Reshaping the future with NFV and SDN

The impact of new technologies on carriers and their networks

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Preface

Network innovation, in the form of Network Functions Virtualization (NFV) and Software Defined Networking (SDN), may seem to be history repeating itself. The cycle is familiar. A significant new technology arrives on the scene and threatens to shake up the status quo. Sometimes the technology is led by customer demand. At other times, it results from a supply-side push. From the 10,000-foot perspective, NFV and SDN may not look much different from any other supply-side technology push. However, the scope and scale of transformational change that lies ahead cannot be overstated. In our view, these technologies could be as significant as the introduction of IP networks themselves.

The late 90's saw mass deployment of IP networking. At the time, large corporations were tired of expensive switched-networking technologies and needed lower-cost, flexible networking solutions. On the residential front, access to free Internet content became the new killer application. Driven by customer demand, carriers overlaid IP networks on to legacy technologies such as ATM[1]. This customer-driven network expansion has continued for nearly two decades, first overlaid and then alongside legacy communications systems.

As a result, IP modernization in carrier networks has been restrained by the need to accommodate legacy network functions and management systems. This has meant, the system gains possible from full IP transformation and modernized operations have eluded most carriers. NFV and SDN, however, could provide both the impetus and the opportunity to change. Carriers are now seeking broad network automation and programmability transformation, by taking advantage of the same technologies and platform designs that have revolutionized the management of applications, data centers for over-the-top (OTT) and web-scale companies and cloud service providers.[2]

The dynamics of NFV and SDN adoption are quite different from those that drove mass adoption of IP networking. The IP networking trend was initiated by a customer pull by enterprises wanting more efficient IP-optimized services; for lower cost Internet access; more mainstream WAN networking technology (similar to LAN), and the prospect of dynamic VPN creation and routing leveraging IP/MPLS technology. However, there are two forces in this new technology cycle. On one side, enterprises are adopting cloud architectures and IT technologies but these are working over less flexible carrier IP/VPN connectivity services, so they are increasing their use of over-the-top Internet VPNs. On the other side, carriers are beginning to leverage cloud and IT technologies to build the type of network service flexibility, dynamics and operational efficiency required to serve their customers' needs in the cloud age. So there is a 'push' and a 'pull' aspect to this new era, which can be attributed to IP networking extension on one side and IT system extension on the other to form a common IP-IT platform.

1 ATM refers to Asynchronous Transfer Mode technologies used for reliable circuit transport of communications signals.
2 Refers to companies that provide services delivered over public IP networks such as YouTube, Netflix, Whatspp, Viber and Line, as well as those providing cloud infrastructure to others, such as AWS, Azure, Google Compute, Rackspace, Softlayer and so forth.

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While the industry has yet to align behind a single vision of future networks, most see NFV and SDN as central to the future. Therefore, industry R&D efforts are being driven by the promise of lower operating expenses, along new value streams from new service portfolios for enterprises, wholesale customers, and emerging web customers served from highly automated operations.

Every previous major technology cycle in the telecom industry has created winners and losers with most ultimately driving higher demand and expanding revenues across the whole industry. Will this hold true for NFV and SDN? In our view, there are many opportunities for the expansion of value in the telecom sector, especially for carriers that purposefully embrace this transformation. But carriers that fail to internalize these changes are likely to find themselves left behind with uncompetitive and potentially untenable business and operating models.

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This joint paper examines the economic impact of NFV and SDN on carriers. It aims at a "rational and informed analysis" — reflecting neither hype curve peak nor trough views — and highlights the strategic and business implications of the change. While the focus of the analysis is Europe, many of the conclusions may also apply to carriers operating in competitive markets in North America and Asia Pacific. The report is offered to a technical audience, business managers and clued-in financial analysts and investors to facilitate debate about new strategic development paths enabled by these technologies.

Arthur D. Little and Bell Labs have collaborated on this report because we recognize that bringing NFV and SDN into carrier networks — while vital — is a major undertaking. Therefore, before investment priorities are set, a rational "big picture" economic and strategic assessment is required to determine the most appropriate long-term goals. Both organizations have a long heritage in serving clients through application of technology and analysis, and together we bring a unique perspective on the future of carrier networks.

We hope it will be an eye-opening read.

Sincerely

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Abstract

A geographically diverse set of Tier 1 carriers is driving initiatives to standardize critical components of network functions virtualization (NFV) and software-defined networks (SDN). Led by AT&T, Deutsche Telekom, NTT, Telefonica and Verizon, among others, these carriers hope to bring new technologies first developed and proven in the data center into their networks. The excitement over NFV and SDN has created renewed interest in the networking business and has fanned debate regarding potential winners and losers. So far, however, there has been only limited analysis of the potential economic and competitive impact of these technologies on the network, operations and the bottom-line.

This joint white paper by Arthur D. Little and Bell Labs aims to fill that gap. It offers our views on the network of the future and discusses the value of fusing carrier networks with the cloud ecosystem, as enabled by these technologies. These changes are both an opportunity and a necessity for telecom operators — and for those that get it right, it will be a game changer.

1. The challenge and the vision

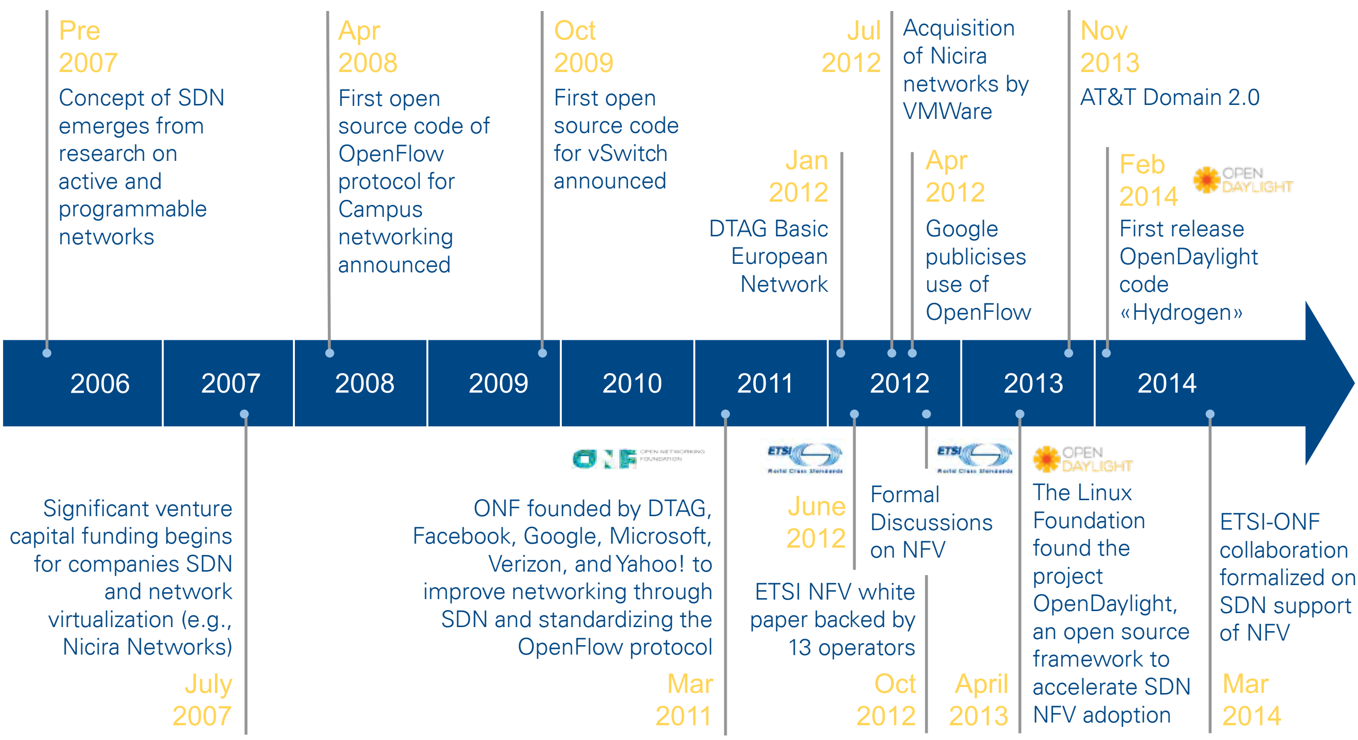
Roughly two decades after the popularization of IP networking and the Internet, much of the telecom industry — especially in hyper-competitive markets like Europe — finds itself in a tightening corner. The industry that enabled the web revolution is now at risk of being marginalized to the role of mere access provider, as nimble OTT, web-scale companies and cloud service providers innovate more quickly.

