WHITE PAPER

The Path to 5G with Programmable Mobility Management

Start evolving mobile networks to support 5G services today

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Today's Mobile World: New IP and Why 4G Is Not Enough

Every 20 years or so, there is a fundamental shift in the communications paradigm and the business opportunities it unlocks. The technology industry refers to this next transformation as the "New IP" or "3rd Platform." The New IP represents a fundamental change in networking—from proprietary, hardware-centric, manually intensive networks to open, software-enabled, automated networks. Mobile networks will need to go through this evolution to achieve the goals and promises of 5G.

The last mega-transitions occurred when the industry migrated from mainframes and private lines (1st Platform) to the client-server model built on an IP network (2nd Platform), which eventually led to the Internet. As the 2nd Platform was untethered, the mobile network itself evolved to incorporate data services, first as an overlay to the existing voice-centric networks (3G), then, more efficiently, as an all-IP data network (4G). These third-generation and fourth-generation cellular networks, however, were still based on the fundamental principles, business models, and use cases of the 2nd Platform. (See Figure 1.)

In short, 3G networks delivered on subscriber expectations for cellular data, and 4G networks enhanced the subscriber experience with increased speeds, reduced latency, and improved spectral efficiency of the network. Depending on the requirements of the mobile operator, mobile networks can be designed to deliver broadband, high-speed mobility, reliability, or latency. However, delivering all of these at once is a costly endeavor; each design decision typically comes at the expense of something else. The New IP helps to solve these challenges by delivering a network that is fully virtualized and automated, so that resources can easily be scaled up and down with applications running anywhere in the network for efficient delivery to customers.

5G standards and technologies represent an opportunity for the mobile telecommunications industry to reinvent itself and deliver on the requirements of the New IP, fundamentally changing and advancing the way we communicate. Brocade believes 5G marks a new communications paradigm, built on entirely new business models that need to be effectively navigated if we are to reap all the benefits and potential 5G promises.

