FUTURE NETWORK

Digital Technology dynamics are rapidly driving Information and Communication technologies together - this is demonstrated by the emergence of the disruptive, but complimentary SDN (Software-Defined Networking) and NFV (Network Functions Virtualisation) forces transforming the Communications network. The outcomes will include reduction in Capex and Opex, greener operations, increased automation and faster innovation.

Digital transformation is evident in virtually every aspect of work and personal life today. The forces driving this are centred on Information Technology and Communications Networks, which have become essential components of industry, business and personal life.

This paper briefly examines the drivers of change and the impacts that they will have on all aspects of a connected world, ushering in the Future Network.

IT TRANSFORMATION DRIVERS

SOA[1], Virtualisation[2] and Cloud Computing have been major factors in the transformation of Information Technology. Other factors, such as universal access to the Internet and the World Wide Web, as well as the availability of computing capabilities on diverse user devices with different form factors, have put this transformation into the hands of end users.

SOA [3]

Design patterns, rules engines, self-contained services, separation of concerns, loose coupling, componentised data models, data-driven processes, service orchestration and the like have established a paradigm that delivers flexibility, agility, speed and quality.

[1] **SOA**, Service Oriented Architecture, is a software design and software architecture design pattern based on discrete pieces of software providing application functionality as services to other applications. http://en.wikipedia.org/wiki/Service-oriented_architecture

[2] **Virtualization**, in computing, refers to the act of creating a virtual (rather than actual) version of something, including but not limited to a virtual computer hardware platform, operating system (OS), storage device, or computer network resources. http://en.wikipedia.org/wiki/Virtualization

[3] http://abdennour-insat.blogspot.co.uk/2012/04/soa-tutorial.html

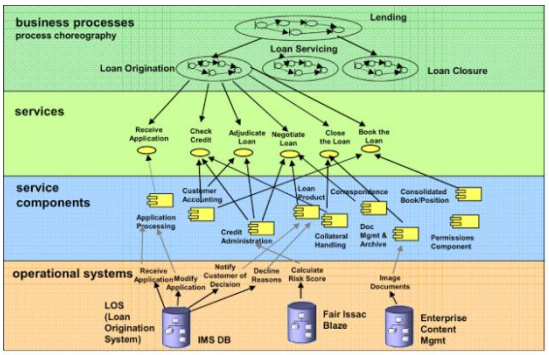

Figure 1: SOA Architecture

This has put the aspirations for Service Delivery of Right-First-Time, reduced Cycle Time and zero-touch into a place where these now have the potential to be realised.

VIRTUALISATION

Virtualisation of:

- Computing power
- Data Storage
- Network

has transformed the Information Technology operational arena, bringing with it many benefits[4], amongst others:

- Maximum deployment of COTS[5] components
- Vendor-agnostic solutions
- Efficient use of hardware and software resources
- Greener operations
- Reduction in Opex and Capex

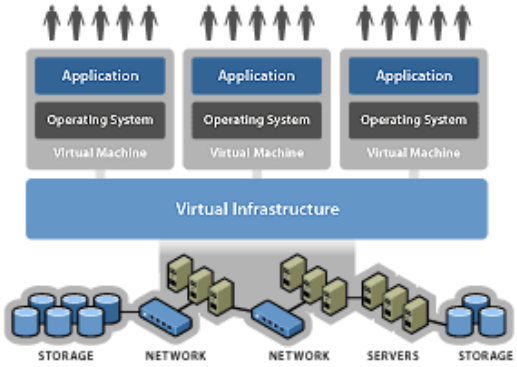

Figure 1: Virtualisation Architecture

CLOUD COMPUTING

Figure 2: Cloud Computing Panorama

Cloud Computing has provided multi-tenant systems with elastic[6], pay-as-you-go use of computer resources, as well as access from virtually anywhere.

In addition adopters are relieved of the O&M[7] overheads of administration, backups and upgrades, as well as the requirements for physical facilities, equipment and local area networks.