This scenario has intensified the need for network transformation. And as a result, NFV and SDN concepts have moved beyond research, becoming core enabling technologies for meeting future demands and ensuring the relevance of service providers in a cloud-centric world. To drive these advances, leading carriers have aligned behind ETSI and ONF initiatives (see Figure 1) and related standards work in IETF, OIF, BBF and other standards bodies. Collectively, they are working to achieve what no carrier could realistically accomplish alone, namely to rewrite the blueprint for the automated, all-IP network of the future.

In this future, existing IP networks will be transformed into elastic, programmable, and dynamically manageable next-generation cloud/IP platforms, which operate at Internet timescales and transaction volumes. To achieve this vision, the industry is drawing inspiration from technologies already widely used in the public cloud and IT environments to implement services and manage connectivity. The largest carriers, like NTT, DT and AT&T, are playing their part by trialing and showcasing their network of the future concepts (see Figure 2). This new approach has renewed interest (and ramped up innovation) in the networking equipment business — from software providers, venture capital investors and traditional equipment vendors — all working to find new ways to transform and simplify the network.

Now it's vital for the telecommunications industry to advance networking to a whole new level of programmability, to facilitate the continued development of the web in the cloud era — and to ensure the industry's relevance in the cloud ecosystem.

Figure 1: Carrier participation in industry standard bodies



Source: ETSI, ONF, OpenDaylight and press articles

For society at large, the value of network transformation that enables next-generation cloud/IP platforms is significant. The benefits include more flexible services, faster time to market, and improved user experience. But for the telecommunications industry, this next-generation networking will significantly change the status quo. That's because being able to expose and manipulate network resources on demand — and at a granular level — will spur service innovation and allow richer collaborations between customers and providers to emerge. At the same time, it will enable a new class of competitors to materialize, creating uncertainty about who will really gain from these new services.

What is clear, however, is that virtualization, programmability and network automation, enabled by these new technologies, will drive down industry operating costs considerably. Bringing NFV and SDN into public telecommunications networks across the EU telecom industry could produce the following results, according to our estimates:

- As much as 14 billion euros in direct network operating expense (OPEX) savings
- A further 25 billion euros of non-network savings from much needed changes in the operating model of the industry — leading to a total savings of 39 billion euros, or 26 percent of overall OPEX

Capturing the potential of network transformation requires not only technical skill, but leadership in making significant changes to current business and operating practices. The ICT industry as a whole — telecom, IT and device manufacturers — as well as governments have all played important roles in creating the conditions for the Internet, cloud and mobile device revolution. Now it's vital for the telecommunications industry to advance networking to a whole new level of programmability to facilitate the continued development of the web in the cloud era — and to ensure the industry's relevance in the cloud ecosystem.

Figure 2: Key carrier NFV and SDN future concepts

NTT

NTT working to enable the next generation network based cloud

- **NTT is a founding member of ONF driving development of SDN and COTS based Carrier Grade virtualization**
- NTT global datacenters footprint and Asia centric network makes it a formidable competitor
- **Acquisition of numerous cloud and communications vendors** including Virtela is a significant commitment to the strategy

T · Basic European Network

Basic European Network (BEN) seeks network modularization

- **Network provides commodity** and generic enabling services
- BEN is a **simplified network** with intentionally limited functionality, and **based on COTS equipment**
- BEN **is pre-integrated network for roll-out as-is** ….. through a set of defined nodes and interfaces
- **Local extensions** should be **decoupled from BEN**

at&t Domain 2.0

Domain 2.0 is transformative

- **Rich APIs that manage**, manipulate, and consume services on-demand and real-time
- Seeks **common infrastructure purchased and provisioned like datacenter pods**
- **Builds on cloud technologies**, including servers, virtualization, SDN switches and controllers, competitive independent software and well supported open source communities

The market is moving rapidly towards the adoption cycle along two dimensions; the "customer pitch" and "purchasing"

Source: Public domain documentation

2. Rewriting the industry's future

Over the last decade, the Internet has transformed the telecom industry. In the next ten years, it will probably continue to be the single most powerful influence, as more devices become connected and new forms of communication continue to change how people interact with one another. Changes have occurred across the globe, leaving no geography untouched by fixed and mobile connectivity.

- Wide coverage of fixed broadband connections is being driven by the continued build-out and adoption of xDSL, cable and fiber-based broadband services, particularly in more developed markets.
- Explosive growth of data-enabled mobile devices is dramatically increasing the number of always-on network endpoints.
- Across both fixed and mobile networks, workloads are changing from communications to cloud-centric new media and data center interconnectivity.
- Machine-to-machine (M2M) growth will only strain networks further.

Looking ahead, there is every reason to believe that the pace of change will continue and, indeed, accelerate.

Cumulatively, these changes are having a profound technical and economic impact on telecom networks by redefining many of the parameters that governed network design. Therefore, a shift in mindset is required from the relatively independent "dynamic compute-static network" models of the pre-cloud networking era to address the following new conditions:

- **Today's shift to large numbers of devices**, which are capable of consuming and sourcing very large amounts of media-centric, geographically-shifting, and time-sensitive workloads on demand — This shift will require more efficient and dynamically adaptable networks.
- **The move to cloud services** — This change requires vertical scaling (adding more resources) and horizontal scaling (adding new locations) of network functions and their interconnection very rapidly (within seconds to minutes, rather than days to weeks).
- **Ever-increasing media quality expectations and consumption patterns** — These changes necessitate new content distribution architectures and more flexible flow controls at the edge to improve performance, offer flexible value-added network services and control network costs.
- **Increased use on a mass scale of signaling-heavy applications**, such as M2M or the Internet of Things (IoT) — Efficient scaling for these applications will require new network architectures that can seamlessly trade off data plane and signaling plane workloads.

In this new environment, significant change is needed to the nature of the services offered and the network implementing them. These changes must allow the network to participate and contribute to the development of the cloud ecosystem. For this approach to be a success, of course, requires a compelling proposition for both customers and shareholders, so the industry can invest in and capture the returns from transformation. On the other hand, choosing not to invest in such changes would severely limit the industry's role in the rapidly growing cloud value chain.

The foundation of this crucial change is next-generation cloud/IP transformation, enabled by NFV and SDN. In our view, it is a clear imperative for the industry.

3. Addressing critical challenges with NFV and SDN

Although it is still early days for the deployment of NFV and SDN, these new technologies are already widely viewed as essential components in the future of networking. Indeed, these concepts have reached an inflection point in their development, industry acceptance, and standardization drive, and are being championed as the core enabling technologies to re-architect carrier networks.

To address flexibility and timescale competitiveness in multiple dimensions, NFV and SDN allow the network to integrate into the cloud ecosystem using the same advanced cloud-based approaches employed by OTT and web-scale companies and cloud service providers. They also facilitate more efficient network scaling to help address the challenges of massive traffic growth. The first crucial step in this change is enabling the network — both functions and connections — to become programmable and automated[3]. In many ways, they are two

What are NFV and SDN?

At its most basic, NFV leverages virtualization technology from the data-center environment to implement network functions as software components. Here's how that works: Previously, network functions typically ran in dedicated (and often specialized) hardware. Now virtualization renders physical functions as software that can be run as virtual machines (VMs) over general-purpose processors (servers). In turn, all hardware resources are managed as a common resource pool.

These VM resources can then be assigned (and repeatedly reassigned) to different functions, on demand. This technique maximizes the use and reuse of hardware resources — and dramatically streamlines hardware-related operating expenses. In data centers, the benefits of this technique have reduced the number of servers by up to 70 percent. Comparable savings can't be achieved for all functions in the carrier network environment due to massive real-time traffic volumes and the processing-intensive nature of many network functions. However, savings are expected to reach the 30 percent to 50 percent range.

SDN addresses a highly complementary need. The instantiation of a service requires the dynamic interconnection of network functions (whether physical or virtual) and the associated service end-points.

These interconnections also need to be created, modified and removed dynamically. In essence, the cloud must be able to consume data center, metro and core networking resources in the same way — with the same speed — that it consumes compute and storage resources.