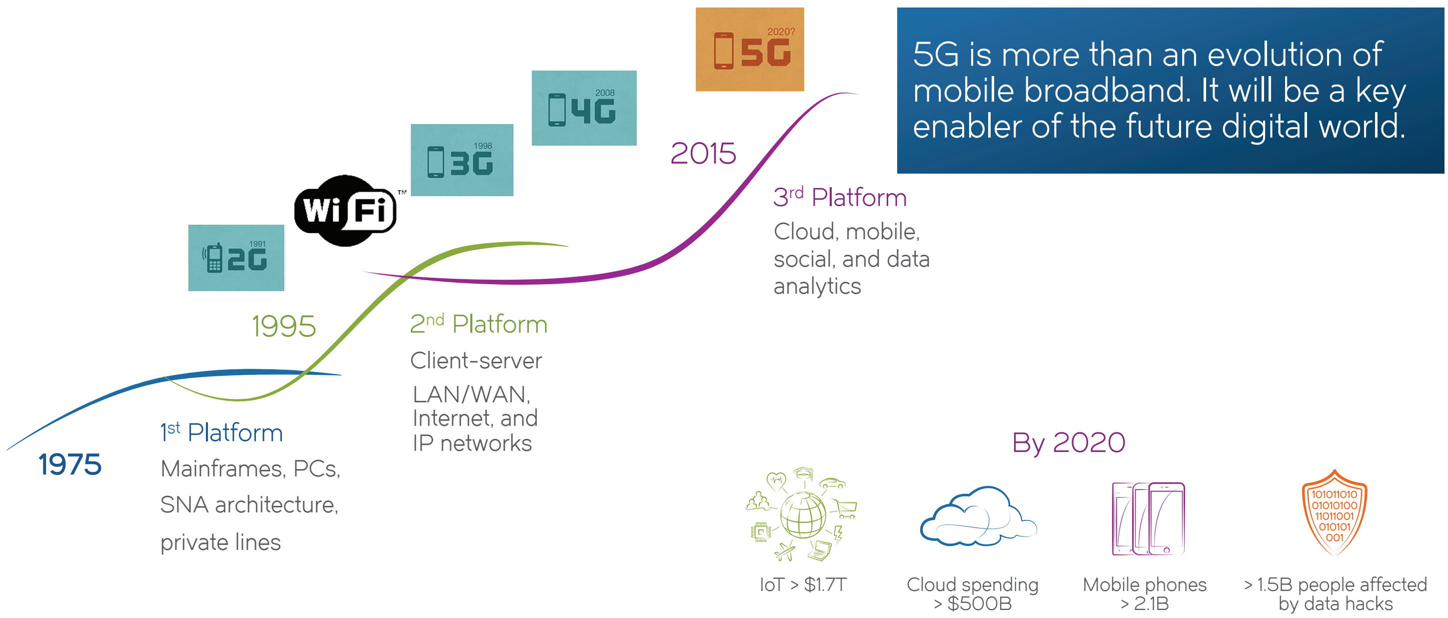

Figure 1: Mobile architecture transitions.

The technology that drove the 2nd Platform is closed and proprietary hardware. This technology is costly to build and operate, as it uses manual processes that introduce significant resources and time to maintain. The 2nd Platform simply is inefficient, from either a Capital Expenditure (CapEx) or Operational Expenditure (OpEx) perspective. Nor is it sustainable for 3rd Platform services, which are inherently more data driven and cloud-centric, and which require the network to scale to unprecedented levels. For example:

- Mobile traffic is expected to reach 24.3 exabytes per month by 2019 (growing at a compound annual growth rate of 57 percent[1]).
- All this data will be generated by both people and "things" connecting to the network:
  - 90 percent of the world's population over six years of age is predicted to have a mobile phone by 2020[2].
  - The prediction is that there will be over 26 billion connected devices by 2020[3].
- The network will be relied on for:
  - **Entertainment:** Currently there are three times as many mobile devices capable of consuming digital media as there are televisions and PCs[4]; total mobile engagement on social networks has grown 55 percent in the past year[5].
  - **Business:** More than 2 billion mobile users will complete a mobile commerce transaction by 2017[6]; global mobile app revenue is expected to grow to 76.52 billion US dollars in 2017[7].
  - **Health:** 64 percent of healthcare executives believe mobile health will dramatically improve outcomes[8].
  - **Banking:** 51 percent of mobile phone owners are expected to access banking services by 2016[9].
  - Use cases that are not yet imagined.

The challenge is not scaling to support the new dimensionality of mobile networking, but instead finding efficient mechanisms to support the variance. All these "users"

[1] http://www.statista.com/statistics/271405/global-mobile-data-traffic-forecast/

[2] Ericsson Mobility Report, June, 2015.

[3] Gartner, Supply Chain Executive Conference, May, 2014.

[4] Ericsson Mobility Report, June, 2015.

[5] http://www.comscore.com/Insights/Blog/Major-Mobile-Milestones-in-May-Apps-Now-Drive-Half-of-All-Time-Spent-on-Digital

[6] http://www.juniperresearch.com/researchstore/commerce-money/mobile-commerce-markets/key-sector-strategies

[7] http://www.statista.com/statistics/269025/worldwide-mobile-app-revenue-forecast/

[8] http://www.economistinsights.com/analysis/how-mobile-transforming-healthcare; http://www.practiceunite.com/30-stats-illustrating-mhealths-impact-on-healthcare/

[9] http://www.statista.com/statistics/244414/percentage-of-us-mobile-phone-users-who-use-mobile-banking/

and services carry with them a number of different, often competing, traffic profiles, each of which drive unique requirements. For instance:

- The mobile network will consist of smart phones and tablets that access data at broadband speeds, while also supporting sensors connecting at speeds slower than dialup.
- Connected vehicles will require support for high mobility, while parking meters and other smart meters will be stationary.
- Public safety applications will require ultra-reliability, while web browsing can be delivered best-effort.
- Voice and collaboration platforms will necessitate real-time communications, while many Internet of Things (IoT) applications will be asynchronous.
- Live video or video communications will demand ultra-low latency, while other streaming video might be delay-tolerant.

