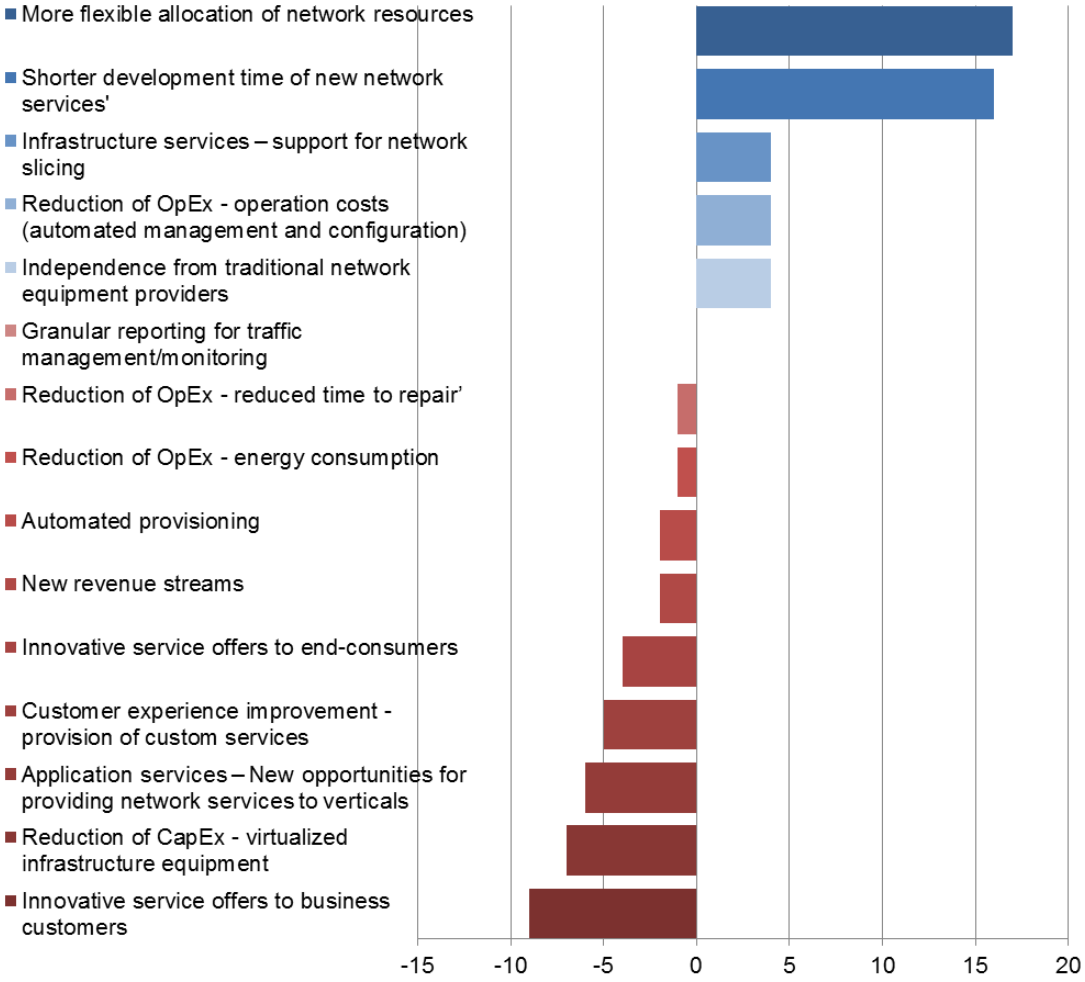


Please use the text box below to indicate any further benefits that you feel are missing from the list in the question above.

Differentiated offer of network services; less dependence on vendors to build innovative services
Isolation
Increased business velocity - end to end and vertical service enablement
Dynamic on-demand scaling of resources
Sustainability and new business models
Ability for the organisation to move faster, deploy faster
Accelerated time to deploy new services (new revenue streams)
We don't expect a significant reduction in CapEx/OpEx, since our expenditure is essentially related with the physical infrastructures of the network, as well as service installation in our customers' premises. Most electronic equipment (Transport nodes, physical links, line cards…) are impossible to virtualise, so OpEx/CapEx reduction through virtualisation is almost negligible. We consider that those technologies can have a positive impact in issues such as support for advanced network abstraction (intent interfaces) allowing for direct application-network integration; Application of software engineering techniques to network planning and management
Operational flexibility of software transferred to network domain, this involves automated provisioning/configuration and management and promises significant savings of OpEx through increased resource allocation efficiency
Some of these questions appear duplicate or overlap!
Reduction of OpEx - alignment with Staffing headcounts ratios of IT industry
support for scale of IOT & 5G
Network management unification and simplification
Customer self-select portal for network services with automated provisioning
Operational Efficiency from using a single infrastructure and resource layer for multiple purposes and the functional flexibility resulting from SW deployment.

Can you think of any policy action that would stimulate innovation of network services related to SDN and NFV in Europe? For instance, is there any legislation or regulation that currently hinders such innovation and that needs to be removed? Or is there a specific support measures that would be useful?

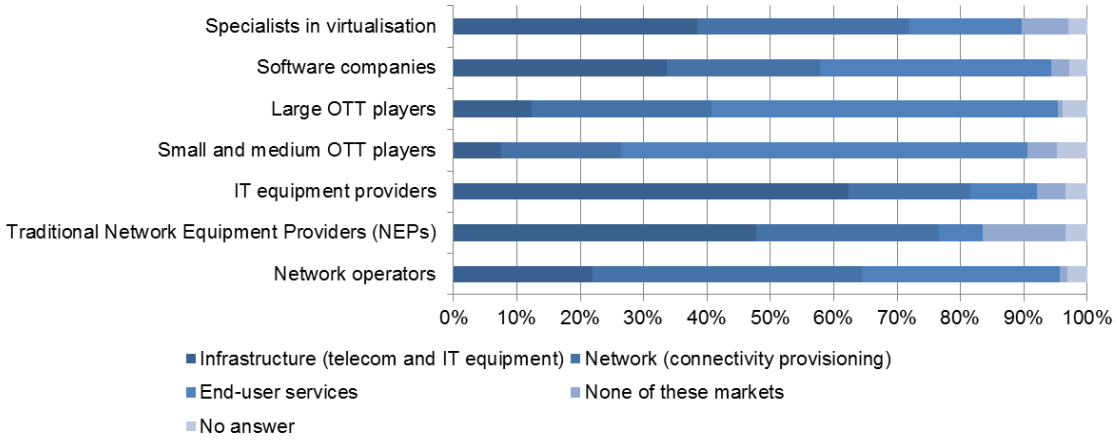
Open standards will be key. In principle, the "softwarisation" of the network and the hardware/software separation enabled by SDN/NFV will tend to lower market entry barriers and pave the way to the emergence of new players (e.g. VNF providers). However, the establishment of standards and open interfaces will be essential to make this vision come true. This will be especially true in specific reference points, e.g. the VNF-VNFM interface.
Any action that would allow take up by virtual operators could create innovation. Verticals or even niche businesses are In particular not sufficiently addressed by current stakeholders. SDN and NFV are enablers that could help to establish many small businesses aside the mainstream.
There could be a specific support measure based on H2020. Similarly like for 5G.
The telco infrastructure world (RFP) is defacto so heavy on paper that small innovative solution does not have a chance, leaving the floor to U.S. giants. Make a EU RFP for accelerating 1 sp to do slicing at large with the constraint to be open to small startup.
Giving further incentives for deployments of IoT devices would foster the "requirement" for SDN/NFV deployments. Nevertheless, SDN/NFV will grow in data centers, if the market brings up important business-cases.
The relationship between data and data management in the context of being able to deliver NFV service offerings in a dynamic and fast manner needs to be considered. What might be considered cross technology regulation will impact our ability to innovate during this transition.
Key point will be to provide cerayinty that no new regulation will imposed on SDN/NFV
Personnal Data protection in country could negatively impact Service providers capabilities for Trans-EMEA services
There is no need to regulate proactively in order to stimulate the SDF/NFV deployment. The current regulation which is based on the provisions of the Access Directive (i.e. access, non-discrimination etc.) is sufficient.
Currently, there is too much pressure on operators by the regulators creating artificial competition rules...

Many of the regulations are hindering competition in general (not specifically for SDN/NFV).
The overhaul of EC Directive 2014/53/EU early in 2014 introduced a new requirement for hardware manufacturers to demonstrate that software running on devices comply with rules regarding the use of certain radio channels. This not only applies to firmware shipped by device manufacturers but also to any kind of software installable on the devices. In Article 3.3 (i) of the directive, it says devices need to be built in a way to “ensure that software can only be loaded into the radio equipment where the compliance of the combination of the radio equipment and software has been demonstrated”. The proposed rule therefore only affects the radios inside these devices. However, because of the economics of cheap routers, nearly every router is designed around a System on Chip – a CPU and radio in a single package. Banning the modification of one inevitably bans the modification of the other, and eliminates the possibility of installing proven Open Source firmware, such as the popular OpenWRT Linux distribution, on any device. This rule would therefore seriously hamper the application of SDN/NFV to equipment with a radio operating in the U-NII bands.
I'm not familiar with European legislation or regulation.
Require isps deploying mec servers to open neutral interfaces and disclose resource allocation algorithms for caching and computing operations
I think the SDN/NFV development is too widespread and needs to be guided to adhere to a common information-model, common service definitions, common architecture, common process and common federated orchestration framework.
The regulation should go in the direction to open up the (physical) infrastructure so potentially anybody could create software network, software services on-top of the infrastructure. In other words, operators who own physical access to customers should not be gate keepers. As creation of complete “software networks” may be difficult for individual “developers”, the concept of Platform as a service should be further standardised and open by regulation otherwise even if physical infrastructure were open, only big ‘players” would be able to crate software networks on that infrastructure and could crate proprietary “app stores”. As currently NFV defines IaaS rather than PaaS, the further standardisation which defines some commodity VNFs and defines a kind of “app stores” for VNFs and network services is needed.
The regulation is the result of market analysis, if it is not competitive and it is premature to be taken at this time, but it is possible that in a few years be necessary to define new markets for networks / services likely ex-ante regulation to aim new technologies. In this phase, the authorities may disseminate information on the benefits that can be achieved by implementing new technologies in order to stimulate the development of business strategies. It is questionable whether the obligation on access to infrastructure may slow process.
I think its not that the current policy is hindering innovatien. Its the way how policy is interpreted and the uncertainty about the interpretation that possibly may hinder innovation
No, not at this stage
In general terms we believe that the introduction of a new technology should be market driven. Policy makers can create a favourable environment to reward players that invest and innovate. Positive signals may come in the way of not imposing regulatory burdens to new technologies, and allowing that first mover advantages are not penalised. Polity makers should not try to “steer” the market towards specific solutions, as it should be market forces those that will command the success of this solution, or any other competing solution.
Regulations that require notification of network changes to a oversight/regulatory body will become impracticable with potential real-time network configuration changes. From a innovation policy perspective, SDN and NFV should be amongst the focus areas in the EU research funding programmes.
Public safety issues
Standartization of BW on demand in terms of pricing, signaling and service definitions
Avoid lock-i with specific ISPs or operators. Buy slices independent of service providers in the form of auctions.
First it is necessary to stimulate the investment in the network deployment and the replacement of existing network components with new ones, allowing the separation of the control plane and the data plane. Next the network services related to SDN and NFV are based on cloud technology and they are similar to Over-?he-?op services (OTTs) provided via global internet network. In this regard may indicate that OTTs are not covered by existing Regulatory Framework for Electronic Communications. Given that the development of SDN networks would significantly increase in supply of such network services they need to be covered by the new regulatory framework.
I expect a competitive dynamic between carriers and OTT players and policies that will ensure that OTT players get access to the same processing resources as carriers would foster more competition, but it could also kill carriers incentive to deploy NFV if they have to open the processing resources of their equipment to OTT players. So ensuring that NFV resources that a carrier deploys would not be required to

be open would foster SDN/NFV adoption.
Radio and broadband regulation
Skills shortage might become a factor to slower down adoption. Add measures/helps in this regard.
* ensure European software standards adhere to "open standards" requirements as defined by the OSI (https://opensource.org/osr)
Policies are needed to harmonize the interconnection of service provider services that implement SDN and NFV so that the benefits these technologies bring to the end user are offered and delivered in an open marketplace.
Perhaps to extend the definition of the market 4 (business services) to include SDN/NFV services within the access definiton to can impose to SMP operator to open such services if they will not to do it at commercial level
OTTs and operators are under different regulatory rules. SDN and NFV will enable operators to act as OTT's and same rules should then apply on the service level.
As deployment of new generation networks, SDN and NFV need important investment, the regulatory framework must then be investment friendly and avoid any measures lowering the capacity of the operators investment and ability to introduce innovative services.
Too strong data security & data protection rules, especially the new European General Data Protection Regulation
As SDN and NFV are in teh early stages of development and deployment legislation and regulation should not act as breaks in these acticities. Policies taht enable and encourage the network transformation are essential in order to create confidence of the operators to invest in the new techniques and upgrade their networks. Additionally, restriction imposed via net neutrality rules should be avoided, as SDN/NFV rely on traffic prioritisation for specific services.
Do not see any regulation obstacle.
I am not familiar enough with European policies to provide a meaningful response
See below.
A SDN/NFV testbed
Limit regulation, enable host services cross countries, regulation about customer sensitive data
Less regulation, apply same regulatory rules to both OTTs and Telcos
standardization
Funding

How will the telecom value chain be affected by SDN and NFV in the long-term?