IP networks are very bandwidth efficient when providing these interconnections and VPNs. However, provisioning network connectivity typically uses management systems and workflows that require varying degrees of manual planning and configuration and, as a result take too long to execute. Thus, satisfying vast numbers of dynamically changing demands requires the abstraction and automation of the provisioning, sourcing and life-cycle management processes for network connections, particularly at the edges of the network, where users attach to the network, and at the carrier data centers where virtualized network resources are consumed.

SDN solves these issues with automated, policy-driven control, distributed across network elements and federated across network regions. This approach enables programmatic control of network resources, using application programming interfaces (APIs) for exposure to applications that want to consume network resources, as well as to network controlling applications that can be used to flexibly monitor, manage and optimize the network.

In the web-scaled data center environment, the operational benefits of this technique have been dramatic, achieving over a 10:1 improvement in some instances. In the carrier network environment, comparable savings cannot be achieved due to the "capillarity" of most carrier networks. However, operational savings are expected to reach the 25 percent to 40 percent range as a result of simplified connection fulfillment and assurance processes. Google and Deutsche Telekom are deploying SDN already in high-volume production networks.

NFV and SDN can be employed individually, but to get the overarching benefit of elastically programmable networks, they must be used together.

3 Programmable in the sense that the network can be customized and controlled through flexible APIs; automated in the sense that the network can fulfill these requests without manual operations.

sides of the same transformational coin. *Programmability* enables the creation of a new, dynamic services portfolio that can make network resources available and consumable at Internet speeds and scale. *Automation* is the underlying zero-touch production environment required to fulfill high volumes of service requests and drive operational efficiency gains. The following sections describe these capabilities in more detail.

The programmable network

NFV and SDN enable a change away from the static service-provisioning model for connectivity services.[4] While new business models and norms may take some time to mature, these technologies enable a rich set of functionalities to be flexibly instantiated within the network. Then they can be offered to "feature consumers" (residential and business customers) and "network consumers" (such as enterprises, verticals and mobile virtual network operators [MVNOs]) using service portals and APIs. These capabilities are similar to what cloud service providers have been able to do with their services.

These services allow on-demand consumption of connectivity, as well as exposing many new types of computing and network functionalities to the outside world. So service providers can dramatically expand the degree of control over the network that can be offered to the customer, while simultaneously providing a wider range of services. The expanded control capabilities include attributes of the service, such as dynamically negotiable resource availability, service quality, time-of-day variation and allocation, localization, resiliency and diversity and more. They also include federation across multiple operator networks.[5]

This control can be combined with flexible, network-embedded virtual-service components, such as application-aware Quality of Service (QoS), encryption, intrusion detection and WAN acceleration, and offered as part of a customizable service menu ("service chain") — creating a whole new network experience for carrier customers. These changes put the network at the heart of the move to cloud and facilitate the move of on-premises enterprise services into a cloud-delivery framework — whether for traditional carrier offerings such as unified communications, collaboration tools and location or for new, emerging or yet-to-be-conceived cloud-like services.

As well as allowing third-party applications to access and manage network resources, the carrier will also be able to use programmatic interfaces internally to efficiently employ mix-and-match, best-in-class network monitoring, analytics, optimization and control functions, so they can leverage network intelligence more effectively to streamline processes and optimize operations. As a result, carriers can better match the agility of OTT and web-scale companies and offer customers *service provider* functionalities and more with cloud-like flexibility.

These advances open the door — to customers and operators alike — to invent new business models, to launch new products and to scale them rapidly. But dynamic transformation of carriers' network and services operations will be required to capture the full potential of NFV and SDN. Then carriers can dramatically reduce time to service (as well as time to market) and significantly streamline production costs — objectives that can only be achieved through automation.

Network automation

The other side of the NFV and SDN coin is network automation. Realizing systemic automation requires systemic process simplification and redefinition of the service delivery model. These advances enable dynamic pricing, policy-based on-demand resource access, service instantiation, assurance, analytics, and charging at cloud speed.

In this new model, the existing network is fully transitioned to a streamlined, all-IP/Ethernet/optical network architecture from the access to the core. Moreover, wherever it's practical and cost effective, service-delivery platforms and network functions will be decoupled from special-purpose hardware platforms and implemented as virtualized software, deployed on commercial, general-purpose computing hardware, in much the same way as typical cloud services. These profound changes will also facilitate the drive toward highly converged platforms and integrated control and operations functions across fixed and mobile operations.[6] Supporting this new architecture will require a new approach to OSS and BSS.[7]

4 Connectivity services are typically private network and virtual private network services of various types for enterprise and data center interconnection, as well as enterprise and consumer Internet access and communications services across fixed and mobile networks.
5 Refers to being able to expand programmable services across partner operators, with the ability to offer the same service capabilities independently of whichever partner owns the serving network.
6 For example, converged IP edge functions (such as IP edge routers, security, CDN, video optimizations and value-added services) consolidated at edge cloud nodes, and IP core functions (IMS/service platforms, policy, subs data, BSS/OSS, etc.) in more centralized data centers.
7 OSS refers to operations support systems, and BSS stands for business support systems — computer systems used by service providers to manage their networks. They support management functions such as network inventory, service provisioning, network configuration and fault management, among others.

Legacy workflow-based, semi-manual processes must be replaced with dynamic control, management and orchestration software working together to achieve real-time resource, service and fulfillment domain management. This software-defined, modular network architecture also enables a Lego-like rapid development, launch and market test cycle (fail-fast) approach to service innovation, from ideation to delivery on the order to cash processes.

This vision of the re-architected carrier network is not entirely new. Many benefits of the advanced IT technologies it uses have already been widely proven in data centers by cloud service providers and leading-edge enterprises. Carriers have lagged in broadly applying these technologies in such an automated manner because of the complexity, heterogeneity and stringent availability requirements of their network infrastructure. In addition, they've lacked an open framework with standardized interfaces and APIs to automate and orchestrate the consumption of network resources.

These barriers made it impractical for carriers to pursue this level of network automation transformation. But now, the standards effort being driven by the industry and expanding across many standards bodies is changing that equation. The standards and frameworks required for automation at scale — that is, virtualized function life-cycle management, flow-level data-plane control, network resource modeling, service abstraction, and much more — are progressing with urgency and broad support.

But to achieve this vision of programmability and automation, carriers need to make difficult choices regarding the continuity of legacy services and the restructuring of network sprawl and operations. Only then can they fully capture the transformation payback of streamlined next-generation network architectures, simplified operations and, ultimately, reduced network OPEX.

The following section examines the potential for new sources of value and value capture, as well as value destruction, associated with adopting these technologies.

4. Cloud networking: a double-edged sword

As carriers begin to transform (or "cloudify") their networks and operations, they will also overhaul existing services and construct entirely new services to monetize network investments. The former will enable new velocity and new types of experiences for existing and new customers. The latter will enable carriers to create "network-differentiated" propositions for the provisioning of cloud networking, larger network-as-a-service offerings and cloud infrastructure services.

These advances are possible because cloud architectures let carriers combine automated provisioning and service chaining, deployed at scale, to develop and launch complex service offerings through virtualized prototyping. They can also offer them efficiently using personalized, self-service portals (see Figure 3).