What is needed is an infrastructure that can simultaneously support all these different traffic models and deliver a level of reliability, scale, and real-time, ultra-high speed performance that has never been seen before. This means that the key requirements for the next-generation mobile network are to provide efficient, cost-effective services that can flexibly support and adapt to changes in traffic types, use cases, and monetization models, such that network design decisions do not affect revenue opportunities. 5G is working towards delivering these requirements.

The Promise of 5G

5G represents a transition from client-server communications to the cloud, to support all the new services that are inherently mobile, social, and data-driven. 5G offers the opportunity for the industry to standardize on a new architecture that is not rooted in inflexible, costly hardware, but rather is software-defined, virtualized, and open. (See Figure 2.)

As a result, 5G promises to deliver an infrastructure that is more CapEx- and OpEx-friendly—one that is flexible, with the ability to leverage automation and intelligence to support new business models and capitalize on changing customer requirements. 5G lays the foundation for innovation, creating an infrastructure that can scale, in a nonlinear fashion, to support all the demands being placed on it, at an order of magnitude that is greater than anything ever seen before. The network needs to be able to support:

- Mobile data volumes that are 1000 times greater than today
- A thousand times greater number of devices connecting than today
- Peak data rates that are 100 times greater than today
- Service deployments that take 1/1000 the time they currently take

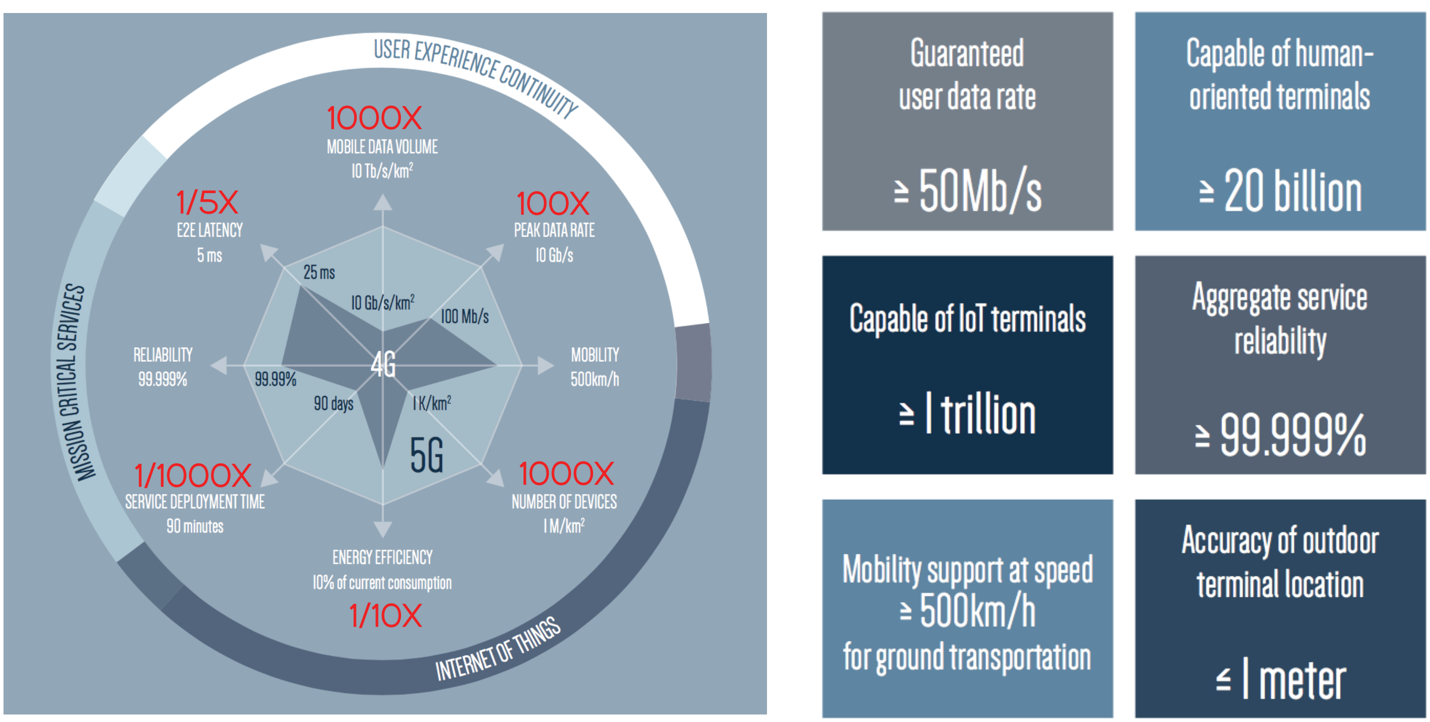

Figure 2: 5G system capabilities.