[4] http://www.techrepublic.com/blog/10-things/10-benefits-of-virtualization-in-the-data-center/

[5] **COTS**,short for ***c**ommercial **o**ff-**t**he-**s**helf*, an adjective that describes software or hardware products that are ready-made and available for sale to the general public. http://www.webopedia.com/TERM/C/COTS.html

[6] **Elasticity** the degree to which a system is able to adapt to workload changes by provisioning and deprovisioning resources in an autonomic manner, such that at each point in time the available resources match the current demand as closely as possible. http://en.wikipedia.org/wiki/Elasticity_(cloud_computing)

[7] **O&M** Operations and Maintenance

The cloud computing stack delivers the service categories of IaaS, PaaS and SaaS[8]- these categories being differentiated as:

- **SaaS** (Software as a Service) applications are designed for end-users, delivered over the web
- **PaaS** (Platform as a Service) is the set of tools and services designed to make coding and deploying those applications quick and efficient
- **IaaS** (Infrastructure as a Service) is the hardware and software that powers it all – servers, storage, networks, operating systems

UNIVERSAL ACCESS, THE INTERNET AND THE WWW [9]

In many parts of the world today, Universal Access, the Internet and the World Wide Web have brought computing power to the end user in almost any environment, making the mantra of 'Anytime, Anywhere, Anyhow' a reality.

UNIVERSAL ACCESS

With the ever-increasing roll out of Broadband digital access to individuals and communities across the globe, mankind is being enabled to gain access to computing resources on an unprecedented scale. De-regulation of telecommunications and radio spectrum has further spurred availability of access to the new generation of devices using the mobile communications spectrum.

This has been enabled by the proliferation of:

- Traditional last-mile[10] fixed line copper connections
- Fibre access via FTTC[11], FTTP and the like, introduced into the last mile
- WiFi introduced into the home, workplace, public spaces and transportation
- Mobile Telephony enabled by both terrestrial and satellite radio

INTERNET

The Internet, based on IPv4 addressing and the TCP/IP protocol, has rapidly expanded into a world-wide network, enabling billions of users to take advantage of whatever digital access is available and access services exposed to the network.

The growing implementation of IPv6 will enable any object in the known world to be connected to the Internet and to interact with other Internet-enabled objects, ushering in the full power of the IoT[12].

Figure 4: Multiple Form Factors

WORLD WIDE WEB

The WWW has brought unprecedented access to information and networking between individuals

[8] http://www.rackspace.com/knowledge_center/whitepaper/understanding-the-cloud-computing-stack-saas-paas-iaas

[9] **WWW**, the World Wide Web. http://en.wikipedia.org/wiki/Www

[10] **Last Mile**, http://en.wikipedia.org/wiki/Last_mile

[11] **FTTC, FTTP,** Fibre-to-the-curb/premises. http://en.wikipedia.org/wiki/FTTC

[12] **IoT**, Internet of things. http://en.wikipedia.org/wiki/Internet_of_Things

via the Internet. New technologies implemented in Web Browsers, such as HTML5[13] and WebRTC[14] promise to bring unprecedented functionality and embedded communications to the end user from a standard web browser.

FORM FACTOR

The evolving Form Factor of computing components and communications devices has brought the computer to a wide array of end user devices, enabling end users to use the device of their choice and spawning BYOD[15]. Examples of this are Smartphone, Tablet, Laptop, Desktop and TV.

Having looked at many of the drivers that have transformed IT, it is evident that this transformation has been enabled through a transformed Communications Network, which itself continues to undergo a momentous transformation enabled by IT.

NETWORK TRANSFORMATION DRIVERS

Today we are witnessing the move by Network Technologies in the same direction as those in Information Technology, evidenced in IT methodologies such as SOA being applied to Network functions and elements, giving rise to Network Function Virtualisation[16] and Software Defined Networking[17], driven by Open Innovation.