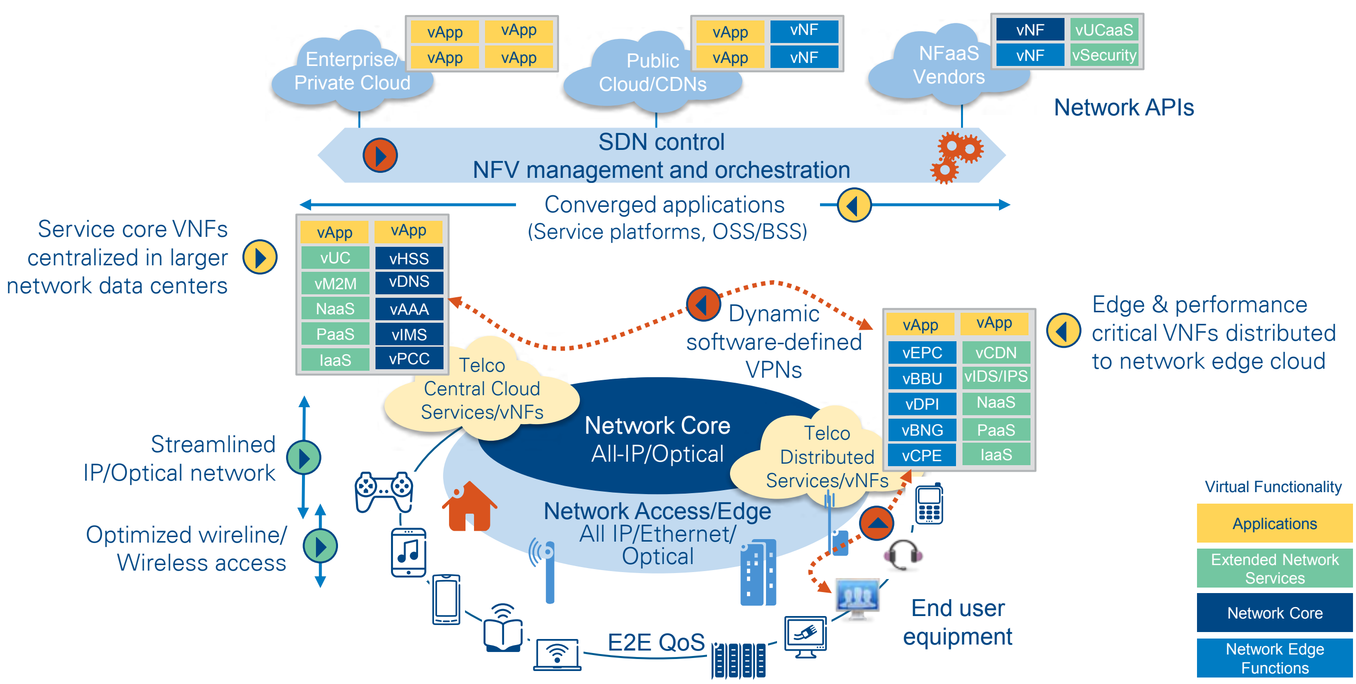
The following sections describe *dynamic services enablement* and *new services creation*, which are expected to enable new revenue streams and, ultimately, result in significant network-based differentiation. In addition, they will also change the basis of competition. New revenue opportunities are not limited to enterprise services, but that's where we expect NFV and SDN to have the most profound and immediate impact.

Dynamic service enablement

> Dynamic services enablement and new services creation are expected to enable new revenue streams and, ultimately, result in significant network-based differentiation. In addition, they will also change the basis of competition.

To overhaul the customer experience, it's important that customers can autonomously manage network functions, based on specific contexts, workload types and traffic patterns. NFV and SDN include programmability that allows services to be requested and self-provisioned, reconfigured and de-provisioned. Real-time APIs make this possible, allowing applications and users to request network resources when needed, based on predefined service policies. There are numerous examples of this capability. Elastic scaling is the most quoted example. It allows network capacity to be varied in line with service demand at short notice, and services can be created and rapidly scaled up *and* down.

Figure 3: Future architecture of the carrier network enabled by SDN and NFV



Source: Arthur D. Little; Bell Labs

With these enhanced networks, along with increased self-provisioning, enterprises gain greater control over the real-time bandwidth use of their applications. They can also use this flexibility to offer a better user experience to both internal and external customers — by tailoring the quality of service to the needs of individual applications and by dynamically scaling service capacity when needed. In each case, elasticity and bandwidth control will create monetization opportunities.

Software-defined VPNs (SD-VPNs) — the virtualized alternative (or complement) to traditional VPNs for enterprises — incorporate many network virtualization and programmability capabilities. They enable rapid site turn-up and secure connectivity over any IP access, along with agile, policy-driven automated provisioning, efficient security management, and enterprise self-administration. They also include programmability that enhances an operator's ability to offer service trials. Such try-before-you-buy offers promote greater market acceptance through broader service awareness, and they can accelerate revenue capture through faster service adoption.

User control of available network capacity, through elastic scaling and bandwidth management, is the essence of policy- and application-driven networking — which is used to create and redefine customized, context-dependent services in real time. The utility of this elastic capability can be bolstered through network analytics that dynamically monitor network state and quickly adapt service delivery accordingly. These dynamic services can be monetized using innovative pricing models that reflect the enhanced user experience and are optimized with respect to current network utilization levels and demand elasticity.

For a typical Tier 1 operator, we estimate that these dynamic services, together with the pull-through services described in the following section, could generate an increase of 10 percent to 15 percent in existing enterprise customer data revenues.

A significant new market segment for dynamically enabled services can be found among web-scale players and large global enterprises. That's because SDN-enabled networking provides the capability to rapidly deploy new multi-national sites (even temporary sites), adapting their inter-connectivity and management to dynamically changing workloads through policy-based control.

New and expanded services

But NFV and SDN allow much more than connectivity. New network offerings can be augmented through dynamically flexible "service chains," significantly increasing the value of basic network connectivity. Moreover, these technologies enable virtual "network slices" to be made available to third parties that considerably expand the monetization potential of networks.

QoS along with security is at the heart of why enterprise VPNs remain important. NFV and SDN allow carriers to offer elastic bandwidth, selectable QoSlevels and a la carte security options. As an example, on-demand "virtualized security appliances" can be embedded into customer networks as service-chained functions. These security services can provide basic secure connectivity elements, such as firewall, network address and port translation (NAPT) and access control lists (ACLs), as well as value-added services such as sophisticated intrusion prevention and detention, denial of service prevention, and on-demand security probes. Reimagining security as an integral part of the network can go much further and extend into application-specific, policy-driven, end-to-end managed security services, enabled by innovative security extensions to network APIs.

These technologies also enable novel uses of existing telecom networks that would appeal to many web-scale, IT and enterprise customers. Specifically, SDN enables "network slicing" or providing an "owned-like" network experience to third parties. Allowing customers to use the network in this way is an emerging opportunity, but several use cases are becoming apparent.

The most obvious use is offering targeted business-to-business-to-consumer (B2B2C) services with customized QoS and functional requirements. These capabilities could attract M2M application providers and specific industry verticals, such as financial services, healthcare and manufacturing. Other emerging use cases include leasing part of the virtualized mobile core to MVNO operators that need subscriber policy control but do not wish to invest in a full-scale, end-to-end core network.

But reimagined versions of traditional telco services are not the only opportunities these technologies enable. Forward-looking carriers can use these technologies to leverage and extend the network into cloud infrastructure services. For example, network-attached infrastructure as a service (IaaS), platform as a service (PaaS), and hosted software as a service (SaaS) could include enhanced localized and network-aware compute, storage and desktop-as-a-service applications, a growth area where operators can leverage their footprint and their connectivity into the enterprise LAN.

Examples of new revenue sources are listed in Table 1, for both new services and dynamic services enablement.

Table 1: Potential new revenue sources

Dynamic service enablement	New and expanded services
▪ Bandwidth on demand and bandwidth calendaring ▪ Enhanced user control of virtual network slices ▪ Automated burst-able elastic bandwidth ▪ Real-time, context-dependent optimization of service quality ▪ Rapid turn-up and configuration of new enterprise sites ▪ Enablement of rapid, customized product trials ▪ Federated multi-operator dynamic virtual networks	▪ Real-time, end-user customizable service options ▪ Security services, such as firewalls, IPS and IDS, content filtering and endpoint security ▪ IaaS: Compute, storage and desktop as a service ▪ Granular network slices: Network functions as a service (virtual IMS and virtual EPC,) ▪ Enterprise connectivity: SD-VPN and virtual CPE services

New revenue streams are expected from both dynamic service enablement and new services. Quantifying the former is challenging. However, dynamic service enablement is likely to shake up the structure of the 22 billion euro European enterprise networking industry, as "dynamical networking" inevitably displaces regular "static networking." The most dramatic growth opportunities will open up as operators can claim a stake in the fast-growing 18 billion euro IT security business, 17 billion euro cloud services market and the emerging non-access-based wholesale businesses. The absolute level of growth for the 113 billion euro business telecom market will depend on multiple factors, including the competitive reality in each geography and execution. But it should allow the industry to stake a credible claim for the provision of differentiated network services and network-differentiated cloud services.

Successful first movers stand to capture a disproportionate share of this disrupted revenue. However, the basis of competition will also be changed irreversibly, through migration away from traditionally monolithic, purpose-built architectures for telecom communications services — and largely static network connectivity services — toward highly virtualized and automated systems architectures, similar to those used in modern IT stacks and cloud delivery models. Four dimensions of this change are considered in the following sections.

New relationships with customers

On-demand and policy-based use of network resources will shift the balance of the carrier-enterprise customer relationship, which is currently structured as rigid, exclusive contracts lasting one to three years. In this new on-demand environment, customers will want to supplement longer-term commitments with supplemental shorter-term contracts to provide elastic connectivity services. Such providers may offer on-demand services on very different pricing models, using daily or hourly timescales or perhaps even real-time usage information to price their services.