- One-tenth the power consumption of current networks[10]
- 99.999 percent reliability, with one-fifth the latency of current networks

The Four Foundational Technology Principles of 5G

5G will deliver on the requirements of the coming years by embracing nontraditional design principles. While designing and evolving the radio technology and air interface to increase the speed and reliability of the network is important, equally important is the deployment of new technologies to handle all the traffic scale and variances and to provide the intelligence, automation, and agility needed to support new innovations, use cases, and monetization models.

In addition to new spectrum, new air interface, and new radio access technologies, the 5G Public Private Partnership (5GPPP) has identified four core technology enablers that will allow the competing, disparate requirements of all the new users, services, and business models to share an infrastructure and support innovation in a sustainable, scalable way:

1. **Software-Defined Networking (SDN):** SDN abstracts the network and decouples the control and forwarding planes to deliver key functionality in software. SDN reduces vendor lock-in and removes a reliance on proprietary hardware, to create an open ecosystem that enables choice and increases flexibility, while reducing costs and complexity. This inherently agile and open ecosystem allows providers to tap into the vast pool of resources needed to keep pace with changes and to build the network and services that want to support the providers' growth and profitability objectives. SDN provides a smart, centralized network that helps accelerate the rate of business innovation, optimize resource utilization, reduce congestion, and improve overall security.
2. **Network Functions Virtualization (NFV):** NFV enables providers to move key network functions into the cloud environment to take advantage of efficiencies and scale. NFV ensures the fast, cost-effective trial and roll-out of new capabilities and services that enable providers to capitalize on changing market needs and opportunities. NFV can help providers attain simple, programmatic control over complex tasks, as well as tight integration with business support systems and high-value end user applications, providing the freedom to quickly and easily deliver on future demands.
3. **Mobile Edge Computing (MEC):** Putting IT and cloud-computing capabilities, resources, and intelligence in the Radio Access Network (RAN) closer to the devices, users, and things that leverage them creates a low-latency, high-bandwidth environment capable of accelerating a wide variety of services and applications. With the growth of IoT, new applications and services are expected to benefit from deployment at the network edge. For example, vertical applications, such as those enabling connected vehicles, and experience apps, based on real-time interactions (such as augmented reality) could greatly benefit from both the low latency and improved bandwidth that results from residing in closer proximity to subscribers. A standardized, open environment that allows for the efficient and seamless integration of third-party applications across multivendor platforms will allow for innovative services, as well as improve the monetization of the network. Mobile providers will be able to offer a distributed Infrastructure-as-a-Service (IaaS) platform for those third-party applications that could benefit from being close to the edge.
4. **Big data/machine learning**: This gives providers the visibility into the network that allows them to learn and automatically pivot to support more efficient use of resources and new business models.

Brocade Programmable Mobility Management

Ultimately, the goal of 5G is to enable providers to embrace SDN, NFV, MEC, and big data/machine learning across all domains of the mobile network. If done effectively, Brocade believes providers can achieve programmable mobility management. The Brocade® vision is for end-to-end software-defined transport that delivers the utmost in flexibility, performance, reliability, and availability at tremendous scale, to support all the exploding (and competing) demands and enable new use cases and business models. (See Figure 3.)