	Infrastructure (telecom and IT equipment)	Network (connectivity provisioning)	End-user services	None of these markets	No answer
Network operators	35	68	50	2	5
Traditional Network Equipment Providers (NEPs)	55	33	8	15	4
IT equipment providers	71	22	12	5	4
Small and medium OTT players	8	20	68	5	5
Large OTT players	16	37	71	1	5
Software companies	47	34	51	4	4
Specialists in virtualisation	52	45	24	10	4



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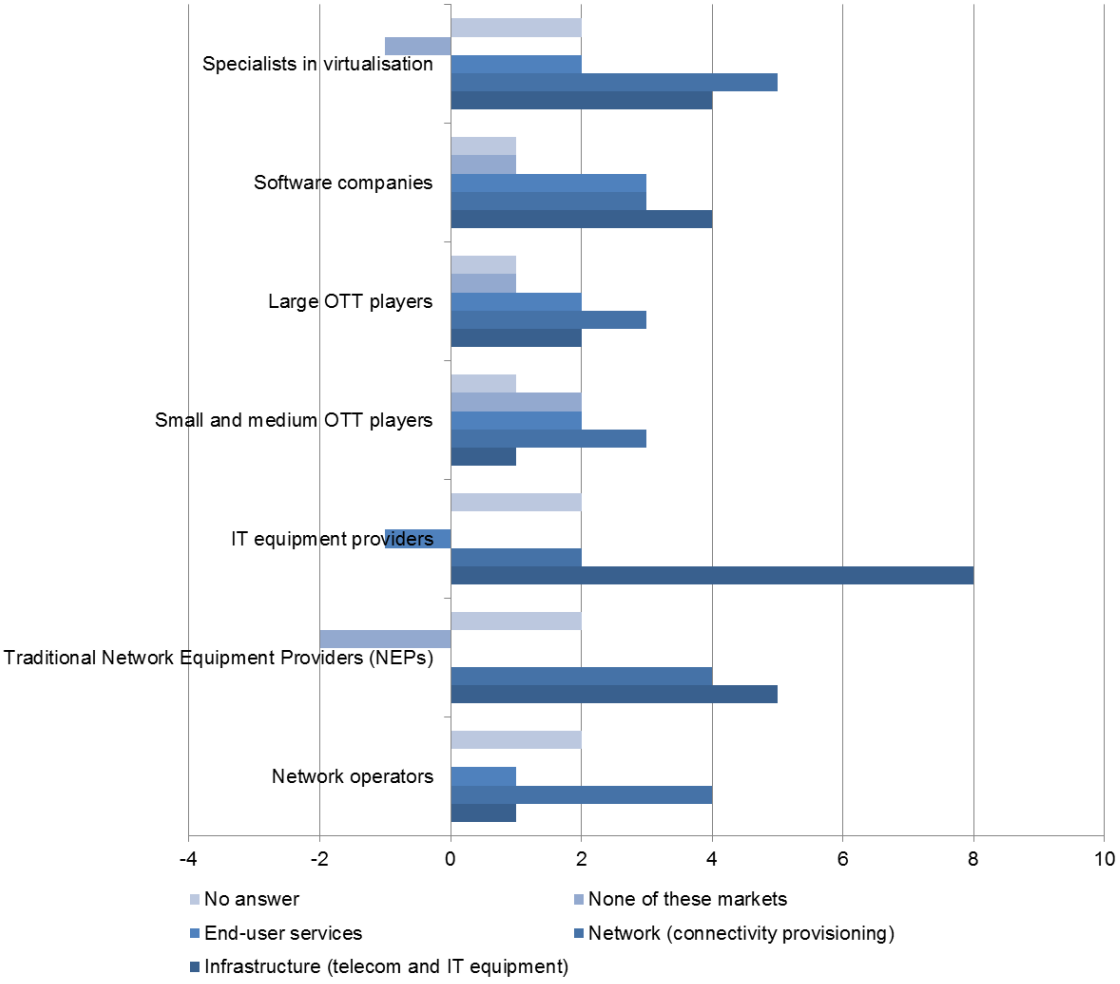
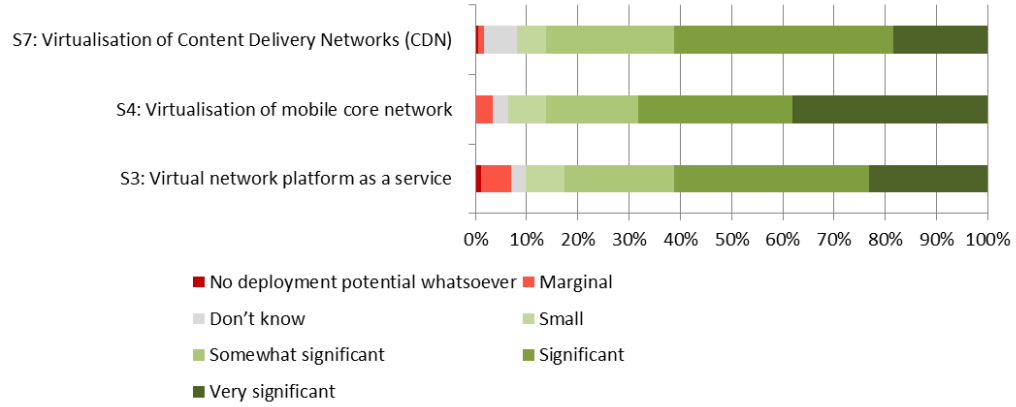


For each usage scenario, please indicate your expectation for its deployment potential in Europe.

	No deployment potential whatsoever	Marginal	Small	Somewhat significant	Significant	Very significant	Don't know	no answer
S3: Virtual network platform as a service	2	10	13	37	66	40	5	11
S4: Virtualisation of mobile core network	0	6	13	31	52	66	5	11
S7: Virtualisation of Content Delivery Networks (CDN)	1	2	10	43	74	32	11	11



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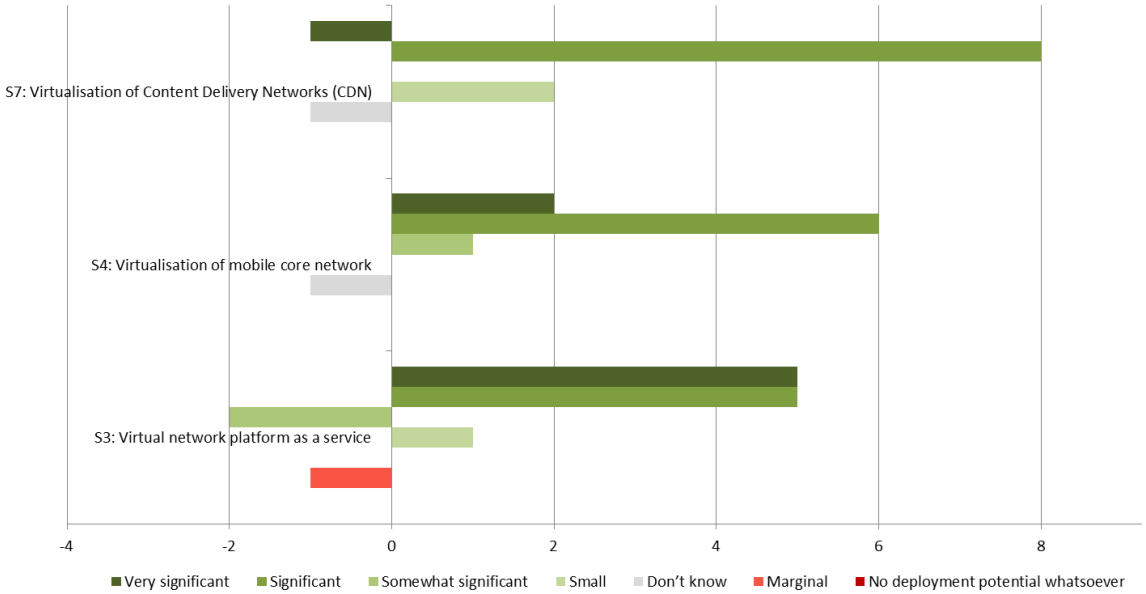
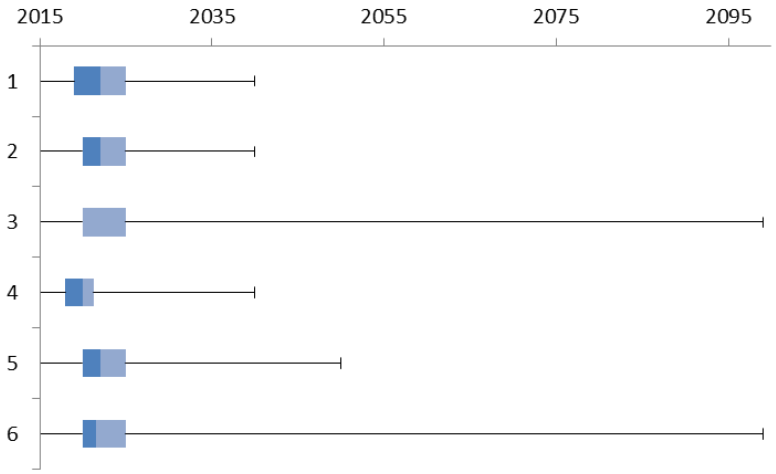
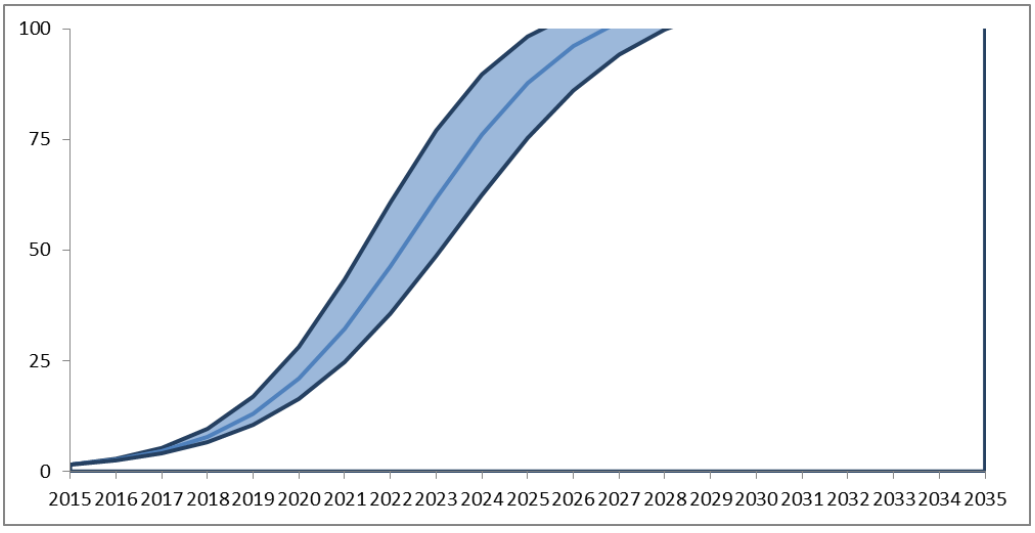


S3:

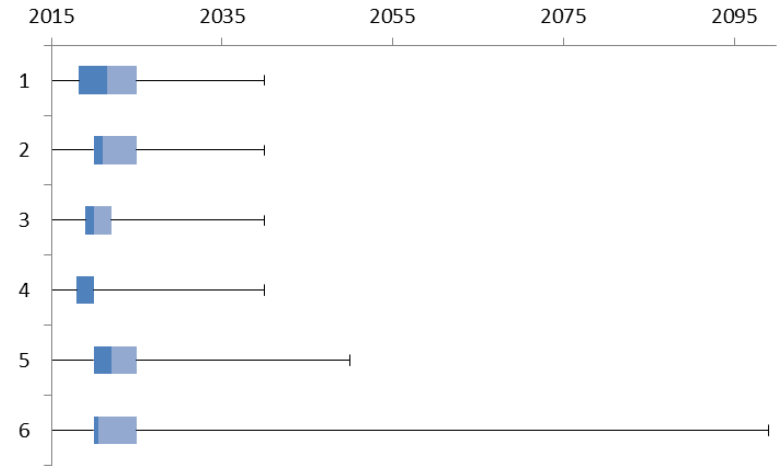
For "Virtual network platform as a service", please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.

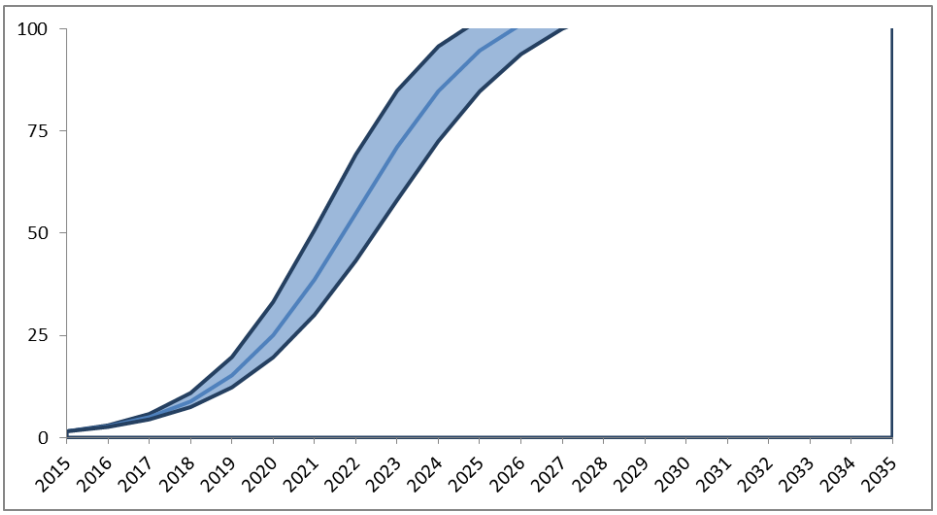
EU





North America





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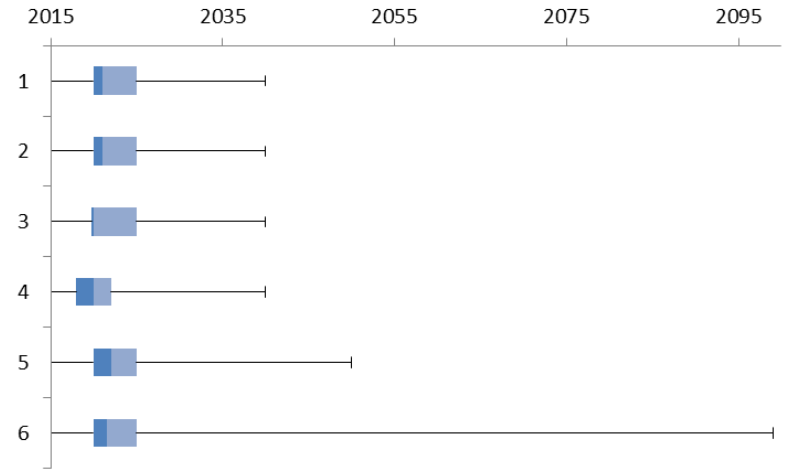
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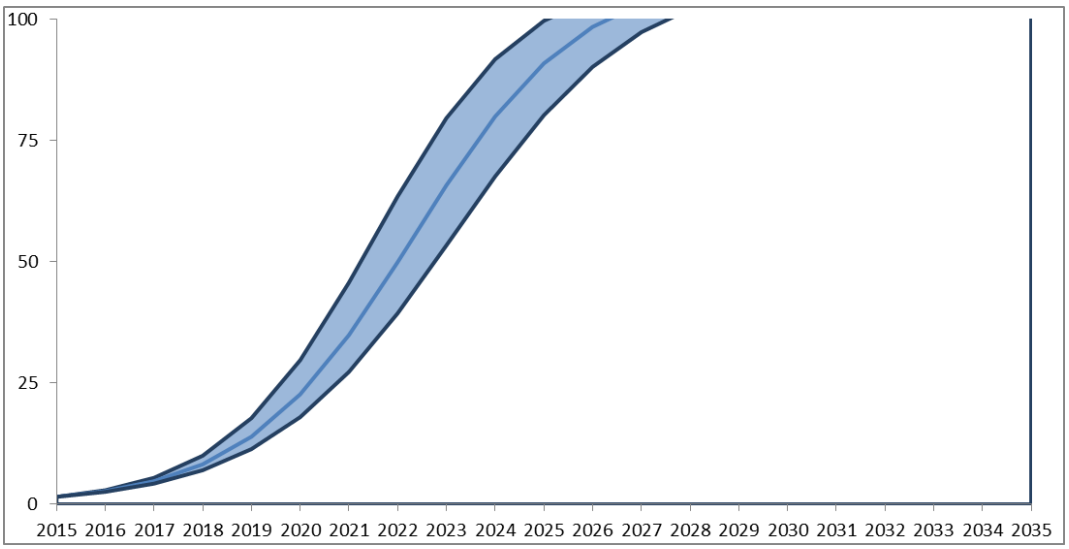
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When you were answering the questions on the SDN and NFV deployment, which specific services in relation to "Virtual network platform as a service", did you have in mind?