The most sophisticated customers may even buy into formal capacity reservation-and-release management ("bandwidth calendaring") business arrangements. To deal with the new service-offering complexity, customers may engage network operators or intermediaries (service brokers) to dynamically manage elastic network resources, so that workloads and purchased capacity are perfectly matched. This may lead to new revenue opportunities for carriers, or it may encourage customers to do away with a primary network supplier altogether and buy all services on demand from the open marketplace. While this latter option seems extreme for an enterprise client, it is hardly unfamiliar to carriers, because this is how the market for wholesale services currently operates.

While full-fledged adoption of wholesale-like communication services will not be for the faint hearted, enterprises that make that choice will act, in many ways, like another carrier. The potential impact is important, because carriers may see relationships with many of their largest customers progressively shift to a wholesale approach. In some cases, the customers may even transform into competitors one day.

New classes of competitors

Virtualization, network service abstraction and programmability will radically change how carriers and their customers see networks. The implications are significant, because, effectively, anyone can become a service provider, since, in effect, network ownership is no longer a prerequisite for service delivery. No doubt, these services will be used by OTT and web-scale companies and cloud service providers to evolve their service offerings. But, more importantly, the emerging market for dynamic services (bandwidth and functions) provides a disruptive opening for smaller, more-focused network operators, such as carriers' carrier providers, to compete more aggressively in the growth markets for large enterprise WAN and data center interconnect (DCI).

At the other end of the scale, many existing enterprise customers like banks, retailers or media companies could become powerful alternative service providers, encroaching in the mass telecommunications market. This new class of mass-market competitor could develop business models based on access to network functionalities that allow them to:

- Build higher-value, embedded cloud-like service
- Create and deliver their own version of traditional network services, such as WhatsApp or Line, thereby competing with SMS
- Develop the "next big thing" in ICT services

The implications of the carrier network converting into a cloud delivery platform are significant. These shifts build carrier value for XaaS services, but they could also result in a significant outflow of value across both consumer and business market segments, in favor of new competitors. Powerful new players could seek (and have the muscle) to drive a wedge between carriers and their customers in the long term, forcing the carrier into a wholesale relationship.

New collaborations

A rich new set of business models, based on flexible forms of network disaggregation, will be enabled, through the mix of on-demand access to connectivity, along with exposing core network functionalities to other entities. This change is a far cry from open-access provisions mandated by market liberalization regulations. Rather, it is a market-driven approach that will enable a much bigger network services ecosystem. Carriers and third parties will work together actively to devise and enrich service offerings, leveraging network-function-as-a-service (NFaaS) capabilities from carriers, as well as federated access and network services accessed with open network APIs.

The implications are both promising and challenging for carriers. Carriers will be able to buy into each other's dynamic VPNs and NFaaS offerings to expand their services beyond their traditional geographic footprints. The ability to link these virtual network capabilities on demand will spur a wave of new product introductions to take advantage of new operating synergies and new business opportunities among carriers, network-equipment vendors and cloud-service providers. This activity will be much like current trends among OTT and web-scale companies and their partner ecosystems. When done right, these collaborations can create promising new value for customers and partners. But in the process, they may accelerate erosion of traditional communication services and tiering of the industry, as a result of market share shift towards service innovators.

Profound changes to operations

Automated networks will lead to a significant change in the traditional carrier operating model. Service fulfillment and assurance will be simplified, and customization will be easier — through global network resource management, abstraction and granular manipulation using APIs. The methods are much like those used with cloud compute resources.

The combination of all-IP, NFV and SDN will allow telcos to transition into a cloud-like operating model. Their customers will be able to dynamically and automatically define, provision and operate the VPNs that support their services, applications and users. The carriers will offer just-in-time access to network connectivity and NFaaS almost instantly, at a better cost than comparable self-managed solutions. They can also enable dynamic control of network resource consumption by individual data flows, according to QoE and customer-defined service policies.

However, taking full advantage of the technologies requires massive process automation and redefinition of the service delivery model. As described earlier, current BSS and OSS do not support the functionalities required for real-time network operations, administration and management. Consequently, these systems should be replaced over time, so they can support the new service portfolio and transition to the cloud-like operating model that's needed to capture major revenue and efficiency gains.

On the flip-side, retiring these systems also means retiring many legacy services and their associated revenues. While this is a simplistic summation of the challenge, it does illustrate the dilemmas that carriers face when making technological and organizational changes to implement automation.

Just as technology disruption has created winners and losers in other industries, these technologies will trigger similar patterns in telecommunications. But in this case, it is not outsiders that are leading the disruptive process. Instead, the largest service providers in the industry are jockeying for a role in the cloud/ICT space.

The following section examines the economic impact of these technologies on current operations.

5. Creating value across the business

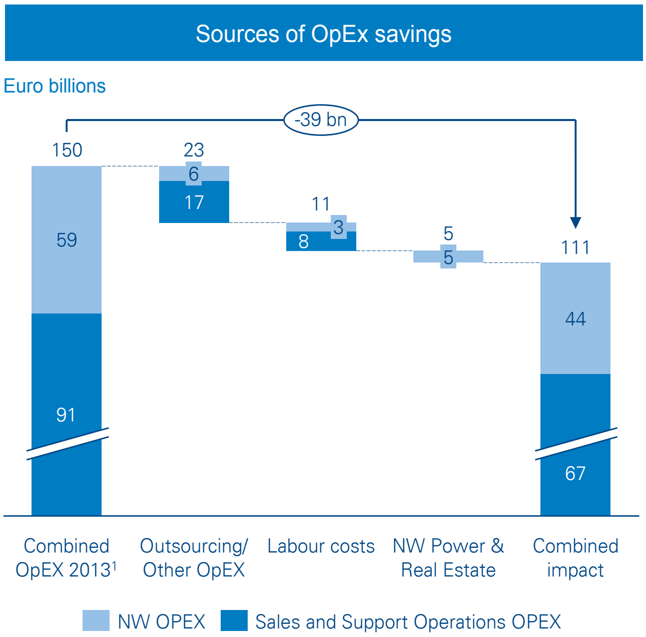
With billions of dollars' worth of assets in equipment, services and human assets, moving to a new automated and programmable architecture in carrier networks is not without risk. So it is vitally important to understand the magnitude of the benefit that is possible. That's why we have analyzed the impact, especially the OPEX benefits, of transforming carrier networks in line with NFV and SDN principles.

The study examined operators in 35 European countries. Collectively, these operators had adjusted revenues of 250 billion euros in 2013, with annual OPEX of 150 billion euros and a staff of 665,000.[8,9] The analysis used telecom expenditure data from financial reports, validated through individual case studies on network evolution strategy. The impact was examined along two dimensions, technology onboarding and changes to the operating model.

Our calculations show that the efficiency impact of onboarding NFV and SDN for these operators could be worth 14 billion euros per year, equal to 10 percent of total OPEX. The results are driven by savings from automation and simplification. These findings are only part of the story, however. A further savings of 25 billion euros per year — equal to 16 percent of total OPEX — can be generated by changing and simplifying the operating model (see Figure 4).

The following sections take a closer look at each dimension of the analysis.

Figure 4: European carrier aggregate savings



1) Adjusted OPEX excludes ICX and handset related expenses which represent 8.3% of the revenues of all fixed and mobile operators in 35 European countries
Source: BellLabs and Arthur D. Little calculations

Technology onboarding

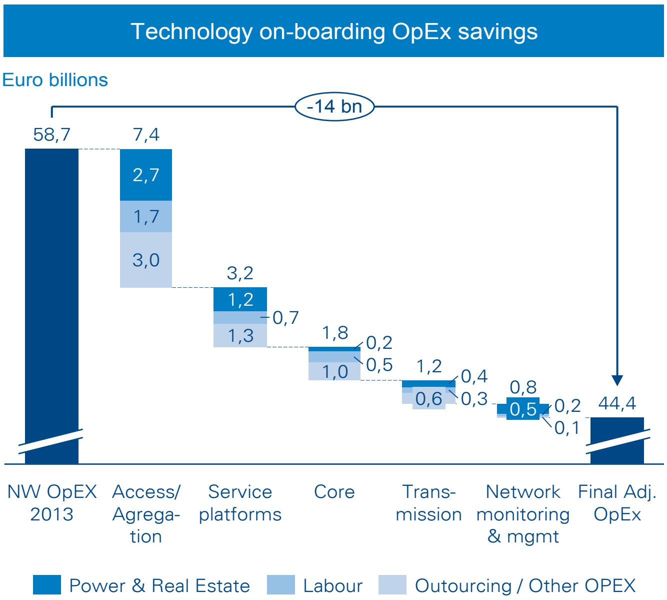
Technology onboarding, as defined here, refers to broadly employing automated NFV and SDN capabilities to transform the carrier network. This process is achieved by adopting software-based network functions, wherever practical and cost effective. These functions are deployed on commercial off-the-shelf hardware, linked by dynamically configured interconnections and united through software control. Optimal coexistence of physical and software-based network functions is made possible through a virtualization and cloud-network orchestration layer, which uses network abstraction to automate and globalize management of physical and virtual network resources.