Cloud Radio Access Networks (C-RANs) will decouple the baseband signal processing from the radios themselves, allowing base station workloads to be easily shifted onto localized compute resources. NFV will provide the foundation for moving operator services, such as IP Multimedia Subsystem (IMS) and Voice over LTE (VoLTE), as well as network services, such as the Evolved Packet Core (EPC), off of proprietary, inflexible hardware onto open solutions that can be easily optimized to meet the varying needs of the different users, services, and locations. A programmable SDN fabric will provide granular control of service paths, programmatic control of mobility events, and context transfer

[10] 5GPPP

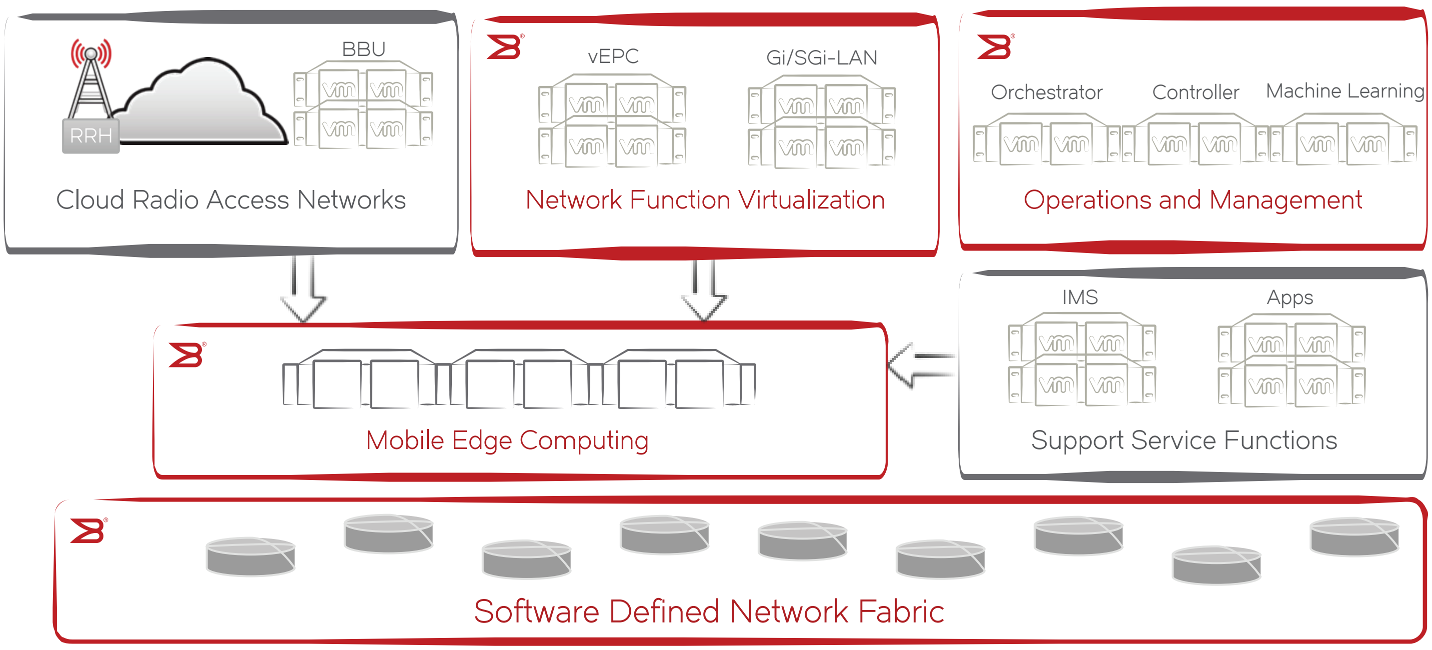

Figure 3: 5G vision: Programmable mobility management.

using overlay headers. Providers can start to shift operational support functions and applications onto open standard interfaces and open source projects, leveraging big data/machine learning models that are protocol-independent and published to support network automation and orchestration.

As workloads become more dynamic, scaling in, out, up, and down on demand, SDN will ensure that the underlying infrastructure is prepared. Separating the control and forwarding planes gives providers more granular control of service paths through the network and service functions. In parallel, operator services and applications will be able to move closer to the end users through a MEC platform to improve service delivery and subscriber experience. This is also true for external (Over the Top, or OTT) services and applications that embrace the 3rd Platform or New IP paradigm—data-driven, real-time, social, and cloud-based—so they can benefit from a more predictable end-user delivery environment. As already noted, MEC can create a new revenue stream for mobile operators who deliver a distributed IaaS platform for all of the third-party applications that can benefit from closer proximity to the RAN.