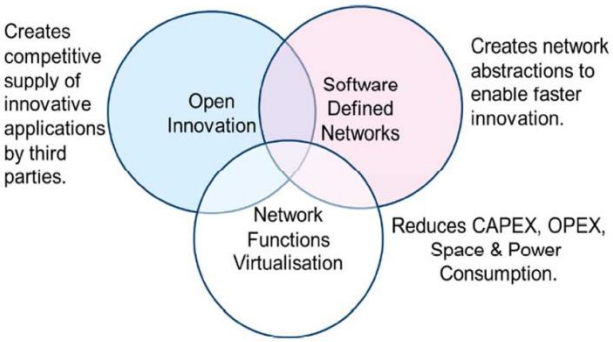

Figure 3: SDN, NFV and Open Innovation interplay[18]

The combination of NFV and SDN is ushering in the Future Network, which will deliver unprecedented efficiencies, RoI[19], scalability, elasticity and also provide the means of extending the lifetime of high-investment legacy components.

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[13] HTML5. http://en.wikipedia.org/wiki/HTML5

[14] **WebRTC**, Web Real-Time Communication. http://en.wikipedia.org/wiki/Webrtc

[15] **BYOD**, Bring your own device, refers to the policy of permitting employees to bring personally owned mobile devices (laptops, tablets, and smart phones) to their workplace, and to use those devices to access privileged company information and applications.

[16] **NFV**, Network Function Virtualisation. http://en.wikipedia.org/wiki/Network_Functions_Virtualization

[17] **SDN**, Software Defined Networking. http://en.wikipedia.org/wiki/Software_defined_networking

[18] http://www.sdncentral.com/technology/nfv-and-sdn-whats-the-difference/2013/03/

[19] **RoI**, Return on Investment. http://www.investopedia.com/terms/r/returnoninvestment.asp

TRANSFORMATION ENABLERS

Hand-in-hand with these transformational influences, other new networking technologies and drivers will help to shape the Future Network, some of these being:

- Everything IP
- Everything Data
- LTE[20]/EPC[21]
- IPv6
- IoT (including M2M[22])

EVERYTHING IP[23]

A plethora of Communications Protocols are required to make the legacy communications network deliver the services delivered to consumers and enterprises today. This complexity requires a costly and diverse set of specialists to maintain and operate.

The evolution taking pace today aims to replace legacy protocols and significantly simplify the way network communications take place, by driving towards an IP-only network, driving the network to a single 'lingua franca'.

EVERYTHING DATA

Traditionally, data and voice traffic have been processed independently of one another. Voice has been the 'senior service' providing traditional telephony services where people could communicate with one another via the medium of voice. Very high quality standards have accompanied this type of service and are expected by those that use it.

Data traffic has evolved from using the same media as voice, to the Frame Relay and ATM[24] protocols that dominated in the decades between 1960 and 1990. In the late 1980's, TCP/IP began its climb to prominence and is the basis of the Internet and data transmission today.

Mobile Communications networks have also made this distinction between voice and data in the past, but with the emergence of new mobile communications technologies, voice and data can now be carried using the same IP protocol, making everything transportable in a data packet and applying quality and prioritisation criteria to deliver the QoS[25] required for the service.

LTE/EPC

LTE, or 4G, is ushering in the era of high-speed transmission of large volumes of data. This capability will be the prime enabler for many IT applications and be the medium carrying the 'data storm'[26] that M2M and IoT are predicted to cause.

The Evolved Packet Core will provide a packet-only transport. Voice services will be packetized and prioritised, just like any other packet of data transmitted on the network.

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[20] **LTE** Long Term Evolution. http://en.wikipedia.org/wiki/LTE_(telecommunication)

[21] **EPC**, Evolved Packet Core. http://www.3gpp.org/technologies/keywords-acronyms/100-the-evolved-packet-core

[22] **M2M**, Machine-to-Machine. http:// http://en.wikipedia.org/wiki/Machine_to_machine

[23] **IP**, Internet Protocol. http://en.wikipedia.org/wiki/Internet_Protocol

[24] **ATM**, Asynchronous Transfer Mode. http://www.webopedia.com/TERM/A/ATM.html

[25] **QoS,** Quality of Service. http://en.wikipedia.org/wiki/Quality_of_service

[26] http://www.ntti3.com/wp-content/uploads/documents/whitepapers/how_m2m_is_changing_the_mobile_economy.pdf

IPv6

When the Internet was conceived, the numbering system of IPv4 was presumed to be adequate for the perceived future. However, the Internet has been so widely adopted that the current situation is that IPv4 addresses have been exhausted and a replacement addressing scheme is required to satisfy the demands of today and the future.