The calculations in our analysis show potential savings worth 14 billion euros, across all network production platforms — from access at the edge of the network all the way to the service delivery and monitoring platforms deep in the core. However, the absolute impact is largest in the access and aggregation,

8 Across the 35 European countries (including Turkey) covered in this study, revenue from services reached 275 billion euros (adjusted 250 billion excluding ICX and handset sales) in 2013. Operating costs represented 60 percent of overall adjusted revenues, equal to 170 billion euros (adjusted 150 billion excluding ICX and handset sales). Across Europe, the industry employed a staff of 665,000, excluding external contractors.

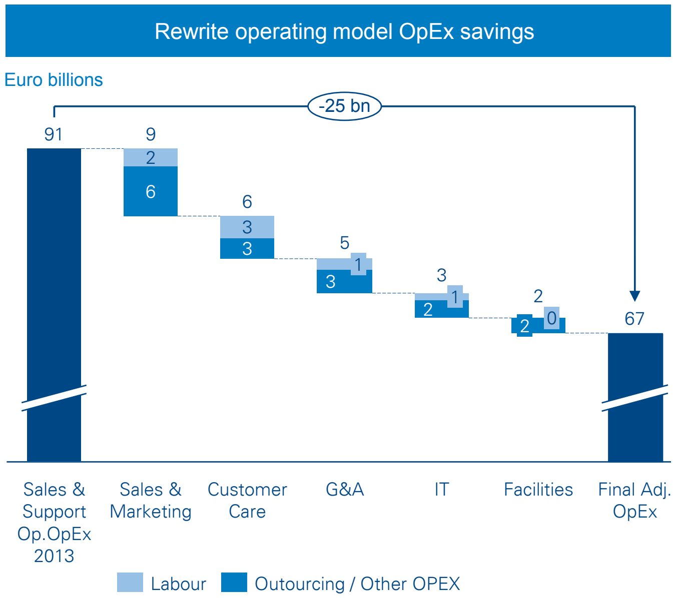
9 Management of the network infrastructure, including all network-related operations and IT, is the single largest OPEX category and is very labor intensive. In 2013, the cost base was 50 billion euros or 33 percent of adjusted costs and employed a staff of 180,000, equal to 27 percent of headcount. These costs increase further by 8 billion, or 6 percent of adjusted costs and 84,000 staff (13 percent), if the costs of installing fixed-line customer premises equipment is also considered in the scope of the network. Fixed network operators outspend their mobile counterparts by approximately 37 billion euros. Moreover, they employ six times as many staff. Of a total of 460,000 employees, network staff is over 50 percent, with approximately 230,000 people. In contrast, all mobile operators employed 205,000 staff, of which only 35,000 performed network-related functions.

Figure 5: European carrier technology on-boarding savings



Source: Bell Labs and Arthur D. Little calculations

Figure 6: European carriers rewrite operating model savings



Source: Bell Labs and Arthur D. Little calculations

service delivery and core platforms across mobile and fixed networks (see Figure 5).

Across all layers, major savings are realized in design, integration, deployment and operations – areas in which remote management significantly reduces labor and third-party costs. Additional savings are achieved from lower power costs for the core and service platforms, driven by virtualization. They result from substantial reductions in special-purpose hardware, cutting electric power consumption by nearly one half.

Please note that the above calculations reflect only the direct impact of NFV and SDN. Additional collateral savings are expected as a consequence of technology onboarding, through accelerated retirement of legacy network equipment to promote an all IP/Ethernet transformation of the network. As a consequence, all other non-IP legacy services are turned down, including ATM, frame relay, ISDN and PSTN. In addition, legacy network support functions are removed from the network and the balance sheet. The outcome is a streamlined all-IP network. That is, it uses an end-to-end IP-Ethernet-optical services and transport architecture with an open IP/SDN-based control plane. Mass simplification at this scale allows network footprints and operations to be radically downsized, particularly for fixed operators.

Revised operating model

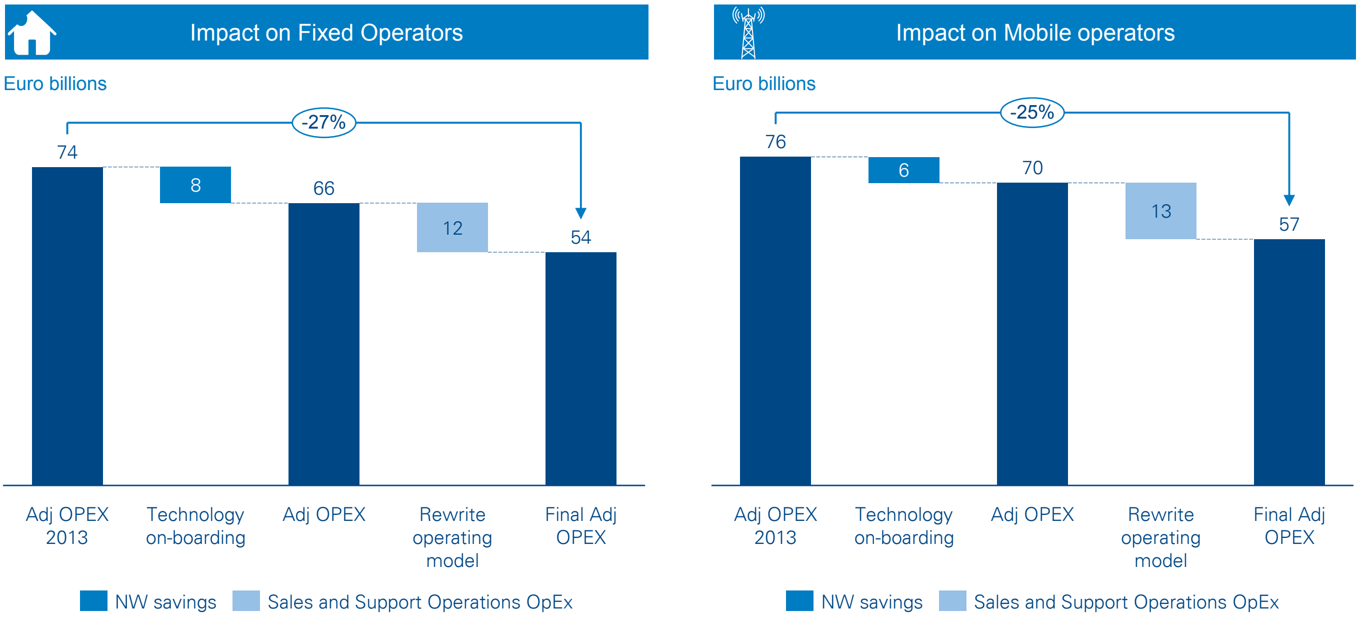
Over time, networks build up operational complexity. It typically results from a high degree of vertical specialization, lack of unifying services and resource abstraction, and a bloated back-office support environment that includes layers of legacy systems, applications and expensive IT workarounds. Rewriting the operating model is about taking advantage of flexible new technologies to streamline operations in the business layer from marketing, sales, back-office and associated IT.

Our calculations show that, for each euro of network OPEX savings, there is considerably more than a euro of value in non-network OPEX savings (see Figure 6), which equates to a further 25 billion euros in our model. These savings could increase yet further, if the industry were to take concerted steps towards online-only selling, service provisioning and self-care.