The Brocade Five-Step Network Innovation Model

The Brocade vision enables providers to reap all the benefits of programmable mobility management in 4G and 5G. This represents a new communications paradigm rooted in software (open standards) to support the highly virtualized (cloud) environments that can deliver the dynamic use cases in social and mobile applications, along with emerging business models. The path to 5G will take time and will require multiple steps. Brocade has developed a five-step network innovation model that helps providers evolve their network to fully realize the benefits described above.

No one can afford a disruptive hardware rip-and-replace solution; rather, providers need to be able to adopt and deploy technologies that are cost-effective in meeting the needs of their users and services both now and far into the future. Here are the five evolutionary steps providers can take to modernize their infrastructure and business to achieve revolutionary results. (See Figure 4.)

Step 1. Shifting from the physical infrastructure to the virtual infrastructure: Today, operators build the networks they need, using a mix of physical and virtual appliances. These virtual appliances, however, are simply software representations of the physical infrastructure they are derived from. They carry forward the same limitations and the same software boundaries. While this is progress, such a path introduces inefficiencies when virtual functions share the same physical resources: compute, memory, Input/Output (I/O), disks, and so on.

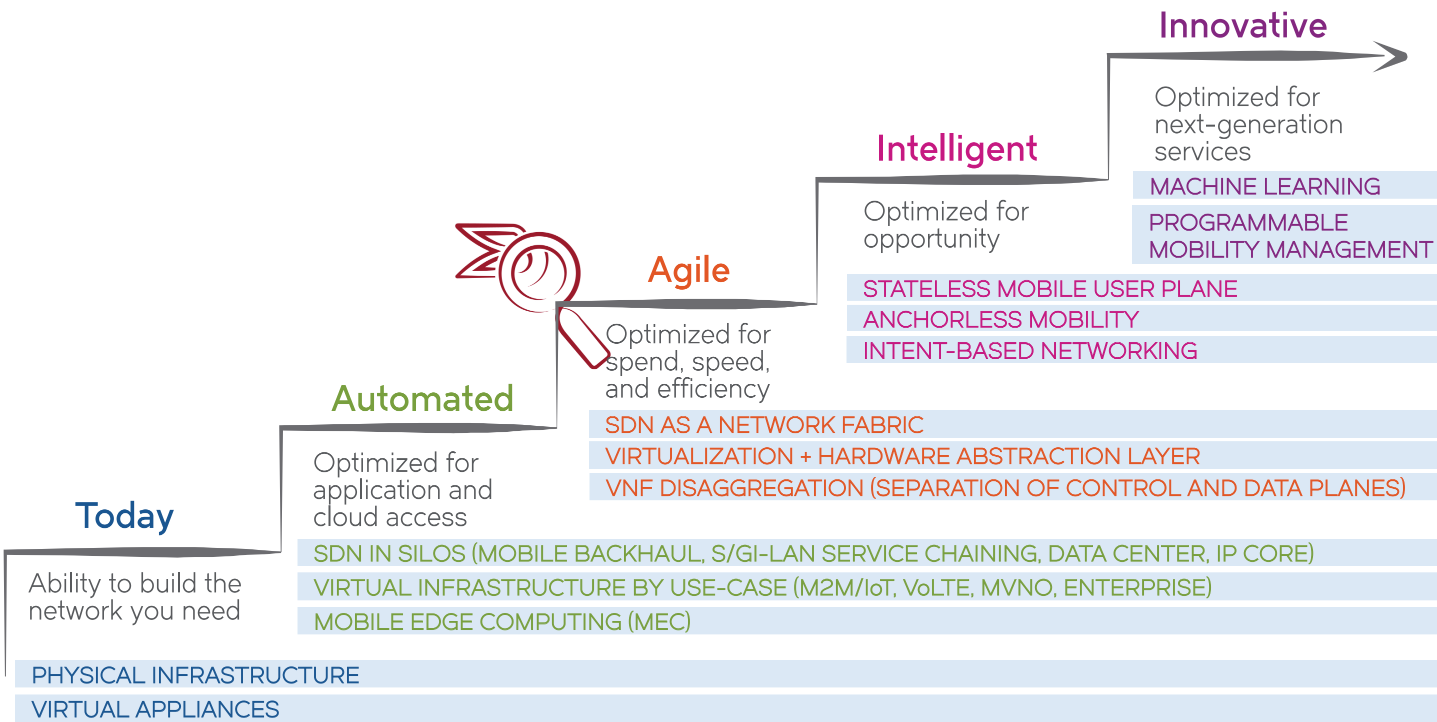

Figure 4: Brocade five-step network innovation model for mobile operators.