IPv6, the successor of IPv4, provides an addressing scheme magnitude greater than its predecessor, but also introduces significant challenges to be implemented across the Internet. Very significant effort will be required in the next decade to introduce and enjoy the benefits of IPv6 universally and ensure that the Future Network can be realised.

IoT

The 'Internet of Things' is rapidly becoming a reality today – more and more objects in our daily lives are connected to the Internet. Technology is not only becoming embedded in our home and workplaces, but is now becoming 'wearable' and communicates with other devices we now find indispensable to conduct our daily lives.

The future holds an environment where anything an organisation or individual would like to control will be accessible via the internet. A prominent example is evidenced in M2M today, where motor vehicles are equipped to communicate their performance to manufacturers on a regular basis – this can be easily replicated to any type of device used domestically, commercially or publicly and will become more and more evident in the near future.

NETWORK FUNCTION VIRTUALISATION[27]

The predominant situation in the legacy Communications Network of today is a host of network elements and protocols which are proprietary to the vendors providing those elements. This 'black box' approach has brought rich spoils to the vendors, but has made the legacy an enormously complex infrastructure, relying on the specialisms of those individuals and organisations initiated into the mysteries of the vendor's proprietary domain.

However, momentous changes are transforming the network arena, led by new players who provide more generic, standardised solutions employing many of the methodologies and techniques employed in the transformation of Information technologies, resulting in Network Function Virtualisation.

Entrenched network device manufacturers are all in the throes of answering the challenge, which will see them move from proprietary devices to COTS hardware and standard Operating Systems, in the same manner as the IT transformation that has preceded it.

This transformation is driven by the ETSI standards body, illustrated by the schematic below:

[27] http://portal.etsi.org/nfv/nfv_white_paper.pdf

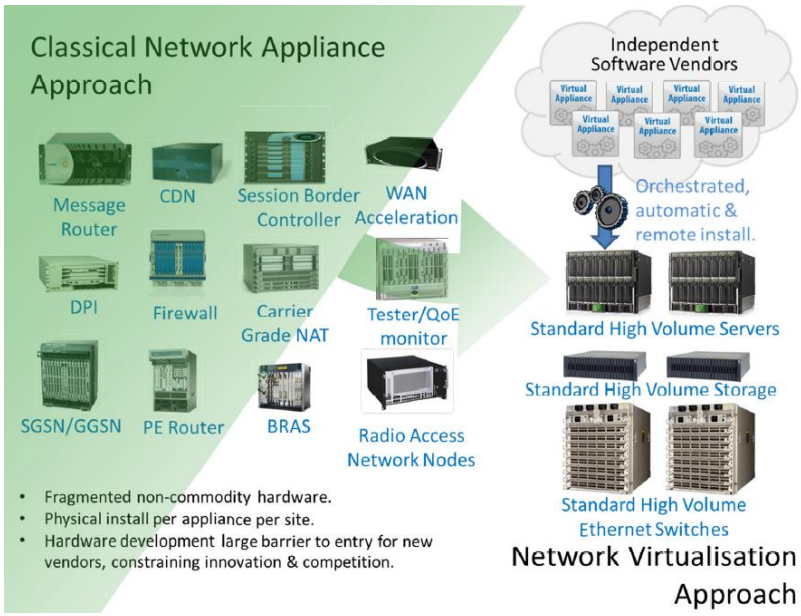

Figure 4: Evolution to NFV [28]

The major implications of NVF are that COTS hardware platforms, such as servers, which are significantly less costly, and software, will reside on the platform in the same manner that IT applications are resident on a server or end user device. The Network Functions exposed by the software running on COTS servers will provide access to the functionality previously embedded in proprietary network devices – this will enable a SOA-like approach to orchestrating the functionality of the next-generation network device.