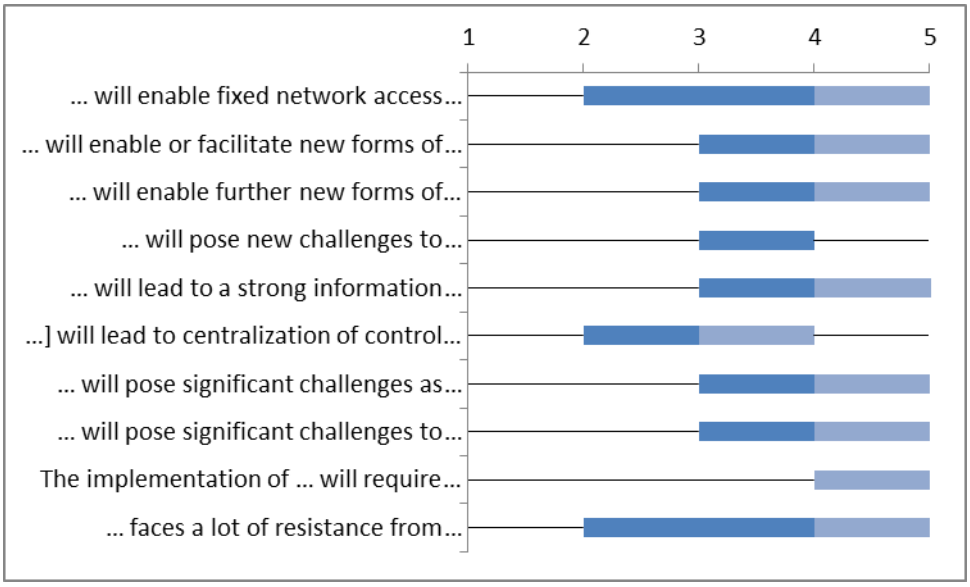
It can be many different things depending on the vertical to which it is targeted. The frontier between VNPaaS and VNFaaS could be fuzzy in some cases.
Distributed Datacenters incl. virtual tenant networks, edge computing for low delay applications, and isolated concurrent virtual service operators on a shared computing and communication infrastructure (e.g. networks and services operated by industrial or automotive stakeholders that tailor and brand the service for their customers).
the all IoT realm and vCDN/gaming etc...
The virtual platform is a very general term and I was considering that a combination in some form of access/encapsulation/security/authorisation and a service service execution framework would available in the VNP.
VPN as a services, security as a services, Voice services
Various services such as routers, BRAS, firewalls and radio access network nodes
No services in particular. More along the lines of Network Slicing.
Services required by an enterprise e.g., firewall or email
VPN services, firewalling, DDoS type functions.
Services deployed in operator's cloud infrastructure and designed for business customers. These services could be reached by customers via different accesses including MAN, global internet network, leased lines, mobile network and etc.
Slicing and Automation
MNVOs
Customized business services
On the B2B market, we are going to launch VPN on demand services, on the fixed or mobile access, and we are thinking about private mobile networks for industrial campus or public safety for example. On the B2C market, we are studying LAN management offers coupled with multi-device management, with potential intervention by a trusted person. Globally we want to define temporary offers based on a per-per-use pricing.
Enterprise network services.
vBRAS, vFirewall, vRouter
VNFaaS can theoretically be applied to all these networks.

Please let us know which hurdles or bottlenecks you see that might delay "Virtual network platform as a service".

Lack of a clear business model that motivates the potential stakeholders to be involved.
Certification and market dominance, since edge elements or endsystems are required to inter-operate with provider infrastructures (earlier example - home network router branding and service locking).
Slicing is more interresting if you see it as operated VNPaaS .. in short service operated/guarrantee by SPs on behalf of the customer (apps/service)
These technologies require infrastructure updating in order to be implemented. The first round of implementation will achieve some level of VNP however further network level iterations (this cycle should simplify each iteration) will bring further capabilities and flexibility.
The maturity of the technology. The non standard and ventor specific developments
Lack of expertise, processes and policies from the provider side.
Ensuring a sufficient level of security and data confidentiality in the provision of services from different providers in a single network platform.
Resource management in HW and regulation of spectrum/broadband access
Refusal from owner of physical infrastructure
There is an important initial cost and timeframe due to the skills adaptation need and the disruption in the operating model, including the alignment with unions. The education at European level should adapt the entering pipe in the job market urgently.
Security, cost, regulation (liability).
performance, capacity, legacy investments
increased complexity, mostly because additional service/network management layers have to be introduced

For " Virtual network platform as a service ", please rate the following statements.

	… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	… will enable further new forms of network access or network sharing.	… will pose new challenges to interoperability across solutions from different suppliers.	… will lead to a strong information asymmetry among actors along the value chain.	…] will lead to centralization of control over critical network functions in the hands of a few actors.	… will pose significant challenges as regards the transitions from legacy to new processes.	… will pose significant challenges to the internal management of stakeholders.	The implementation of … will require significant organizational changes.	… faces a lot of resistance from established actors in the legacy ecosystem.
1	3	3	1	1	1	4	1	1	1	0
2	14	9	3	8	12	16	5	2	4	14
3	13	11	8	17	15	12	9	13	6	12
4	10	16	22	18	10	11	25	20	25	14
5	7	10	17	7	3	6	10	10	14	10
don't know	6	4	2	2	12	4	3	7	3	3
no answer	2	2	2	2	2	2	2	2	2	2



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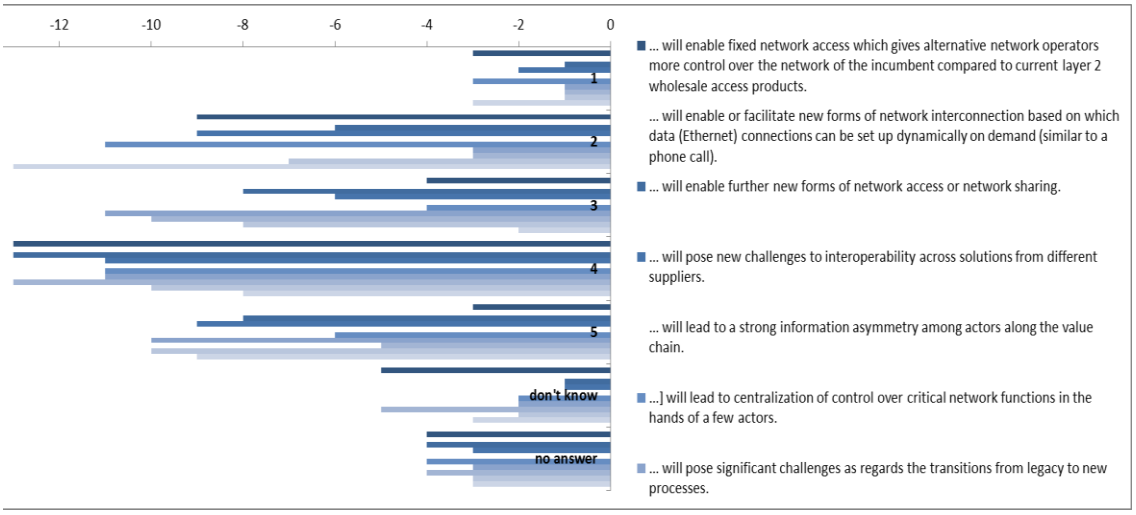
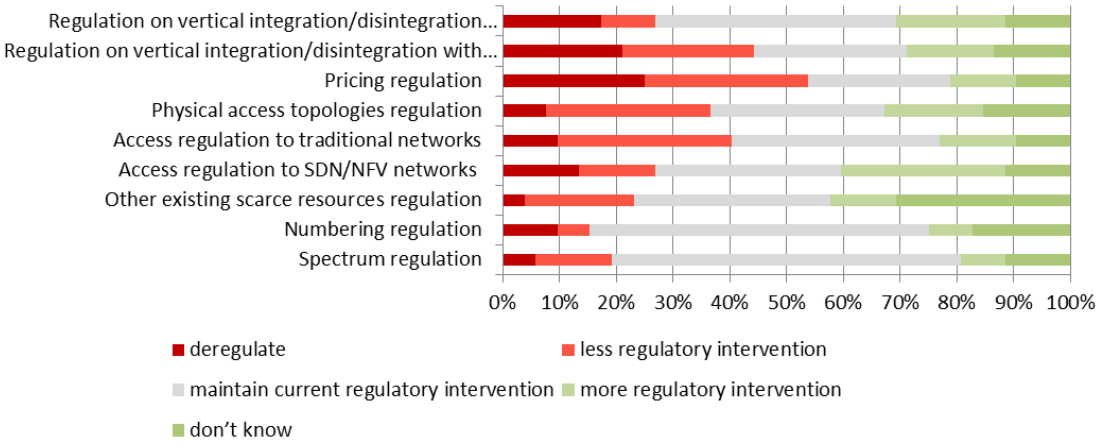


For " Virtual network platform as a service " please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.

	Spectrum regulation	Numbering regulation	Other existing scarce resources regulation	Access regulation to SDN/NFV networks	Access regulation to traditional networks	Physical access topologies regulation	Pricing regulation	Regulation on vertical integration/disintegration with services (upward integration)	Regulation on vertical integration/disintegration physical infrastructure (downward integration)
deregulate	3	5	2	7	5	4	13	11	9
less regulatory intervention	7	3	10	7	16	15	15	12	5
maintain current regulatory intervention	32	31	18	17	19	16	13	14	22
more regulatory intervention	4	4	6	15	7	9	6	8	10
don’t know	6	9	16	6	5	8	5	7	6
no answer	3	3	3	3	3	3	3	3	3



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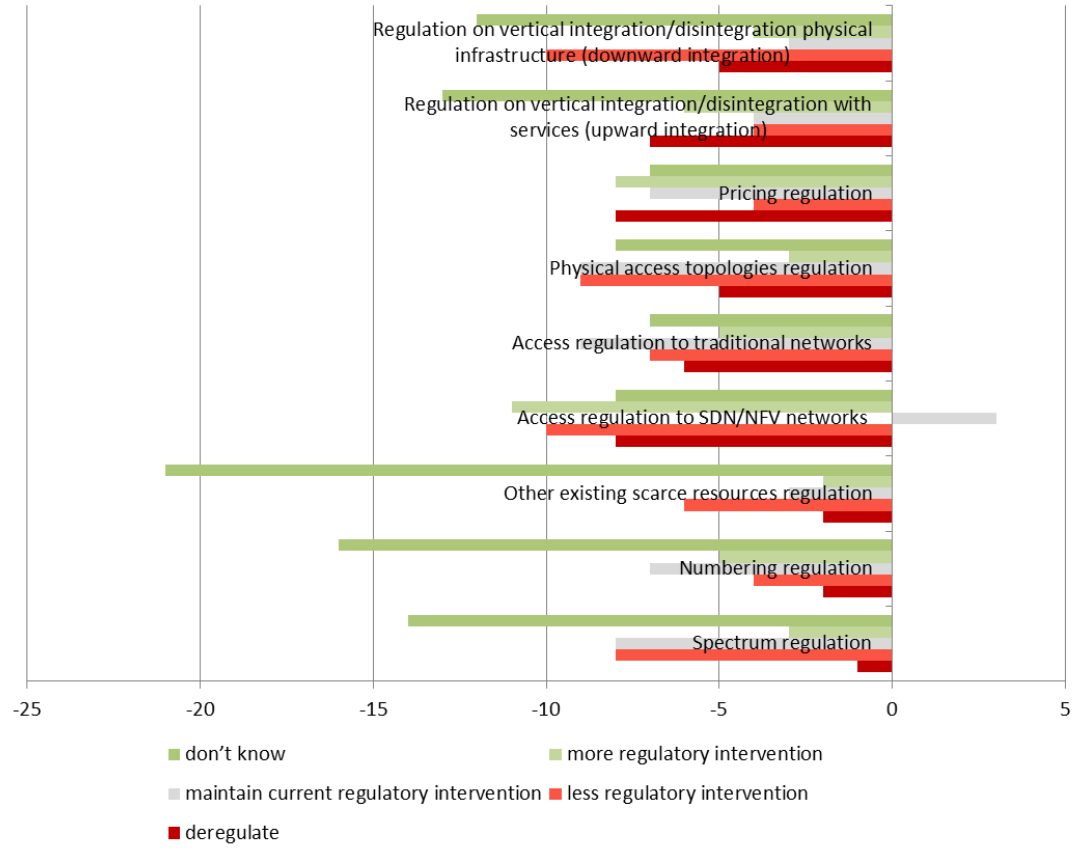
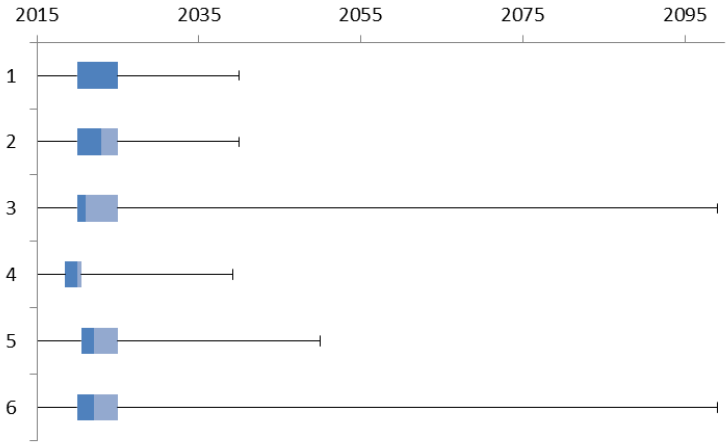
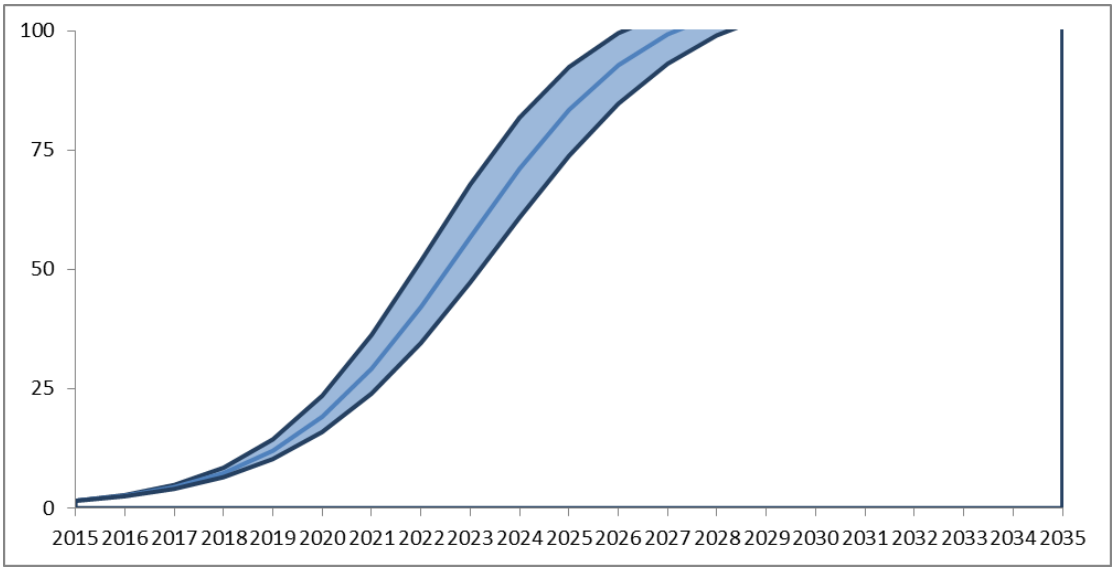