Step 2. Adopting automation holistically: As operators strive to automate their infrastructure, it is important to ensure it is being done holistically, in order in to derive optimal benefits. Today, mobile networks tend to be managed by operational teams responsible for a particular domain (RAN, mobile backhaul, mobile core, and so on). This means that SDN and NFV capabilities are being adopted at varying degrees for specific use cases and business problems in specific parts of the network, by specific teams, without disrupting existing operational models. For example:

- SDN is being delivered for both optical and metro-Ethernet transport in backhaul networks.
- SDN-based service function chaining is being tested and deployed to evolve the mobile S/Gi-LAN network.
- SDN is being used within data centers for managing underlays and overlays, especially for multitenancy.
- NFV is being used for Machine-to-Machine (M2M) and IoT platforms.
- NFV is being deployed for Mobile Virtual Network Operator (MVNO) and Mobile Virtual Network Enabler (MVNE) platforms.
- NFV is delivering IMS-based VoLTE.
- NFV-specific services for the enterprise are being used, including private LTE or enterprise Access Point Names (APNs).

The long-term goal is not just about accepting new technologies within existing operational models, but determining how new technologies can drive completely new operational models. Providers can look for ways to break down operational domain walls and improve collaboration between teams to support network-wide deployments that can automate functions end-to-end, to maximize efficiencies. This is especially important with the introduction of service-level requirements, such as Narrowband IOT (NB-IOT) and network slicing, both of which require end-to-end service-level automation.

Providers have the opportunity to rethink where the boundaries of a virtual appliance exist and where splits between network functions truly belong. Providers can start to deploy solutions that eliminate redundancies (in memory, processing, and so forth) and make the shift from physical to virtual. These innovations have already started, as Network Address Translation (NAT), firewall, and virtual routing capabilities combine and as virtual EPC functions collapse. The functional network boundaries will continue to be redefined in a virtual world. This evolution—functional aggregation—is a key aspect of building efficient Virtual Network Functions (VNFs).

Step 3. Ensuring agility: This phase starts to transform processes to ensure that the environment can pivot and adjust to changing needs and demands.

This step builds on the lessons learned in steps 1 and 2, as providers rethink their use of network resources and break down operational barriers to optimize their infrastructure spend, speed, and efficiency. Providers will be "crossing the chasm" and building the skills and processes that capture the expertise needed to operate the network of the future.

This process combines these things:

- An understanding of networking
- An understanding of compute and virtualization environments
- An ability to write software—either coding or scripting—for network functions
- An applied knowledge of data science

With this foundation, operators will be able to break the vertical operations silos and employ SDN as a network fabric that extends from the cell site to the data center. This SDN fabric provides operators with end-to-end overlays, each consisting of their own paths, network functions, and network and subscriber policies, and all controlled via intelligent applications that reside on the Brocade SDN Controller. This is paramount to offering many of the end-to-end services necessary for 5G, such as network slicing, where each slice exists within an SDN overlay and where optional network functions such as mobility, security, optimization, and so forth are chained together in those overlays to deliver service-specific requirements.

The use of NFV further evolves the network, following a path similar to SDN that disaggregates the VNFs themselves into control planes and data planes. This allows providers to scale control and data planes independently, to eliminate any location dependence and allow traffic to be optimally routed throughout the mobile network. By incorporating a hardware abstraction layer, providers can then combine this location independence with hardware independence, adopting new, programmable Application-Specific Integrated Circuits (ASICs) that use extensible programming languages, such as P4 (see p4.org) to enable workload placement on the most efficient processing environment for the particular task. This gives providers complete agility, enabling any workload to be placed on any platform at any network location: cell site, Central Office (CO), backhaul aggregation sites, IP peering points, or data centers. This ensures the most efficient processing (directly in the traffic path between the subscriber and the application) and most flexible configuration.