This COTS approach has also enabled NFV to usher in the elastic capabilities of IT virtualisation into the Communications Network.

This has set the stage for the demise of the proprietary traditional 'black box' and related EMS[29].

SOFTWARE DEFINED NETWORKING

SDN is a new approach to designing, building and managing networks. The basic concept is that SDN separates the network's Control (brains) and Forwarding (muscle) planes to make it easier to optimize each plane.[30]

In this environment, a Controller acts as the "brains," providing an abstract, centralized view of the overall network. Through the Controller, network administrators can quickly and easily make and push out decisions on how the underlying systems (switches, routers) of the Forwarding plane will handle the traffic. The most common protocol used in SDN networks to facilitate the communication between the Controller (called the Southbound API) and the switches is currently OpenFlow[31].

[28] http://portal.etsi.org/nfv/nfv_white_paper.pdf

[29] **EMS**, Element Management System. http://en.wikipedia.org/wiki/Element_management_system

[30] http://www.sdncentral.com/what-the-definition-of-software-defined-networking-sdn/

[31] http://archive.openflow.org/wp/learnmore/

Simply stated, the generic SDN architecture is illustrated by the schematic below:

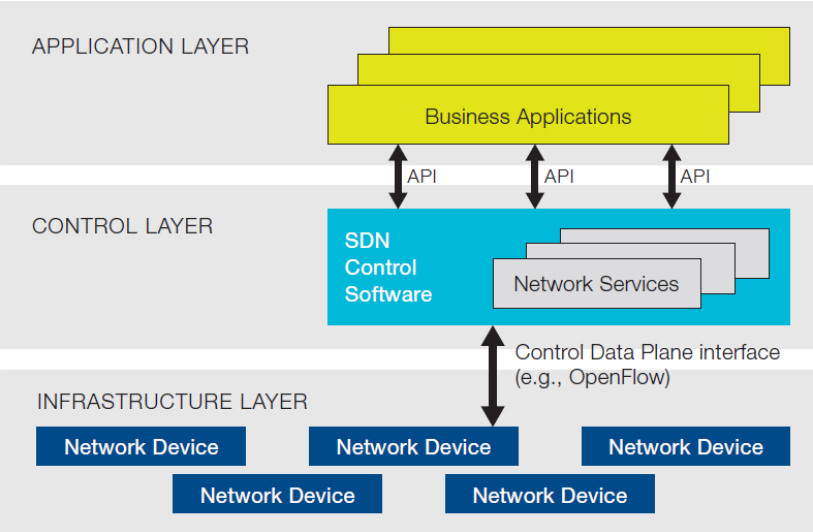

Figure 5: SDN Generic Architecture [32]

An SDN environment also uses open, application programmatic interfaces (APIs) to support all the services and applications running over the network. These APIs, commonly called Northbound APIs, facilitate innovation and enable efficient service orchestration and automation. As a result, SDN enables a network administrator to shape traffic and deploy services to address changing business needs, without having to touch each individual switch or router in the forwarding plane.

The OpenFlow interface conveys packet-transfer instructions from the network operating system to the network devices, allowing a network operator to mix and match devices from different vendors and make independent choices for the control and data-plane solutions.

CARRIERS AND SERVICE PROVIDERS

SDN offers carriers, public cloud operators, and other service providers the scalability and automation necessary to implement a utility computing model for IT-as-a-Service, by simplifying the roll-out of custom and on-demand services, along with migration to a self-service paradigm. SDN's centralized, automated control and provisioning model makes it much easier to support multi-tenancy; to ensure network resources are optimally deployed; to reduce both CapEx and OpEx; and to increase service velocity and value.

Software-Defined Networking: The New Norm for Networks

ONF White Paper April 13, 2012

The well-defined API for the network operating system means third parties can develop and sell network control and management applications, creating more choice for the network operators.