S3b

For "VNPaas (Sub-Scenario) Multi-Tenancy for Verticals", please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.

EU





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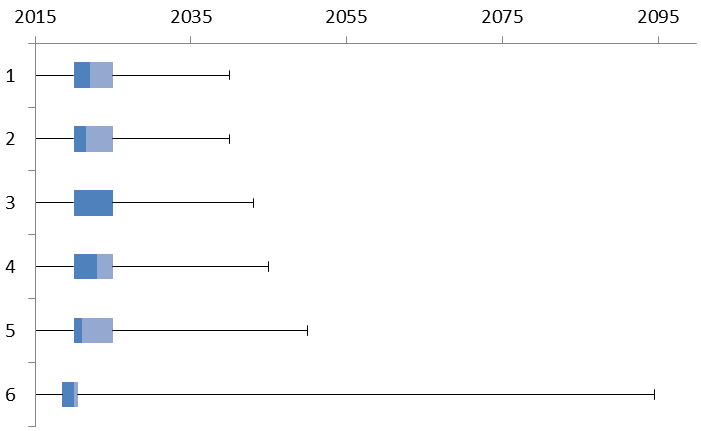

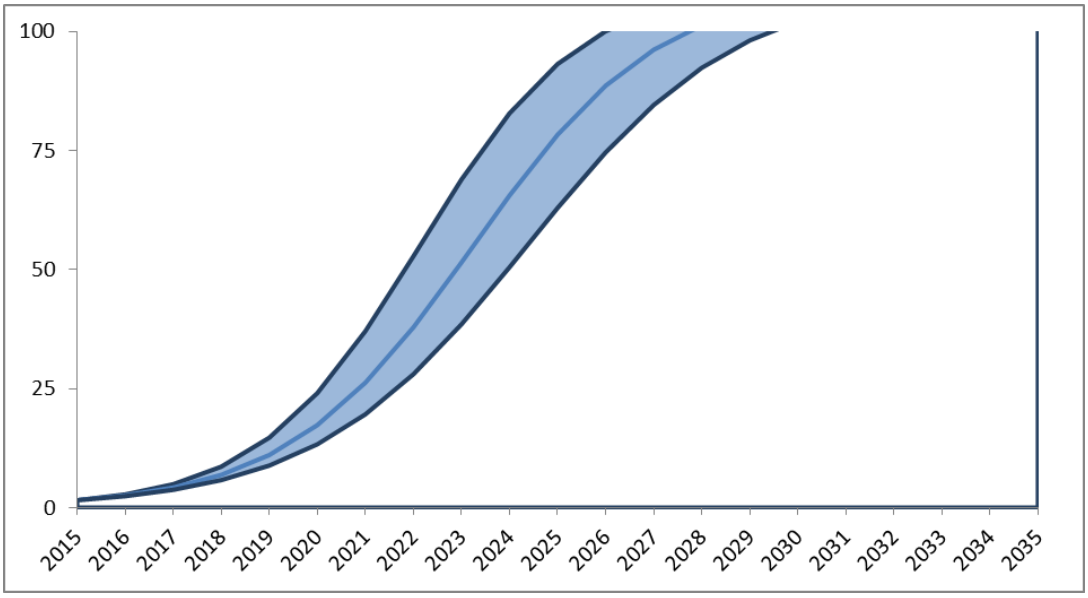
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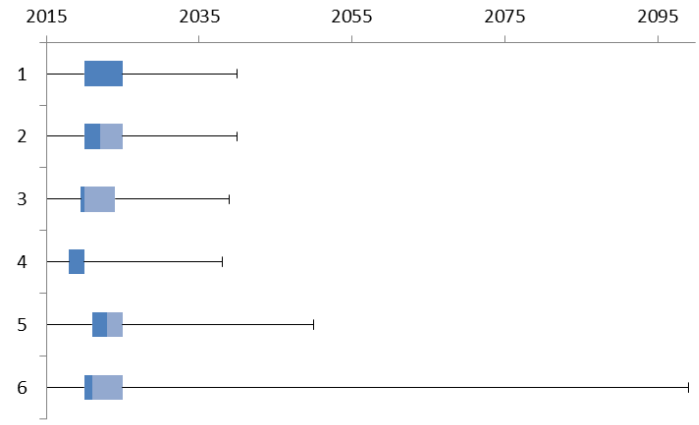
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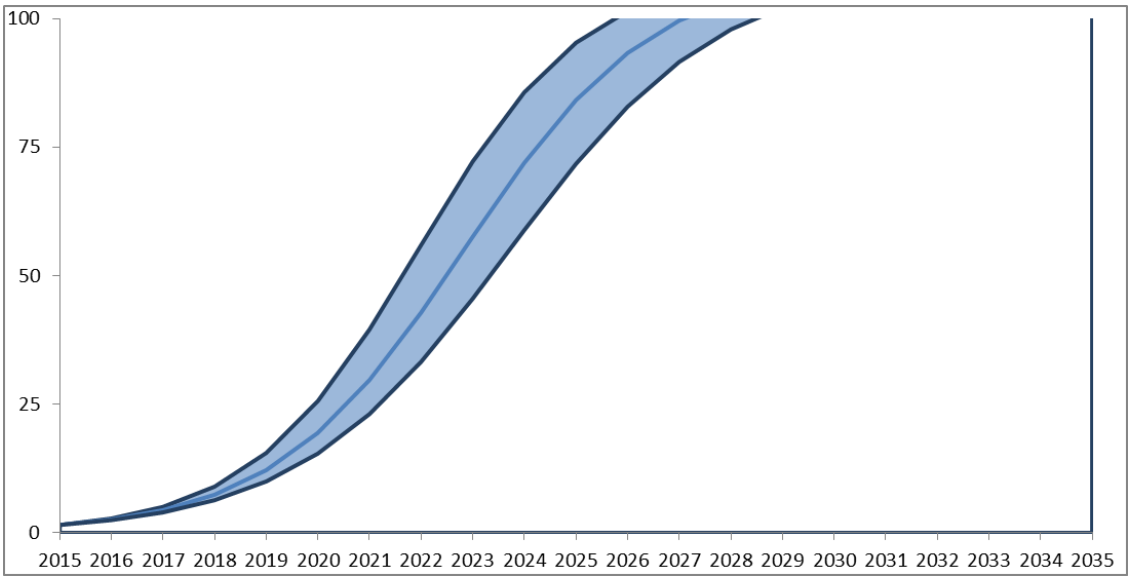
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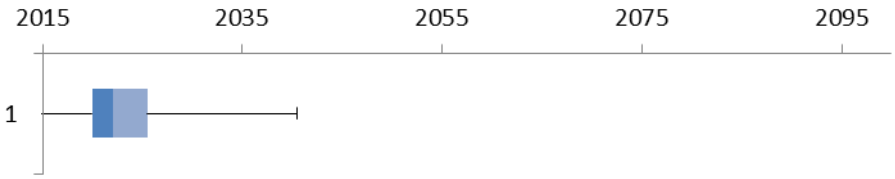
When do you expect to see significant multi-domain deployment of ...?



When you were answering the questions on the SDN and NFV deployment, which specific services in relation to [USAGE SCENARIO 1] did you have in mind?

Verticals such as IoT, eHealth, industry, automotive
Industrial services and all other types of services that significantly benefit from a standard component model (standard service components and shared components from multiple providers). Referring here to business tailored offerings aside the usual cloud model similar to component based SaaS.
Not really in line with this scenario
the ability to automate the creation of a tenant (virtual) implementation of the associated network (or horizontal) service.
GSM-R Public Safety
public safety network service, video streaming service and health care service
e-health, alarm/security/safety, smart grid.
none - new verticals will likely emerge
IoT, M2M
VNPaas for Cars, medical, virtual network operators
Mobility, e-health, IoT partnering, e-energy services
Connectivity services.
Verticals customization of services
Services deployed in operator's cloud infrastructure and designed for business customers. These services could be reached by customers via different accesses including MAN, global internet network, leased lines, mobile network and etc.
Customized services for business
multi-country deployments
use cases that require low latency and

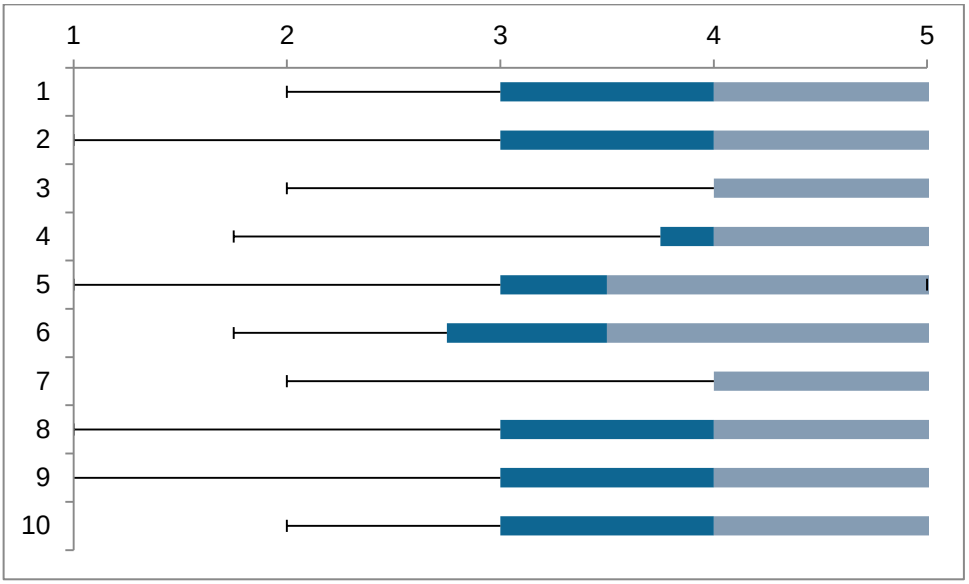
Please let us know which hurdles or bottlenecks you see that might delay VNPaas (Sub-Scenario) Multi-Tenancy for Verticals.

Conciliating conflicting requirements on a common infrastructure may not be easy.
Lack of widely accepted and interoperabel repositories of re-usable components and service building blocks.
Strong local lobbying. Security may be foreseen as a Weakness.
The maturity of the technology
* General service adoption of e-health, etc. * As the SOHO/Enterprise/Home network is a different managed domain than the operator networks, multi-domain orchestration will become crucial for the successful USEFUL implementation of VNPaaS. However, R&D into multi-domain orchestration is still grossly underfunded.
Lack of open, standardized platform with well-defined Northbound Interface for innovation in aspect to "dedicated" network for business requirements.
Security, technology immaturity, regulatory uncertainty with tendency to overregulate in doubt
Sharinh resources and supporting QoS at large scale and across operators
Ensuring a sufficient level of security and data confidentiality in the provision of services from different providers in a single network platform.

Refusal of access by owner of physical infrastructure
There is an important initial cost and timeframe due to the skills adaptation need and the disruption in the operating model, including the alignment with unions. The education at European level should adapt the entering pipe in the job market urgently.
maturity of technologies, performance, automation, scalability
political/regulatory issues related to network neutrality

For " VNPaas (Sub-Scenario) Multi-Tenancy for Verticals ", please rate the following statements.

	… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	… will enable further new forms of network access or network sharing.	… will pose new challenges to interoperability across solutions from different suppliers.	… will lead to a strong information asymmetry among actors along the value chain.	…] will lead to centralization of control over critical network functions in the hands of a few actors.	… will pose significant challenges as regards the transitions from legacy to new processes.	… will pose significant challenges to the internal management of stakeholders.	The implementation of … will require significant organizational changes.	… faces a lot of resistance from established actors in the legacy ecosystem.
1	3	3	0	0	1	5	0	1	0	0
2	5	4	2	1	7	4	1	2	2	6
3	7	9	6	8	11	10	7	8	8	6
4	8	7	12	11	6	7	15	12	13	11
5	4	3	9	8	0	1	5	3	5	5
don't know	6	7	4	5	8	6	5	7	5	5
no answer	5	5	5	5	5	5	5	5	5	5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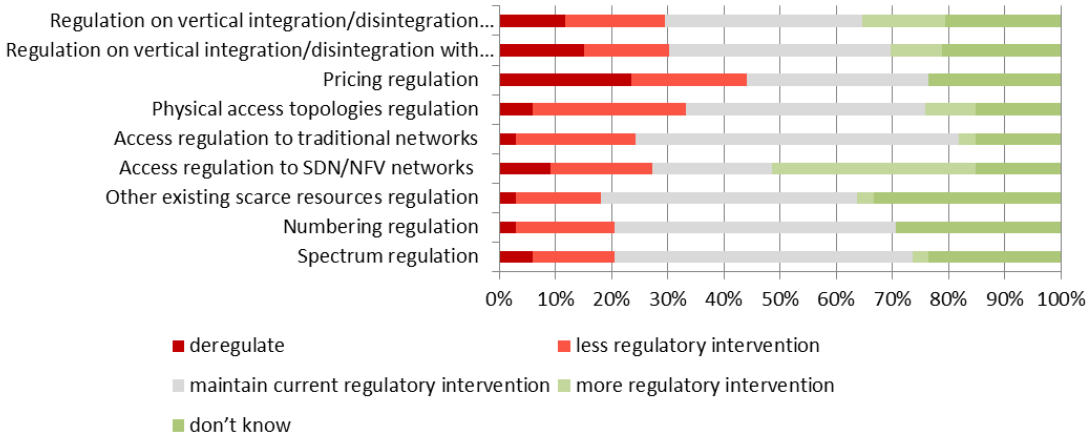
For " VNPaas (Sub-Scenario) Multi-Tenancy for Verticals " please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.

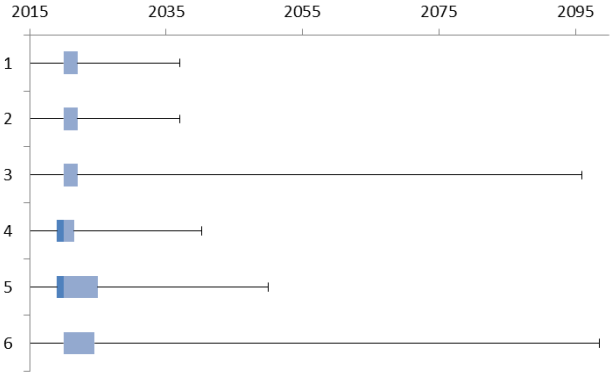
	Spectrum regulation	Numbering regulation	Other existing scarce resources regulation	Access regulation to SDN/NFV networks	Access regulation to traditional networks	Physical access topologies regulation	Pricing regulation	Regulation on vertical integration/disintegration with services (upward integration)	Regulation on vertical integration/disintegration physical infrastructure (downward integration)
deregulate	2	1	1	3	1	2	8	5	4
less regulatory intervention	5	6	5	6	7	9	7	5	6
maintain current regulatory intervention	18	17	15	7	19	14	11	13	12
more regulatory intervention	1	0	1	12	1	3	0	3	5
don’t know	8	10	11	5	5	5	8	7	7
no answer	3	3	4	4	4	4	3	4	3

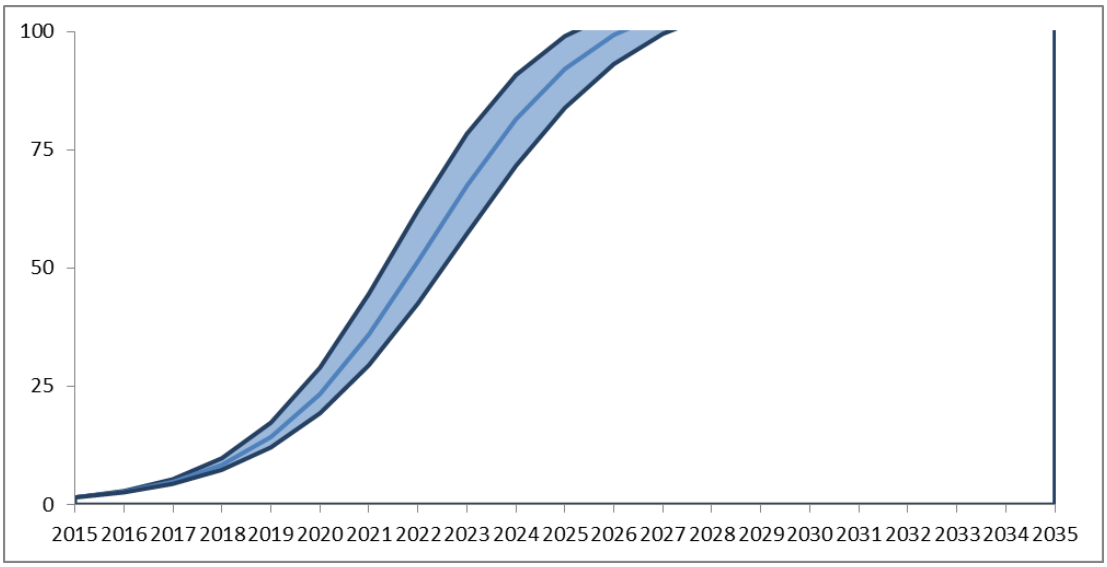


S4:

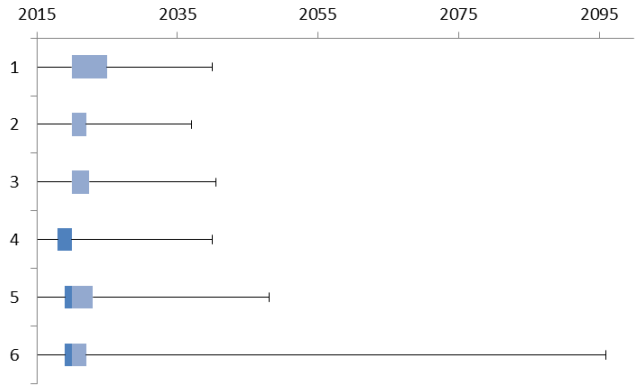
For " Virtualisation of mobile core network ", please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.

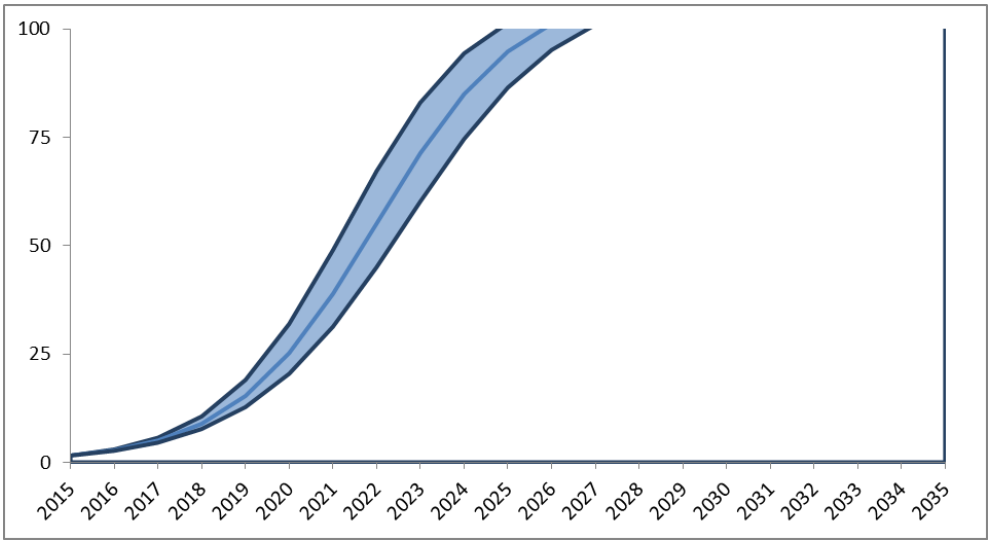
EU



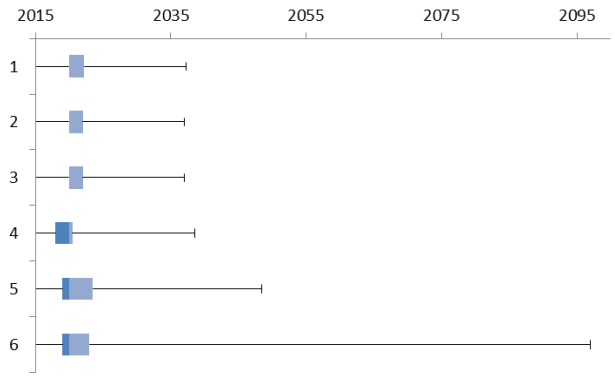


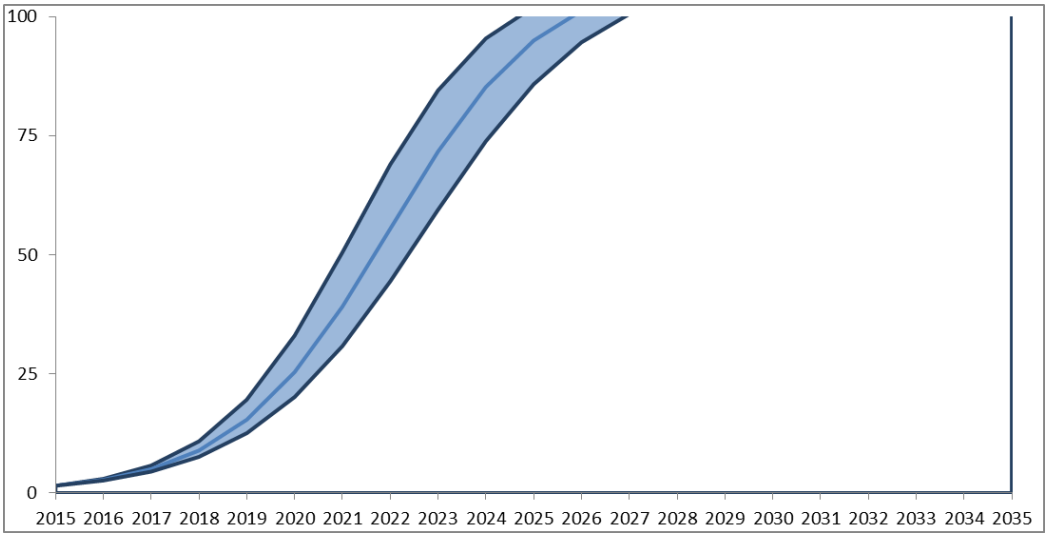
North America



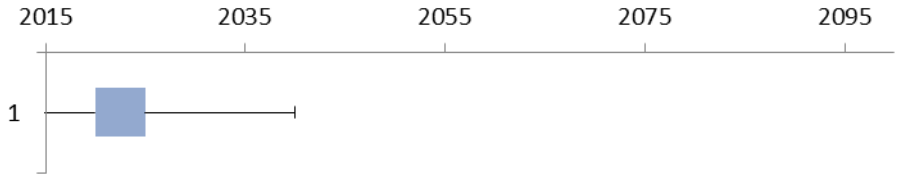


Asia





When do you expect to see significant multi-domain deployment of ...?



When you were answering the questions on the SDN and NFV deployment, which specific services in relation to Virtualisation of mobile core network did you have in mind?

Services provided by mobile network providers, whatever they are. I don't think that the virtualisation of the mobile core, by itself, will necessarily have a strong impact on services to end users.
Point-of-presence virtualisation, Cloud-RAN, Edge mobility services, isolation of service domains and MVNOs.
5G, IoT, Slicing, EPC
the network domain leveraging or hosting virtualised functional capabilities providing mobile core network capabilities.
routers, sgsn/ggsn, IMS
EPC
Support of data services.
Virtualisation of MME, SGW, PCRF etc. to assist mobile access for end-customers
We believe that when it comes to thinking about services it is necessary to have a complete environment in mind. Virtualise just a network function does not allow to think in services, which belong to a higher level of abstraction that is not deployed, or even defined. Furthermore, network function virtualisation has implications that goes well beyond the implementation of current architectural proposals on a virtualised infrastructure. Our current

pilots in other environments show that architecture enhancements due to virtualisation are not only achievable but essential in many cases. Thus a holistic view of the virtualisation process becomes necessary.
vEPC, vGGSN, vSGW, vSGSN, vMME, vPCRF, vEMS
EPC,PCRF
I have no interest in mobile
virtual EPC applications for large corporates,
Value added services that relate with video streaming
The new generation mobile networks based on packet switched core like LTE enable supplying of OTT services including VoIP, video and instant messaging services.
vEPC
vEPC and all related services SBC, IMS, PRFC, SFC
mobile data, network slicing, mobile voice...
vEPC, Gi LAN

Please let us know which hurdles or bottlenecks you see that might delay Virtualisation of mobile core network

Lack of clear economic incentives, difficulty to guarantee carrier grade reliability
General availability of shareable infrastructures (e.g. flexible multi-tenant capable access points / base stations)
Technical literacy of aged workforce and decision makers at SPs
Vendor specific solutions and payback period of current infrastructure
Recouping investments in legacy equipment.
Mobile Core is a minor part of mobile networks OpEx/CapEx, so virtualising this part of the network will imply very small gain compared with the costs of the change. The busy hours in the network are essentially the same in every network node, so there are no gain in having this resources assignment flexibility. Besides this, latency is really an issue for most services, so it is impossible to attend certain processes from a distant point. It is important to bear in mind that Virtual Enhanced Packet Core (EPC) is just one piece within a system requiring more elements that are not only to be deployed, but also to be defined, in order to get the benefits of a virtualised environment, not only a virtualised network function.
Performance, security, missing standardization due to technology infancy (particularly impacting vendor substitutability conflicting with dual-vendor sourcing strategies to avoid vendor lock-in)
legacy platforms lifecycle, throughput issues in virtualised environment, readiness of telco vendors SW for cloud environment
I have no interest in mobile
Performance issues and reliability when transitioning to a software platform
Generally the bottleneck in mobile network sharing and virtualisation of mobile core network is in the use of limited radio-frequency spectrum resources.
There is an important initial cost and timeframe due to the skills adaptation need and the disruption in the operating model, including the alignment with unions. The education at European level should adapt the entering pipe in the job market urgently.
cost, maturity of technology, operational aspects

For " Virtualisation of mobile core network ", please rate the following statements.

	… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	… will enable further new forms of network access or network sharing.	… will pose new challenges to interoperability across solutions from different suppliers.	… will lead to a strong information asymmetry among actors along the value chain.	…] will lead to centralization of control over critical network functions in the hands of a few actors.	… will pose significant challenges as regards the transitions from legacy to new processes.	… will pose significant challenges to the internal management of stakeholders.	The implementation of … will require significant organizational changes.	… faces a lot of resistance from established actors in the legacy ecosystem.
1	8	6	2	0	5	7	2	2	2	4
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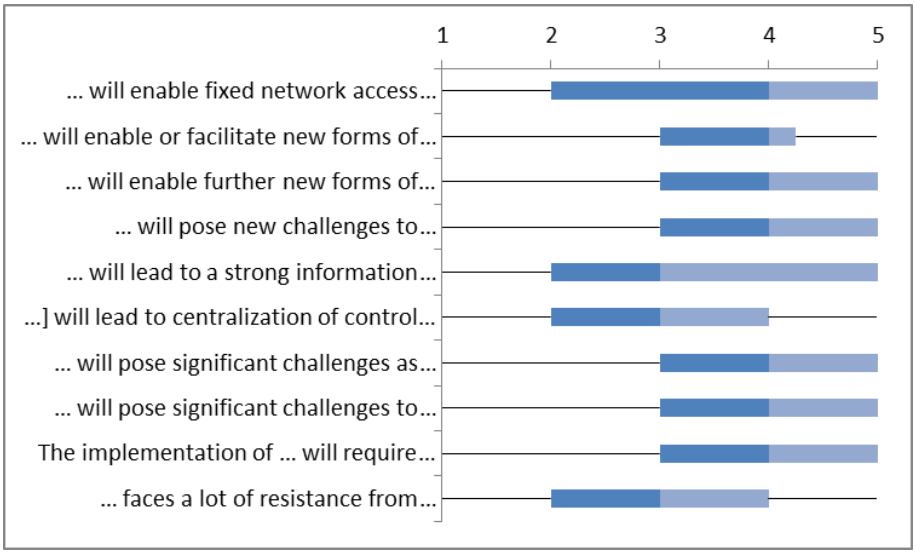
4	12	21	24	22	3	12	25	22	23	15
5	6	6	17	15	5	4	13	11	14	7
don't know	9	4	2	0	12	1	1	4	0	0
no answer	3	3	3	3	3	3	3	3	3	4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...] will lead to centralization of control...
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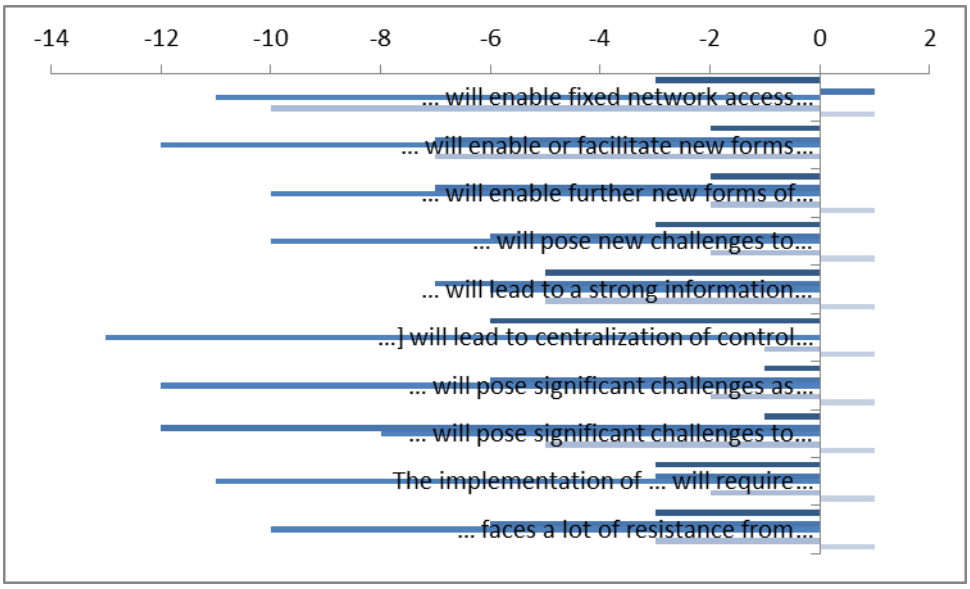
The implementation of ... will require...
... faces a lot of resistance from...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For " Virtualisation of mobile core network " please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.

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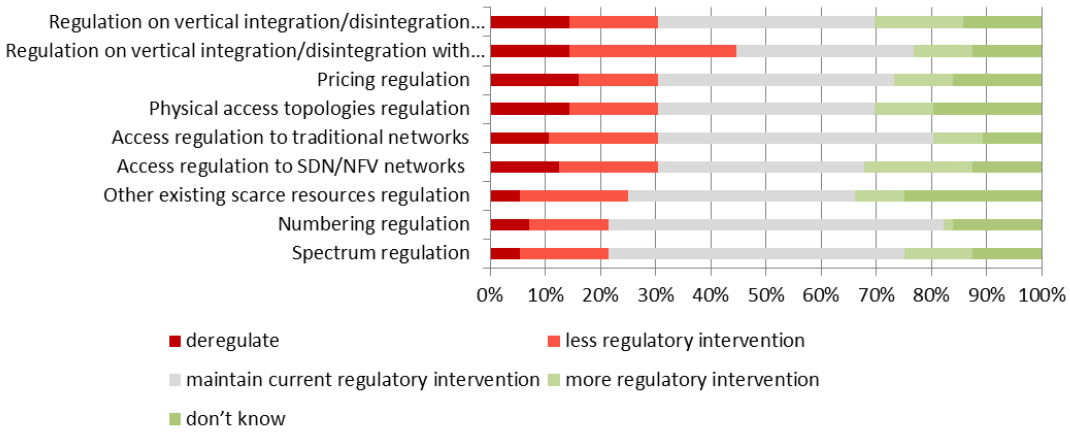
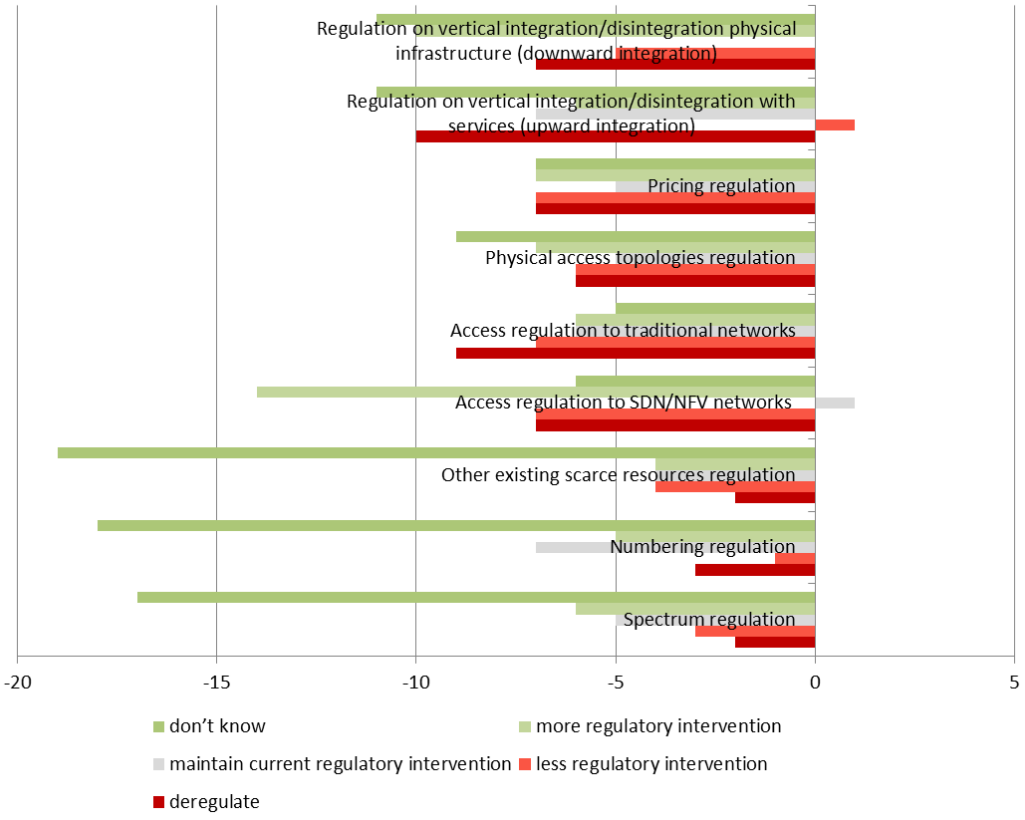
deregulate	3	4	3	7	6	8	9	8	8
less regulatory intervention	9	8	11	10	11	9	8	17	9
maintain current regulatory intervention	30	34	23	21	28	22	24	18	22
more regulatory intervention	7	1	5	11	5	6	6	6	9
don’t know	7	9	14	7	6	11	9	7	8
no answer	3	3	3	3	3	3	3	3	3



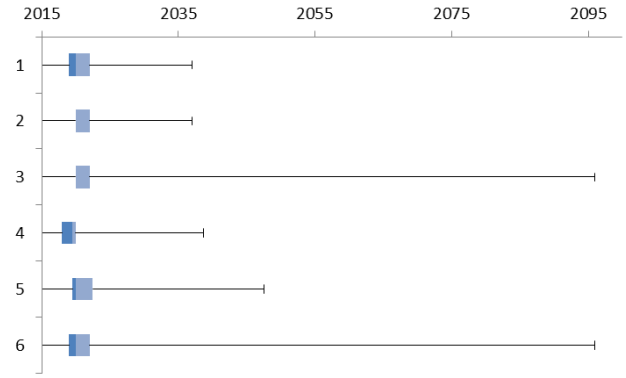
Compared to first Delphi Round

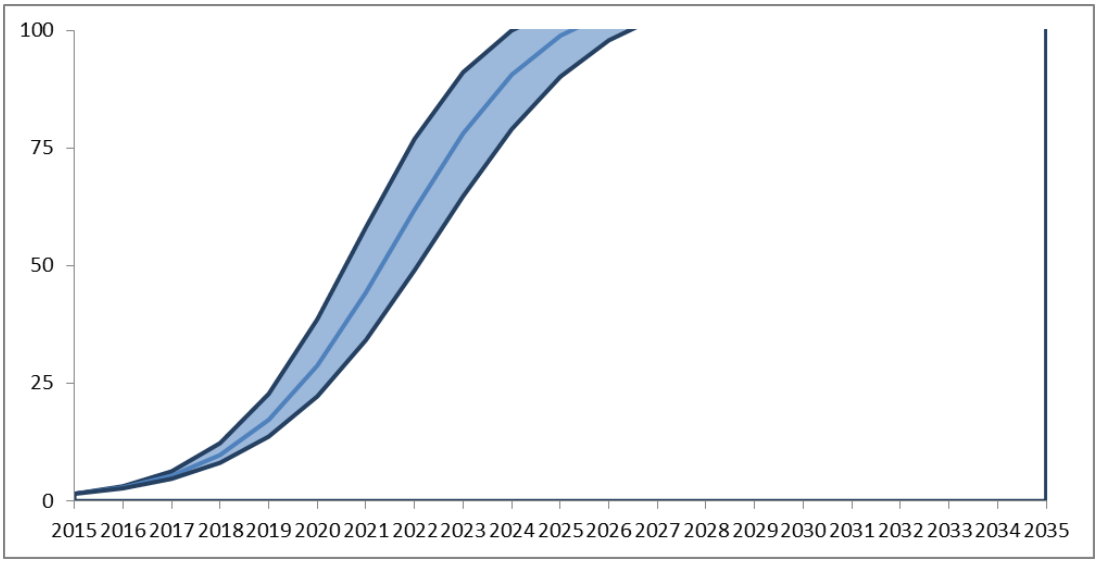


S7:

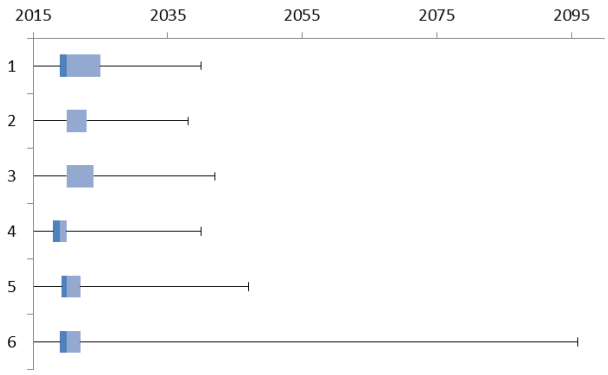
For " Virtualisation of Content Delivery Networks (CDN) ", please state the year, in which you expect 50% of the respective networks in each region to feature corresponding functionalities.