1. **Leveraging intelligence to optimize decision-making around opportunities:** With the ability to place workloads efficiently across both geography and network platforms, operators are then able to start optimizing their operations and networks to deliver services. To this point, operators have embraced SDN to program the network for end-to-end paths but retained the traditional mobility concept of stateful anchoring in the user plane. With SDN as a network fabric, Brocade envisions incorporating contextual transfer capabilities that leverage the network service headers in order to ensure the availability of information about network conditions downstream, subscriber profiles, and flows along with the subscriber traffic itself. These headers will help operators provide mobility functions by anchoring only the subscriber session in the control plane and allowing programming information to be incorporated directly into the service path, via the SDN controller, to deliver statelessness in the user plane.

   This "intent-based" networking allows either the user or the application to provide requirements for the infrastructure (for example, latency, Quality of Service (QoS), path, and network services) via an explicitly-defined model and interfaces. The network then responds, configuring itself to support those requirements. In addition, network functions can be self-managed, extracting metadata to build learning models to determine how best to manage that infrastructure. This eliminates the need to explicitly classify traffic, with tools such as Deep Packet Inspection (DPI), in the network itself.

   For example, mitigation actions can be implemented in reaction to faults and network errors, using anomaly detection capabilities to identify and address security issues. This model of intelligent networking allows network functions to themselves be decision makers, with the ability to classify and identify irregular data while passing more complex, multinode decisions to more centralized network management systems.

2. **Enabling innovation: Up until this point, the focus has been on introducing automation and flexibility to the infrastructure;** decision making and logic has remained highly manual (with help from analytics systems). The introduction of machine learning can improve networking and Operations and Management (O&M) decisions, as well as automate the service creation itself. Algorithms can be trained to invoke on-demand policies (for instance, security, charging, mobility, infrastructure, service chain) to address specific situations, such as responding to anomalies or other security vulnerabilities in real-time and pushing appropriate policies into the production network.

Network demand and service demand can be predicted and learned, instead of being tracked. These machine learning tools are used to model and predict network capacity and availability, mobility events on the network, the location of content and services in the cloud, and the best available access networks and paths between mobile devices and the applications with which they need to communicate.

This minimizes the risks associated with introducing new services and enables faster time to market, with more rapid spin-up and spin-down of services, based on demand predictions. As a result, operators can achieve service profitability, even if adoption is small. The intelligent, virtualized, programmable network enables providers to innovate, both in their service offerings and operations. They can predict and deliver new services on demand to improve the overall efficiency and monetization of their infrastructure.

Summary

The mobile network is struggling to support all the requirements of the services, applications, and devices that are accessing it, and the rate of change for all those requirements only promises to accelerate. 5G is designed to support the fast approaching reality of the next-generation mobile networks that can take us wherever we want to go.

To support the growing demands of the IoT, cloud, social network, and future innovations, providers must build flexibility and automation into network capabilities, as well as into operational and decision-making processes. Brocade has accomplished this by introducing a five-step network innovation model that provides a path to achieve programmable mobility management:

Step 1. Virtualize the infrastructure to lay the foundation for SDN/NFV.

Step 2. Adopt automation to improve the programmability of the network.

Step 3. Increase the agility of the network to ensure that it is optimized for spend, speed, and efficiency.

Step 4. Leverage intelligent machine learning to optimize the network management.

Step 5. Apply machine learning to service creation to deliver innovative, profitable next-generation offerings.

Brocade can support providers in every step of the process to help them reap all the benefits of a 5G mobile network. To learn more about Brocade Mobility, visit http://www.brocade.com/en/possibilities/technology/mobility-technology.html

About Brocade

Brocade networking solutions help organizations achieve critical business initiatives as they transition to a world where applications and information reside anywhere. Today, Brocade is extending its proven data center expertise across the entire network with open, virtual, and efficient solutions built for consolidation, virtualization, and cloud computing. Learn more at www.brocade.com.

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