The aggregate impact of NFV and SDN is somewhat greater for fixed operators than mobile operators. Expressed in economic terms, we estimate that fixed operators will capture 20 billion euros or 27 percent of fixed OPEX, whereas mobile operators will capture the balance of 20 billion euros, representing 25 percent of mobile OPEX. Expressed in unit costs[10], fixed line OPEX in 2013 stood at 205 euros per year per line. By contrast, mobile OPEX per SIM was lower at 98 euros per year, a reflection of the relatively simpler service portfolio, lower ratio of legacy networks and systems, and higher starting level of automation. NFV and SDN technology on-boarding will, by itself,

10 Across the 35 European reference countries, 360 million fixed lines and 775 million mobile SIMs were in service in 2013.

Figure 7: Total SDN/NFV fixed and mobile operators OpEx savings

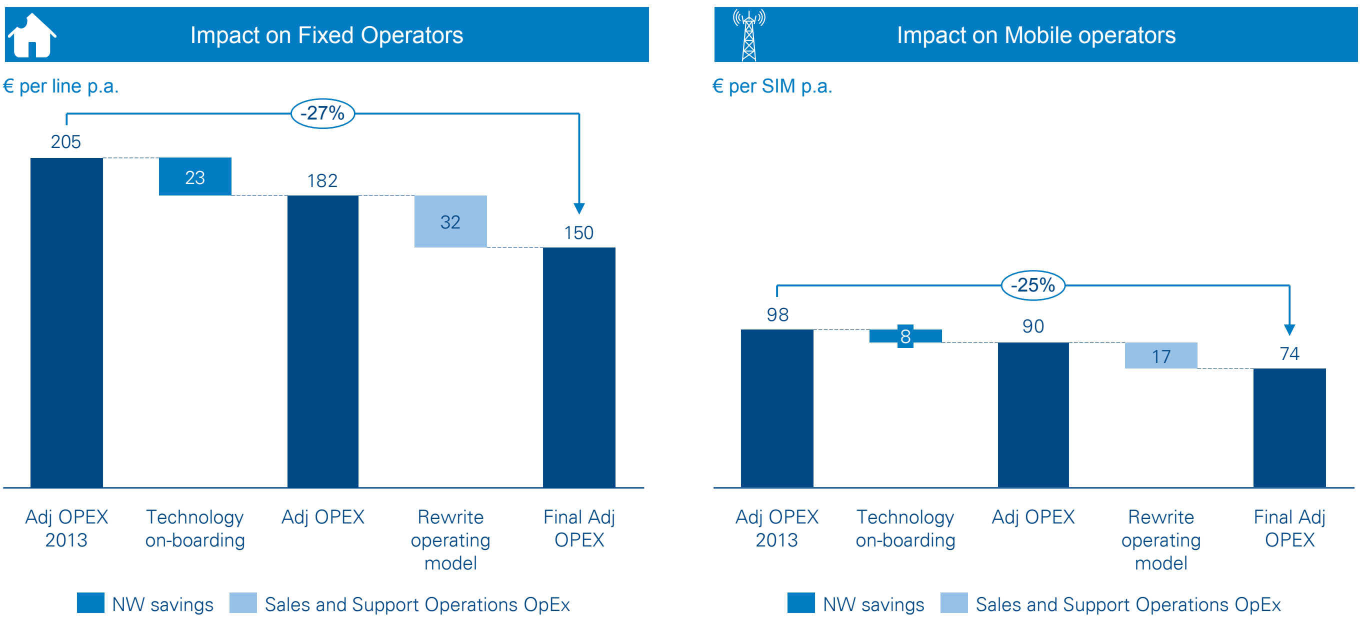


Source: Bell Labs and Arthur D. Little calculations

enable savings of 23 euros per fixed line and only 8 euros per mobile SIM, whereas rewriting the operating model will generate a further 32 euros per fixed line and 17 euros per mobile SIM (see Figures 7 and 8).

The following section discusses how the industry and individual operators should respond to the opportunity.

Figure 8: Unitary SDN/NFV fixed and mobile operators OpEx savings



Source: Bell Labs and Arthur D. Little calculations

6. Choosing the right business model for each carrier

The race for the cloud/IP networking space started before the arrival of NFV and SDN, with cloud service offerings from players like NTT, Verizon, AT&T, Orange and BT. Now, adoption of these new technologies into the very fabric of the carrier network will dramatically accelerate the pace and magnitude of change. Deciding how to move forward will require choices regarding the best business models for the future and the right playbook to get there.

Carriers can no longer afford to ponder if and when to make the transition. Instead, they need to start planning how and where to implement these technologies and support them with credible customer adoption and business economics. In our view, there's no single roadmap for the industry. Rather, each carrier must decide its own path, balancing the needs of the marketplace with the reality of investment cycles and the needs of the shareholders.

Upfront efforts at standardization and R&D investments for proof-of-concepts are vital to "get ahead" on the learning curve. But staying ahead to capitalize on this opportunity requires individual carriers to think more broadly about the business and operating model consequences of the transition. In this context — while service providers re-evaluate their business models, product portfolios and supplier relationships — it's a good time to question some industry taboos.

For example, the industry has traditionally associated being an access-only provider as a fool's prize.[11] While there's more than a grain of truth here, it reflects the vertical and monolithic business designs of hard-wired access, transport and service platforms. However, the relevance of these all too familiar structures is being challenged. The challenge grows out of the flexibility enabled by IP networking, first, and now by NFV and SDN technologies, coupled with the ever-expanding use of cloud technologies by carriers' clients.

In this new environment of flatter, programmable and automated networks on a global scale, the monolithic structure is outdated, neither defensible nor suited for sustaining competitive advantage. To compete, carriers must move toward more flexible multi-level service delivery architectures. In addition, they must even go so far as to cooperate with each other, with OTT and web-scale companies, and with cloud service providers to ensure cloud relevance and global scale. Moreover, as the industry expands to offer new service functions from the network, carriers must learn to work with new partners using nontraditional models.

That means carriers must consider what will be the most appropriate business model for success. The following sections briefly outline two major alternative paths, the *access-centric carrier* and the *cloud carrier*. Each carrier can then consider how its capabilities and goals fit these descriptions.

- **Access-centric carriers** use automated networking to allow flexible disaggregation of telco service, control and access layers, which provides control to a slice of the access layers through standardized APIs. Access carriers leave behind the complexity of service-delivery platforms and operations, and their associated revenue, for a lean business model that's optimized for efficient operations. Access-centric carriers become the de facto access providers to cloud carriers and enterprises, as well as IT and OTT players. The carrier may not completely abandon its non-access-related service portfolio. Rather it manages the business challenge by ensuring its service portfolio remains lean and contributes measurable value.
- **Cloud carriers** use the full suite of programmable, automated, orchestrated NFV and SDN techniques to carve out a sustainable value in the new cloud ecosystem. The value comes from offering consumable on-demand network services that are elastic, secure and seamless across clouds and WAN. The carriers can do this because their scale is great enough to allow investment in transformation, leveraged across a large service footprint, and they have the geographic reach to directly serve the large enterprises and OTT and web-scale companies that will be the upfront adopters. Cloud carriers will typically also be access carriers in one or more domestic markets, and work with partner access carriers in other markets. The connection between these two models typically will be made by carriers using the global cloud they create to serve the international needs

11 The telecom industry, threatened by OTT and web-based service providers, has argued that they must absorb the massive costs of developing and operating the global networks, while OTT players benefit from these without apparent regard for the traffic they generate.

of the enterprises that are homed in their domestic markets, i.e. by essentially 'following the enterprise' into their global markets.

Moreover, by managing end-to-end cloud networking and compute resources, these carriers can implement the strictest compliance standards for data localization, privacy regulations and service performance. They can partner with local access providers (including in-house access businesses) to serve customers across the world, leveraging their brand, distribution capabilities and service portfolio to capture and retain customers. Cloud carriers[12] will be able to provision a homogenous global experience, directly connecting through their own and partner access, which gives them full control of the user experience, limited only by the technical characteristics (coverage, bandwidth limits and latency) of the access type. This platform architecture will also enable cloud carriers to partner efficiently with many third-party software vendors across a range of applications, from security, mobility and unified communications, to deliver these solutions on demand.

While both models offer value-creation alternatives for existing carriers and their shareholders, their key success factors are very different. An operator aiming at an access-centric carrier model should concentrate its technology investments to enable dynamically consumable access, but otherwise focus relentlessly on cost and efficiency.[13] An operator aiming at a cloud-carrier model should consider focusing on building a portfolio and ecosystem of world-class innovative services, combining in-house developed services with third-party offerings to deliver unique value-added dynamic services.