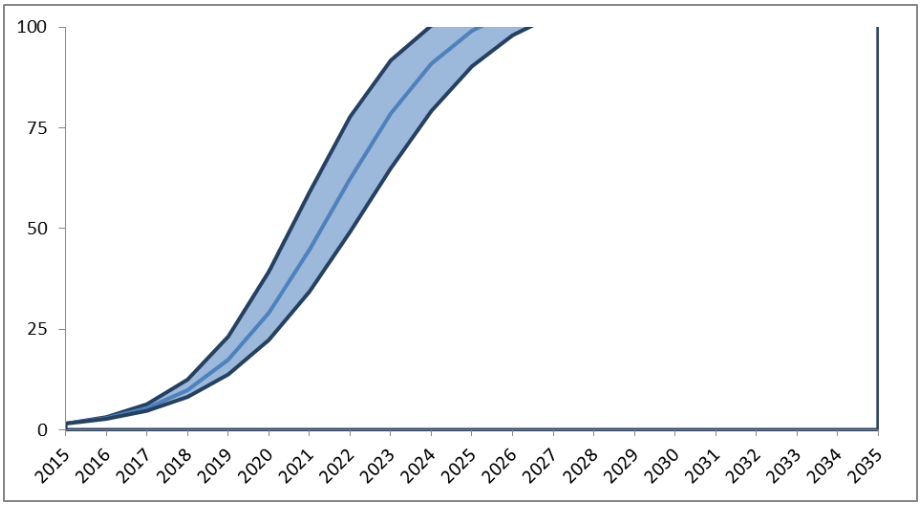
EU





North America

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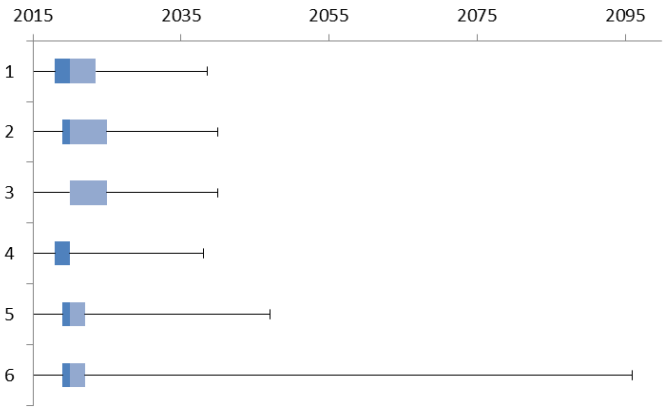
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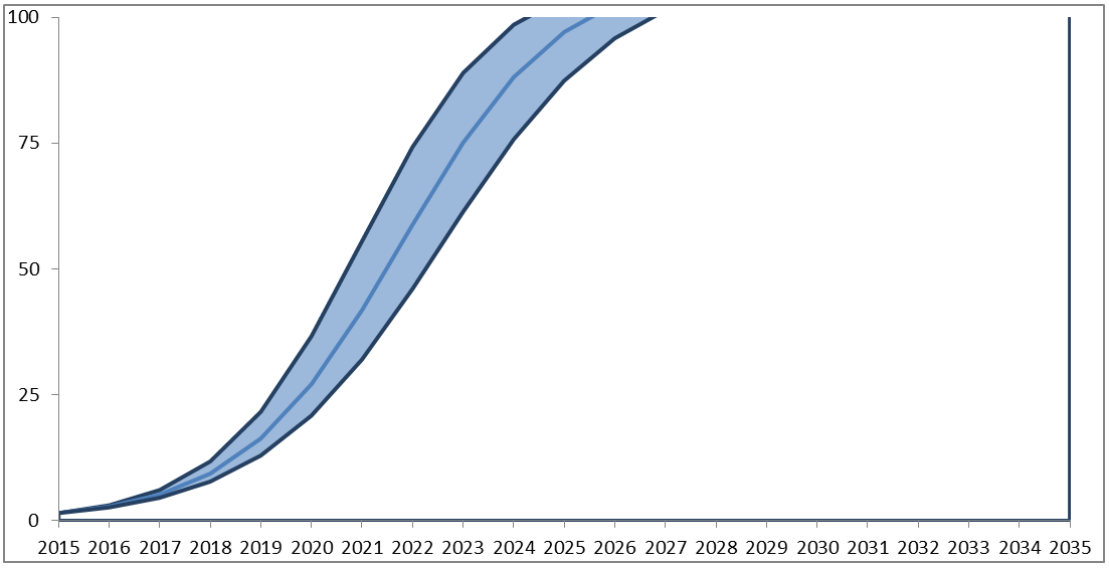
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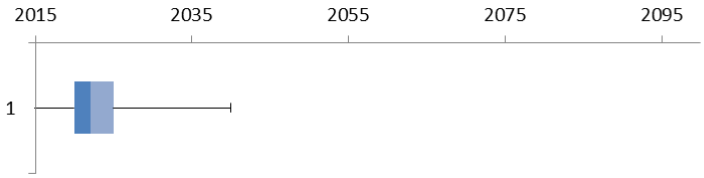
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035

When do you expect to see significant multi-domain deployment of Virtualisation of Content Delivery Networks (CDN)?



When you were answering the questions on the SDN and NFV deployment, which specific services in relation to Virtualisation of Content Delivery Networks (CDN) did you have in mind?

Multimedia services, e.g. video on demand
VoD, Gaming, and information systems, potentially social media since all will sooner or later integrate with CDN services
Per service CDN using the concept of slicing. Take netflix pushing/managing their own apps/keys in the network for better movement of the content (on demand 4k) to end users.
running CDN as virtual functions in the various network
Streaming of course but also Gaming could drives a lots of traction. Content Injection could be also foreseen as a strong push like Virtual or Augmented Reality.
streaming audio, video, and Internet television (IPTV)
All services including MEC and distributed cloud infrastructure
Netflix
OTT video.
Media (primarily video) streaming.
Mobile edge computing where content can be dynamically moved closer to the customer based on statistics.
We believe that when it comes to thinking about services it is necessary to have a complete environment in mind. Virtualise just a network function does not allow to think in services, which belong to a higher level of abstraction that is not deployed, or even defined. Furthermore, network function virtualisation has implications that goes well beyond the implementation of current architectural proposals on a virtualised infrastructure. Our current pilots in other environments show that architecture enhancements due to virtualisation are not only achievable but essential in many cases. Thus a holistic view of the virtualisation process becomes necessary.
Moving physical CDNs to virtual environments.
Content from CAP
Mobile contecnt
Large scale real time streaming and video-on-demand
Video streaming services based on IP transport and supplied by service providers, different from network operator. These services are similar to OTT video services, distributed through the Global Internet Network and include uni-cast video delivery services like Video-on-Demand and other file download services.
Content caching and ad insertion technologies.
HD/4K video delivery from the edge
none this is just a delivery network normally cashing of content. does not have much to do with SDN nor NFV
video streaming, web caching, edge computing
migration from dedicated CDNs from OTTs into a public infrastructure

Please let us know which hurdles or bottlenecks you see that might delay Virtualisation of Content Delivery Networks (CDN).

An appealing business model to all involved stakeholders (e.g. communication service providers, content providers, data center providers, customers/end users) is key to enable the uptake of the technology.
none
Lack of understanding and business commitment for the SPs to move to a slicing (operated apps/services in their networks) model
Today it's more a technology issue (network topology, slicing...)
The technology is not mature. The current solutions are proprietary.
there is no business case not to much of a technical need for doing that.
Gateways between networks (interconnection points), and any compensation adjustments if the traffic is not symmetric between the administrative domains.
Inter-carrier orchestration.
Competition between OTT Players vs. network operators who instead to collaborate may compete in "an fair" way.
We consider that this scenario is already in place The only open aspect is the integration with NFV orchestration mechanisms as they become widely available.
Currently highly specialized hardware in use, performance gap between virtualised and existing technology.
Not many, as ISPs currently host CDNs, so this particular migration may move forward quickly.
OTTs are encrypting content and thus rendering carrier's CDN useless
Managing interconnectivity across multiple operators. Bottleneck: wireless medium (including mobile networks).
this is already used by most operators / content providers.
cost of deployment, maturity of technology, ROI

For " Virtualisation of Content Delivery Networks (CDN) ", please rate the following statements.

	… will enable fixed network access which gives alternative network operators more control over the network of the incumbent compared to current layer 2 wholesale access products.	… will enable or facilitate new forms of network interconnection based on which data (Ethernet) connections can be set up dynamically on demand (similar to a phone call).	… will enable further new forms of network access or network sharing.	… will pose new challenges to interoperability across solutions from different suppliers.	… will lead to a strong information asymmetry among actors along the value chain.	…] will lead to centralization of control over critical network functions in the hands of a few actors.	… will pose significant challenges as regards the transitions from legacy to new processes.	… will pose significant challenges to the internal management of stakeholders.	The implementation of … will require significant organizational changes.	… faces a lot of resistance from established actors in the legacy ecosystem.
1	15	9	7	4	6	9	5	5	4	4
2	12	9	13	15	14	17	16	14	13	10
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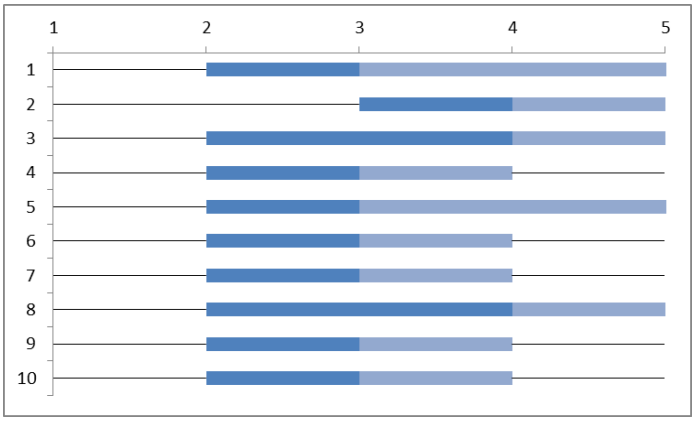
4	5	14	12	13	9	9	12	15	13	11
5	4	7	9	8	5	4	6	4	6	9
don't know	10	7	7	4	11	4	3	9	4	5
no answer	4	4	4	4	4	4	4	4	4	4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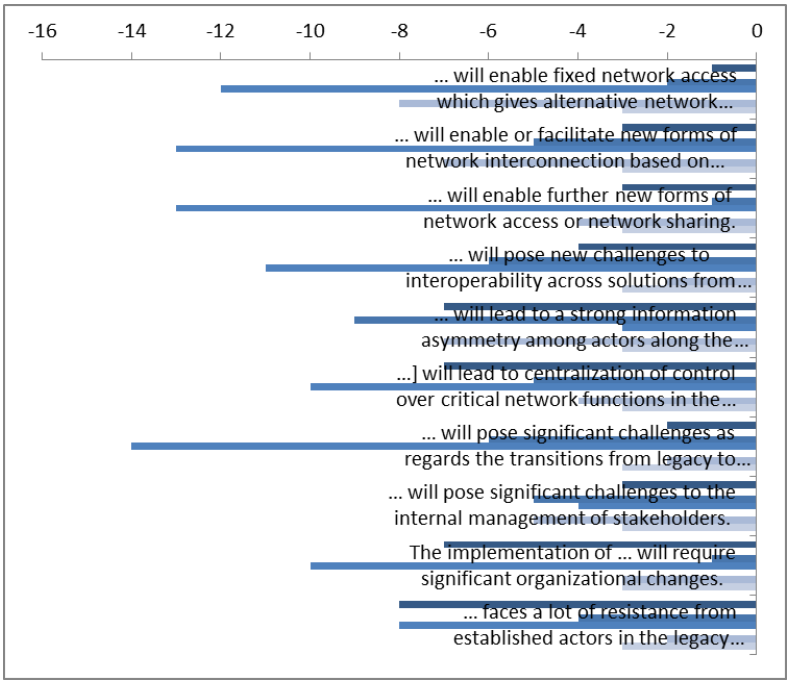
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... will pose new challenges to interoperability across solutions from...
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...] will lead to centralization of control over critical network functions in the...
... will pose significant challenges as regards the transitions from legacy to...
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The implementation of ... will require significant organizational changes.
... faces a lot of resistance from established actors in the legacy...

For " Virtualisation of Content Delivery Networks (CDN) " please indicate your expectation as regards the need for future regulatory intervention in each of the areas below taking the existing relevant regulatory measures that you are aware of as a point of reference.

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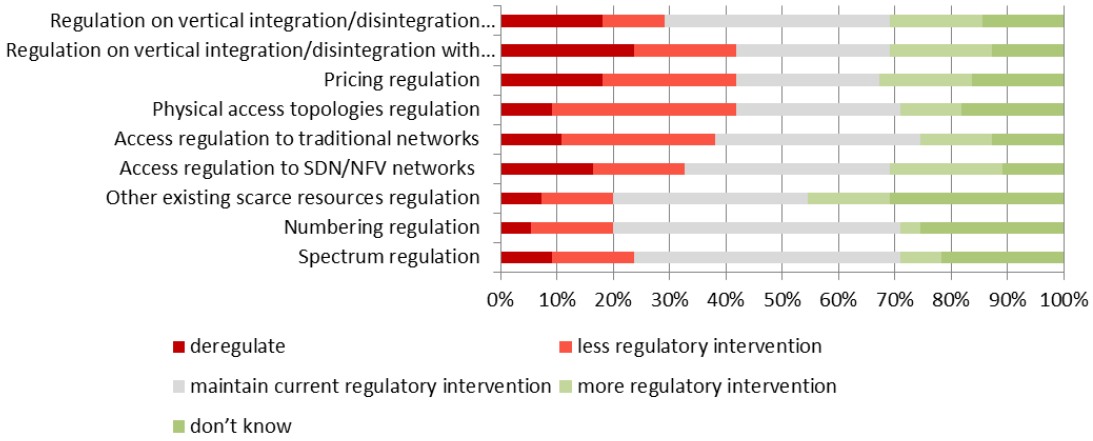
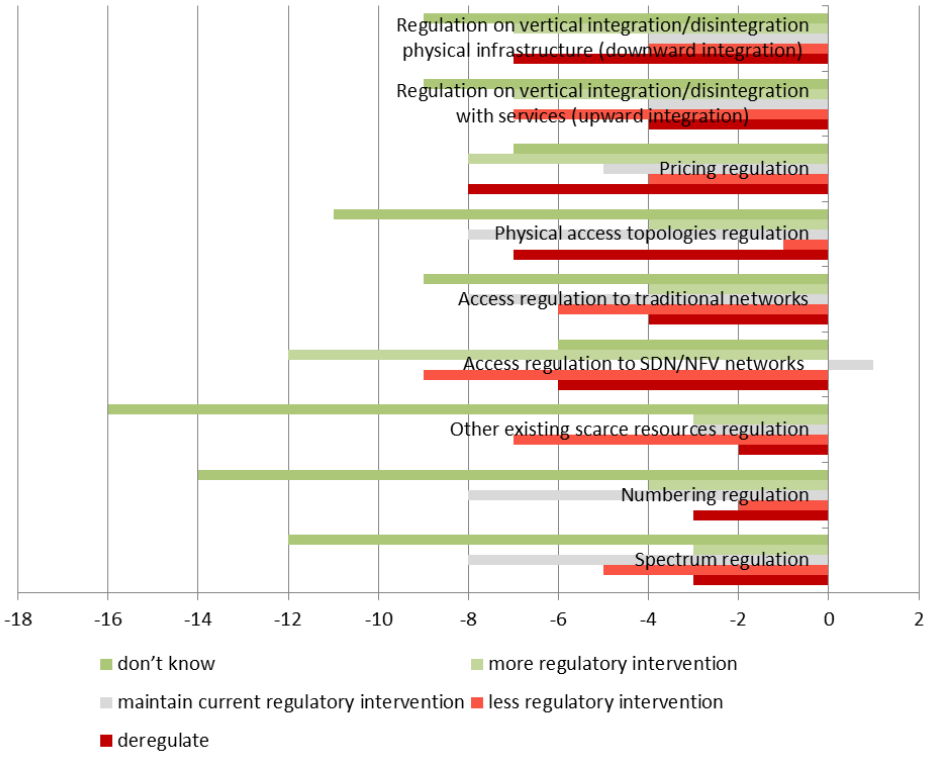
less regulatory intervention	8	8	7	9	15	18	13	10	6
maintain current regulatory intervention	26	28	19	20	20	16	14	15	22
more regulatory intervention	4	2	8	11	7	6	9	10	9
don’t know	12	14	17	6	7	10	9	7	8
no answer	8	8	8	8	8	8	8	8	8