Finally, network virtualization allows a network operator to use different and customized control plane solutions for different virtual networks and thus not become dependent on a single vendor.

In short, SDN makes the network open and programmable. Creating new capabilities or services becomes a simple matter of writing software applications – as the PC, mobile and Web industries are already doing. In other words, SDN allows the network to catch up with other parts of the IT infrastructure.

[32] https://www.opennetworking.org/images/stories/downloads/sdn-resources/white-papers/wp-sdn-newnorm.pdf

SUMMARY[33]

The table below provides a brief comparison of some of the key points of SDN and NFV:

Category	SDN	NFV
Reason for Being	Separation of control and data, centralization of control and programmability of network	Relocation of network functions from dedicated appliances to generic servers
Target Location	Campus, data centre / cloud	Service provider network
Target Devices	Commodity servers and switches	Commodity servers and switches
Initial Applications	Cloud orchestration and networking	Routers, firewalls, gateways, CDN, WAN accelerators, SLA assurance
New Protocols	OpenFlow	None yet
Formalization	Open Networking Forum (ONF)	ETSI NFV Working Group

INDUSTRY RESPONSE

In response to these transformational forces, many Communications Providers (CPs) have, or are in the process of amalgamating their Network and IT organisations into a single, unified digital force addressing a technology continuum.

Most large Communications Providers are both implementing NFV and evaluating SDN. To date, the most successful commercial implementations of SDN are seen to be:

- Google
- Amazon[34]
- NTT Japan[35]

Device Vendors are all in the race to provide NFV and SDN solutions and actively exploring the implementation aspects of NFV and SDN with CPs.

Many new players have entered the market and are offering both hardware and controllers in competition with the established device vendors, opening up the market with new innovations and offerings.

CONCLUSIONS

The Future Network has arrived, evidenced in technology virtualisation, NFV and SDN. This will rapidly become more evident, revolutionising CP operations and providing End Users, be they individuals or organisations, with unprecedented access to digital services.

- **Communications Networks** will provide ever-increasing bandwidth, IPv6 will enable the Internet of Things and all network traffic will evolve to packetized data.

[33] http://www.sdncentral.com/technology/nfv-and-sdn-whats-the-difference/2013/03/

[34] http://www.infoworld.com/t/sdn/sdn-secrets-of-amazon-and-google-242011

[35] http://www.lightreading.com/ntt-taps-sdn-to-enhance-cloud-flexibility/d/d-id/708133

- **Communications Providers** will merge their technology organisations into a single end-to-end organisation where the network and IT will be an inseparable continuum. They must have a strategy that includes the co-existence of NFV and SDN with legacy network elements and develop a roadmap towards full NFV/SDN adoption.

- **Device Vendors** must hone their SDN strategies to adopt open standards and have an aggressive roadmap for delivering their NFV and SDN offerings to the communications market.

- **Software Vendors** with Network Monitoring (NMS) and/or Network Performance offerings must enable their offerings to encompass SDN and NFV.

- **End Users**, be they consumers or enterprises, will be the winners, benefitting from the:
    - Reduction in complexity
    - Speed of delivering new services
    - Speed of communications
    - Control over what they want, when and where.

THE FUTURE NETWORK IS WITH US NOW – ENJOY THE BENEFITS AS THEY UNFOLD!

Acknowledgements:
Whilst this white paper is a reflection of Sytel Reply's current viewpoint of NFV and SDN, it also contains information available on many public web sites. Where information has been used to either support or supplement Sytel's viewpoint, this is indicated in the footnotes.

REPLY
SYTEL

Sytel Reply is the Reply group company specialising in the Telecommunication, Media and Entertainment (TM&E) markets. The Sytel Reply mission is to support clients during their technology and business innovation processes by planning, developing and managing solutions for Networking, BSS and OSS and Mobile Applications within TM&E service provider market. Sytel Reply, thanks to its in-depth competence and experience, boasts a team of highly skilled professionals able to manage any end-to-end business and technology transformation programmes.

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