The most appropriate path for any specific carrier will be dictated by geographic scope and scale, as discussed above, as well as by their current product portfolio, their local competitive environment and their internal culture for business innovation. In our view, the critical challenge for a carrier, and the industry as a whole, is not simply to make the right choice for their particular strategic condition — but also to see it through in a focused, purposeful and timely fashion.

Without strategic clarity and a realistic assessment of their own capabilities, carriers run the risk of losing focus for their transformation by trying to compete equally in both cloud- and access-carriers models. This can lead to unsustainable investments, or even worse, making uncorrelated investment decisions that waste company cashflow and resources. Clearly the larger opportunity lies with carriers that are in a position to become cloud carriers. However, in both segments, the carriers that lead in executing a clear strategy will grow market share at the expense of the rest.

The following section discusses how individual operators should start bringing NFV and SDN into their networks.

12 This characterization does not preclude that a telco may create an internally focused cloud carrier to centralize management of international network of OpCo.
13 Such an archetype could continue to provide non-access services through white-label cloud carriers or traditional partners XaaS offerings.

7. Driving the process of transformation

To gain the benefits of NFV and SDN, carriers need to begin with actions in the following three high-priority areas.

Develop a new cloud-enabled product roadmap

The OTT and web-scale and enterprise cloud ecosystem is advancing rapidly. To stake a claim to their share of the value, carriers too must move quickly. Convincing enterprise customers to migrate their applications to a carrier-based cloud may be a challenging sell upfront. But a more accessible, immediate opportunity is to make the case for dynamic networking in support of their cloud strategies.

The first-mover advantage will allow carriers to capture share in these enhanced VPN services from traditional (static) networking competitors, and it will position them to up-sell value-added NFV- and SDN-based services as part of automated turnkey solutions.

The following five broad actions for carriers and their clients can help drive the transformation:

- Work directly with clients and through industry forums to co-create high-value use cases for adoption of next-generation enterprise network services — and prioritize technical and operating models development.
- Develop thought leadership on key compliance issues linked to use of distributed cloud computing, particularly data placement and security in outsourced, out-of-country and out-of-region data centers.
- Define the technical requirements, standards, architectures and certification processes that can meet operational control, data security, localization and privacy needs across different industries.
- Begin planning for the evolution of network service catalogues and business models to ensure timely and relevant investment in new platforms and systems, as well as retirement of legacy network systems.
- Finally, start early to build up federated alliances similar to those seen in the travel industry (SkyTeam, Oneworld and Staralliance), as well as joint ventures and marketplaces among carriers and with clients — with the goal of serving client automation needs globally. We recommend forming an alliance of network operators that will allow the expedited development of federated dynamic connectivity and higher layer services, multi-operator service chaining, and coordinated marketing of federated services across the alliance members' combined channels. This is essentially a operator analog of the airline alliances such as the Star Alliance and Sky Team, which allow flight code sharing, federation of reservation systems and sharing of hubs and other facilities. Forming such a global network alliance ('GNA') will enable operators to bring to market ubiquitous global automated services and compete effectively with web-scale providers.

Driving this agenda forward with large enterprises and OTT and web-scale companies will allow carriers to use network automation as a tool to bundle multiple services, which is especially important while standards are still developing, and there is no single standard for interworking service components on a mix-and-match basis across service providers. Moreover, by engaging with clients at an early stage, carriers can fine-tune the roadmap for their future service catalogue and make sure it is supported by credible marketplace investment cases for transformation.

Build up programmability and systems engineering capabilities

A new service catalogue of automated, programmable services will not be built overnight. It must necessarily be phased and will require a coordinated parallel evolution of the virtualization infrastructure, automated networking control and operations model. The roadmap for virtualization of network functions will be influenced by feasibility, degree of benefit and investment cycles. The roadmap for SDN automation is also likely to be rolled out in phases involving intra-data center, intra-data center overlay, and finally full WAN SDN control.

Given the need to build up this transformation step by step, it is vital for carriers to begin early with some "low hanging fruit"–type applications, such as enterprise overlay (that is, software-defined) VPNs or the service chaining of network-service functions for consumers and enterprises. Carriers that establish a leadership position in these early stages will have a learning-curve advantage, along with a much better chance of maintaining that competitive lead in later phases.

The standards that must be developed, the components that must be interworked, and the operations that must be integrated within the network will freely combine IT and carrier networking. In practice, that means each carrier must build services, while simultaneously filling in missing IT capabilities.

One core challenge is the operating model schism between network operations (mobile, fixed access and core) and IT operations (back-office systems, collaborations, communications systems and so forth). Currently these teams operate in vertical silos. But introducing NFV and SDN into the network blurs these boundaries. As a result, the operations workflows and the management systems at both the business and network layers will need to be integrated in new, better-abstracted, and much more automated ways.

To achieve a fully automated state, carriers must be able to systematically bridge the gaps across these domains. That means building up what we'll call "cloud network systems engineering" expertise, a vital skill set that combines both IT and networking disciplines to enable an effective and timely transition.

Streamline network and accelerate legacy retirement

Investing time, effort and resources in operational service automation and network programmability only makes sense for mainstream IP-oriented services and networking technologies. In fact, automation transformation provides a powerful incentive to rigorously streamline the network, which simplifies development and deployment of a new automated control, management and operations environment.

Today's IP-based services are already operationally efficient compared to legacy services such as PSTN, ATM, frame relay and SONET/SDH. With automation, operational expenses for the transformed services will be reduced to a whole new level, per service and especially per service transaction. With this widening gulf in operational efficiency, coupled with an urgent need to reduce OPEX broadly to accelerate investment in automation, the conclusion is plain: The best way to ensure effective and timely transformation to a streamlined and automated network is to aggressively accelerate the retirement of legacy services and networks.

Traditionally, legacy services have had very long lives, because carriers want to retain their durable, though diminishing, cash flows for as long as possible, while also providing continuity of services to long-time customers. But maintaining these services comes at a hefty price — namely the inefficiency of operating parallel overlay networking and service infrastructures, which includes the complexity and extended proliferation of OSS and BSS systems and all the associated parallel staffing and footprint costs. To prevent competitors from scooping up these customers with their own differentiated offerings, carriers may prefer to "cannibalize" their own legacy services by proactively providing incentives to move to automated IP/Ethernet/optical services (with higher capacity, at much better price per megabit per second). In this bargain, the carriers end up with a more agile, innovative and competitive business.

8. Conclusion

Network innovation based on NFV and SDN holds tremendous promise for the future of networks. But for this promise to be realized, carriers must transform their heterogeneous networks into a streamlined, automated whole. To achieve this goal, they need to seek inspiration from cloud peers, while maintaining the reliability and service quality customers expect. None of that is simple. However, the prize for carriers that get it right is significant. It includes systemic streamlining of operations, exposure of network services to high-volume, dynamic consumption by cloud applications and cloud-based enterprises — and perhaps even the opportunity for decommoditization of the network.

Carriers must plan and phase such an extensive network transformation carefully. The process includes iterating frequently and working closely with both suppliers and lead customers to maximize the benefit and the learning at each phase. It also involves building up increasingly value-rich solutions that advance toward the ultimate goal. Some key actions include:

- Adapting business models to actively shape marketplace adoption of cloud/IP networking services from enterprise customers as well as wholesale segments (OTT and web-scale, carrier's carriers, IT players, etc.)
- Engaging openly with other carriers regarding standards alignment to facilitate cloud/IP networking enablement, including tackling regulatory issues of cross-border data storage and privacy concerns
- Involving suppliers in the early stages of planning network transformation, and monitoring the emerging cloud networking ecosystem to identify disruptions in the supplier landscape as this space matures
- Developing alliances and joint ventures (similar to airlines') to support the global dynamic cloud network needs of multi-national corporations and OTT and web-scale companies, based on a shared vision of an automated network services catalogue evolution
- Formulating a strategy and a timeline for aggressively retiring legacy services that will facilitate a more rapid transformation to the cloud/IP network

The opportunities and decisions that carriers now face, given the expected breadth of changes from SDN, NFV, and the cloud-networking market, make this one of the most exciting, pivotal times in the history of communications networks. A lot is at stake. And as in any major disruption, there will be winners and losers. We believe that the winners in this case will be the carriers that:

- Move early and purposefully
- Co-create the future with lead customers and partners
- Take the opportunity to not only virtualize and automate their networks, but also thoroughly converge and streamline them

These will be the agile service providers equipped to thrive in the cloud ecosystem.

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Arthur D. Little and Bell Labs

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