Regulation on vertical integration/disintegration...
Regulation on vertical integration/disintegration with...
Pricing regulation
Physical access topologies regulation
Access regulation to traditional networks
Access regulation to SDN/NFV networks
Other existing scarce resources regulation
Numbering regulation
Spectrum regulation
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
deregulate
less regulatory intervention
maintain current regulatory intervention
more regulatory intervention
don't know


Regulation on vertical integration/disintegration physical infrastructure (downward integration)
Regulation on vertical integration/disintegration with services (upward integration)
Pricing regulation
Physical access topologies regulation
Access regulation to traditional networks
Access regulation to SDN/NFV networks
Other existing scarce resources regulation
Numbering regulation
Spectrum regulation
-18 -16 -14 -12 -10 -8 -6 -4 -2 0 2
don't know
more regulatory intervention
maintain current regulatory intervention
less regulatory intervention
deregulate

8.5 Discussion Guide for the expert interviews

Discussion Guide
Expert Interviews – Project SMART 2015/0011
Forecast Study
"Implications of the emerging technologies Software-Defined Networking and Network Function Virtualisation on the future Telecommunications Landscape"

Target audience: SDN and NFV experts
Expected duration: 60 minutes (on average)
Setting: Face-to-Face or (video-)conference call

[Relevance internal scale + can be ignored in interviews with different emphasis; ++ would be great if it was asked when time / circumstances permit it; +++ must be part of every interview independent of its main emphasis]

No.	Question / Content	Relevance [internal]
Introduction		
1	Short introduction of the project and the respective interviewer(s) / interviewee(s)	+++
2	Introduction of the three selected usage scenarios **Virtual network platform as a service (VNPaaS) (S3)** Some companies want to keep full control over the services that run on their networks; in some cases they might even prefer to develop their own services. Service providers can offer these companies a Virtual Network Platform as a Service (VNPaaS). In that case the company can focus on running their services – now on a virtual network platform. By running services on a platform which is maintained and managed by a third party (the service provider), the company may realise savings. **VNPaas (Sub-Scenario) Multi-Tenancy for Verticals** During the workshop it was suggested to introduce 'vertical slicing' as a subscenario of VNPaaS. This **sub-scenario** (Multi-tenancy for verticals) describes the situation in which multiple vertical services are being deployed over a single SDN/NFV telecommunications infrastructure, using VNPaaS. The key idea is that by using SDN and NFV, it becomes more cost-effective to deploy vertical-specific network services over an existing infrastructure, rather than building a new network for the purpose of a single vertical network service. Further, improvements and changes to vertical services can be better accommodated by using SDN and NFV than in case of a (stove-pipe) separate infrastructures. Examples of verticals are an automotive network service, a public safety network service, a live video streaming service or a health care service. **Virtualisation of mobile core network (S4)** NFV aims at the reduction of the network's complexity and thus wants to reduce operational costs by using standardised virtualisation technologies, and map them to high-volume hardware. By virtualising the mobile network core, network operators can assign available resources in a flexible manner and dynamically adapt to the current load of the network. This flexibility is important due to a high level of complexity in the mobile core network and fluctuating demand for network resources of end-users	+++

	over time. Virtualising the mobile network core helps mobile network operators to save energy by activating the 'sleep-mode' for some of its base stations. Mobile core network resources can then be used for some other purpose until they are needed again. **Virtualisation of Content Delivery Networks (CDN) using Mobile Edge Computing (S7)** Based on the comments received here an during the first two workshops, this scenario has been detailed to clarify which particular application we had in mind. Please refer to this description, when you consider your initial responses. Mobile Edge Computing (MEC) is a technology in which cloud-computing capabilities are introduced at the edge of the mobile network, for example at the eNB or at another location in the RAN (e.g. collocated with CloudRAN). The scenario vCDN using MEC describes the situation in which a Content Delivery Network (CDN) provider uses MEC components of a network operator to deploy its CDN network functions, e.g. content caches. The edge locations are in this way part of the NFV Infrastructure. Pushing CDNs towards the operator edge can have advantages in terms of achieving lower latencies for content services, offloading the core and access networks and offloading end-user devices from computing and storage-intensive tasks.	
General Questions		
3	Can you tell us a bit more about your involvement with SDN and NFV in your organization?	+++
4	What are the main objectives for your organization to be involved in SDN and NFV activities?	+++
Business Implications (IDATE)		
IMPACT ON BUSINESS MODELS		
5	What are the most significant effects that you expect SDN and NFV to have on the telecommunications landscape?	+++
6	What are the main economic drivers for introducing SDN and NFV?	+++
7	Please name relevant hindrances for introducing SDN and NFV?	+++
8	Now, we would like to look more closely at the individual usage scenarios that we have selected for this project. Can you please tell us which effects you expect the usage scenarios to have beyond the telecommunications landscape? - S3: Virtual network platform as a service - S4: Virtualisation of mobile core network - S7: Virtualisation of Content Delivery Networks (CDN)	++
9	Do those usage scenarios have an impact on the telco cost model structure? if yes, how in terms of CapEx (networks, IT), in terms of OpEx(operations, maintenance, energy, sales)?	++
10	What are your expectations as regards the size and the relevance of the investment necessary to deploy SDN and NFV?	+
11	Can those usage scenarios generate new revenues for telcos? How relevant are these revenues going to be?	+
IMPACT ON THE EXISTING TELECOM VALUE CHAIN		
12	What are your expectations as regards the impact of SDN and NFV in general on the current value chain?	++
For each usage scenario:		
13	How disruptive is this usage scenario to established network equipment providers?	+
14	How significant will the impact on the traditional activities revenues of	+

	the Network Equipment Providers be?	
15	In your opinion, what is the likelihood that IT players will replace traditional Network Equipment Providers in provisioning infrastructure solutions?	+
16	Do you see third party players (like Google) developing and provisioning network functions instead of telecom players?	+
CREATION OF NEW BUSINESS MODELS - For each scenario :		
17	Do you see a creation of new value? For whom?	+
18	What are the probable services/models that can be developed by telecom operators? (Wholesale and retail)	+
19	Do you see an opportunity for telcos to leverage on their network and non-network assets (network data, billing capabilities, personal data) to generate revenues from new stakeholders (OTT, banks, governments, merchants) as a complement to retail revenues?	+
20	The Delphi experts expect a strong information asymmetry among actors along the value chain for S3 and S4 than S7. What is your opinion on this?	+
21	The Delphi experts expect centralization of control over critical network functions in the hands of a few actors for S3 and S4 than S7. What is your opinion on this?	+
22	The Delphi experts expect S4 faces a lot of resistance from established actors in the legacy ecosystem than S3 and S4. What is your opinion on this?	+
Economic Implications (WIK)		
23	What are the most significant effects that you expect SDN and NFV to have on the telecommunications landscape and beyond?	+++
24	What are the main economic drivers for introducing SDN and NFV?	++
25	Please name relevant hindrances for introducing SDN and NFV?	++
26	Now, we would like to look more closely at the individual usage scenarios that we have selected for this project. Can you please tell us which effects you expect the usage scenarios to have on the telecommunications landscape? - S3: Virtual network platform as a service - S4: Virtualisation of mobile core network - S7: Virtualisation of Content Delivery Networks (CDN) Specifically, we would be looking for indications of: - New entrants to the market - Implications for competition among market actors Implications for the position of incumbents / infrastructure owners as compared to OTTs and others	+++
27	More specifically, what do you think will be the effect of SDN and NFV on the wider ICT industry and major telecommunications (business) users? Major business users include: - Financial sector - Manufacturing - OTTs	++
28	The Delphi expert panel results show that in particular: - More flexible allocation of network resources - Shorter development time of network services - Reduction of OpEx and CapEx Are major effects of SDN and NFV. How do you think these ware going to impact the IT and adjoining sectors (i.e. customers)?	+
29	Which innovative service offers to business customers do you expect as the effect of the deployment of SDN and NFV?	++
30	We have talked about the new services that operators may offers their	++

	customers, but what (new) potential do you see for business customers to build and use their own virtual networks based on SDN and NFV?	
31	What would that mean for traditional operators and infrastructure owners?	+
32	What potential do you see for new platform business models to emerge based on SDN and NFV?	+
33	What approaches do you see for the European economy to reap the benefits of SDN and NFV's effects?	++
Regulatory Implications (WIK)		
34	How do you assess the state of competition in telecommunication markets in general?	+
35	Do you see a need for regulation / deregulation on telecommunications markets in general?	+
36	What are the most significant effects that you expect SDN and NFV to have on the telecommunications landscape?	+++
37	Do you see regulations which hinder the adoption of SDN/NFV?	++
38	How should regulation be designed to foster the development of SDN/NFV	+
39	Do you expect SDN and NFV to ease market entry for new players?	++
40	Business users need EU-wide harmonized telecommunication products, Operators want to offer these even in regions, where they have to use wholesale products instead of own access assets. How can SDN/ NFV change this situation?	++
41	Now, we would like to look more closely at the individual usage scenarios that we have selected for this project. Can you please tell us which effects you expect the usage scenarios to have on the telecommunications landscape? - S3: Virtual network platform as a service - S4: Virtualisation of mobile core network - S7: Virtualisation of Content Delivery Networks (CDN) Specifically, we would be looking for indications of: - New entrants to the market - Implications for competition among market actors - Implications for the position of incumbents / infrastructure owners as compared to OTTs and others	+++
42	How will the effects on the telecommunications landscape that you just described affect the regulatory framework for telecommunications and/or competition? ADDITIONAL PROMPT The Delphi panel revealed a potentially strong effect of SDN and NFV on centralization of control, depending on the usage scenario. Can you describe the risks for such a centralization of control arising from SDN and NFV from your perspective? For instance, S7 seems to be less prone for centralization of control than all the other scenarios. S2 (Virtual network function as a service) emerged as the strongest driver of centralization.	+
43	IF INTERVIEWEE SEES NO REGULATORY IMPLICATIONS WHATSOEVER Can you think of scenarios in which SDN and NFV would have regulatory implications? Please elaborate!	+
44	How do the three usage scenarios that we consider in this study differ as regards the effects you just mentioned?	+
45	Interoperability has emerged as one of the key challenges for SDN and NFV in our study so far. How do you see this issue in the context of SDN and NFV?	++

46	Interoperability has many facets, can you describe in more detail which challenges you as regards interoperability across the various interfaces as well as across networks?	++
47	Looking at the selected usage scenarios, S3 and S4 score significantly higher as regards expected interoperability challenges than S7. What is your explanation for that?	+
48	For S4, we found a significantly weaker indication for more regulatory intervention in the Delphi panel than for S5, which refers to the mobile base stations (instead of the core network). What would be your explanation for this difference?	+
49	For S4, the Delphi study indicates a potentially stronger need to intervene as regards downward vertical integration as compared to upward vertical integration. How would you explain this result?	+
50	For S7, the Delphi expert see a relatively strong need to regulate pricing as compared to all other scenarios. Do you have an explanation for this results?	+
51	What consequences do you see for non-discrimination and net neutrality? (emerging from the specific usage scenarios as well as SDN and NFV in general?	++
52	SDN and NFV may result in in a more global approach to providing network services, what implications do you see for national regulation?	+
53	In this light, what would be the right European regulatory/policy response to reap the benefits of SDN and NFV?	+
Technological Implications (TNO)		
54	How will SDN and NFV change the technological telecommunications landscape?	++
55	Which other effects of SDN and NFV do you expect?	++
56	Do you think that when SDN and NFV are more widely deployed, network services innovation will skyrocket, since anyone can program new network services on top of the infrastructure (‘appification’ of networks)?	++
57	Do you think that such services will mainly draw from both SDN and NFV (i.e. a combination of some kind) or do you see significant potential for SDN and NFV standalone services, functions, etc.?	+
58	Do you agree that the practical combination of SDN and NFV will mainly be that SDN is used to control data flows to realize Network Forwarding Graphs (or Service Function Chains) connecting the VNFs of a virtual network service? If not, what other combination of SDN and NFV do you foresee?	+
59	What SDN-only scenarios do your foresee, and do you think such a scenario could lead to any requirements in terms of policy and regulation?	++
60	In your opinion, what is the influence of standardization on SDN and NFV deployment, adoption, etc.?	++
61	In this context: What are the most crucial interfaces in SDN and NFV that should be standardized in order to achieve major expected outcomes such as: • asynchronous replacement cycles of hardware, software and management, orchestration and control systems (to prevent vendor lock-in for an operator); • Maximize innovation of network services; • Multi-domain network services; • other	+
62	Can you sketch the expected migration strategy for an operator towards full SDN and NFV deployment and what is the respective transition period? What are the main bottlenecks?	++
63	What vertical markets do you expect to benefit from SDN and NFV and	++

	why? What vertical market network service do you expect to be the first being deployed using SDN and NFV?	
64	When SDN/NFV enabled networks become fully deployed and when their configuration and management and operation have become fully automated, what will change for the role of traditional network operator? Will it still be there, or will all operators become VNOs?	+
65	With everything becoming software, what do you expect to be the major issue for managing this complex SDN/NFV environment?	+
66	When do you expect NO to become VNO (on its own infrastructure) if ever? And will this lead to market consolidation (2-3-4 pan-European 'SDN/NFV infrastructure operators') ?	+
67	What is in your opinion the relation and difference between VNPaaS and Vertical Slicing?	+

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