WHITEPAPER

The New Mobile Network Economics

Why mobile operators are transforming to virtualized RAN for 5G

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MOBILE WORLD LIVE

Executive Summary

The dawn of the 5G era is upon us - promising a renaissance of sorts; a re-birth of the halcyon early days of growth and innovation in the global mobile communications industry. This whitepaper discusses how and why the 5G era will eclipse its predecessors through new & compelling services built on open software and hardware platforms operating in end-to-end fully virtualized environments deployed at web-scale and operating at web-speed. The exciting transition to 5G is urgent and accelerating. The new momentum is being driven to satisfy the imperative of fundamentally changing network economics and increasing operator revenues - increasing shareholder value and enhancing customer experiences.

5G unleashes peak data rates of multi-gigabits per second, transmits significantly higher volumes of data, and supports myriad Internet of Things (IoT) devices as well as new services for massive machine communications and ultra-reliable low latency applications.

The sheer volume and variety of 5G data traffic shatters legacy cost-per-bit service delivery models. Current infrastructure architectures cannot cost-effectively scale to meet demand nor can it provide the flexibility to allow rapid introduction of revenue-generating services. Future consumer and business demands on wireless networks requires the web-scale capabilities pioneered by innovative software-based companies like Amazon, Facebook and Google.

Wireless operators are under growing pressure to meet ever-increasing capacity demands and grow service revenue while containing and reducing costs. In a significant change, time spent on wireless devices has tripled over the last five years yet time spent on operator services has decreased from 40% to 9% of the services consumed, in the U.S., according to the GSMA. Operators must also contend with supporting the relentless growth of connected devices, which Gartner estimates will reach 20.4 billion by 2020. Importantly, the decisions operators make today for upgrading 4G networks to cope with current demand will ultimately affect their ability to compete, and even survive, in the 5G era.

This whitepaper outlines the critical factors for survival in the 5G era, examining network virtualization from the Packet Core through the Radio Access Network (RAN) layers, and how this virtualization positively transforms mobile network economics, as well as optimizing network flexibility and service agility to drive increased revenue & profit. The paper focuses on Virtualized RAN (vRAN), analyzes the dramatic total cost of ownership (TCO) reductions enabled by vRAN, and examines the new business models and revenue opportunities enabled by control user plane separation (CUPS) in the Virtualized EPC (vEPC). It discusses the imperative for standard open interfaces and natively designed network functions, as well as the implications for traditional Network Equipment Provider models.

Introduction

As of December 2018, according to research from GSMA Intelligence, the total number of unique mobile subscribers is nearing 5.1 billion, and represents 67% of the world's population, with further penetration growth projected to reach 5.9 billion by 2025, equivalent to 71% of the world's population.

However, although GSMA Intelligence put operators' revenue at US$1.05tn in 2017, it projects revenue growth to just US$1.1tn by 2025. Given the projected uplift in subscribers and the billions of devices routinely predicted in the IoT market segment, it's clear that revenues will be constrained. GSMA Intelligence says global revenue will grow by around 1% between 2017 and 2020 (CAGR) and will roughly stabilize beyond 2020 at US$1.1 trillion.

Meanwhile, global capital expenditures for the mobile industry are estimated to total US$479bn in the period 2018-2020. The expansion of 5G to a larger footprint will likely require incremental spending above the approximately US$160bn predicted for 2020. As many wireless markets face increasing revenue per subscriber pressure, any further capex increase beyond 2020 would push global capex as a percentage of revenue above the 15% expected during 2018–2020.

Current capex levels constrain wireless operator profitability and hamper the operator's ability to transform and participate in new service revenues. China Mobile, for example, has reported that it spent 22.3% of its revenue from telecoms services on capex in the first half of 2018. The operator spent RMB 79.5bn (US$11.44bn) in the period, US$3.68bn of which was on 4G networks. Other operators are spending similar amounts as they progress 5G roll-out and technology transformation.

In the US, AT&T has reported capex of US$5.9bn in the third quarter of 2018 and earned revenues of US$45.7 billion in the same period. Verizon has reported that at the end of its third quarter, in which it generated revenues of US$32.6bn, it has spent US$12bn in the year to date. It expects total capex for the year of between US$16.6bn and US$17bn.

In Europe, Deutsche Telekom has reported capex of €3.1bn in the third quarter of 2018 in which it generated revenues of €19.1bn. Meanwhile, Vodafone Group has stated earlier in 2018 that its capex remains stable at around 16% of sales. The operator says that is in spite of a 2.5x increase in absolute data traffic.

Against this financial backdrop, the volume and variety of mobile traffic continues to surge. According to Cisco's Visual Networking Index (VNI), mobile data traffic will increase sevenfold between 2017 and 2022, growing at a 46% annual growth rate. The number of Internet of Things (IoT) connected devices is also rapidly increasing. Gartner forecasts 8.4 billion connected things in use in 2017, up 31% from 2016, and growing to 20.4 billion by 2020. At the same time, 5G network capabilities are pioneering ultra-low-latency (ULL) applications and, for the first time, massive machine-type communications, which will drive the volume and variety of data traffic ever higher.

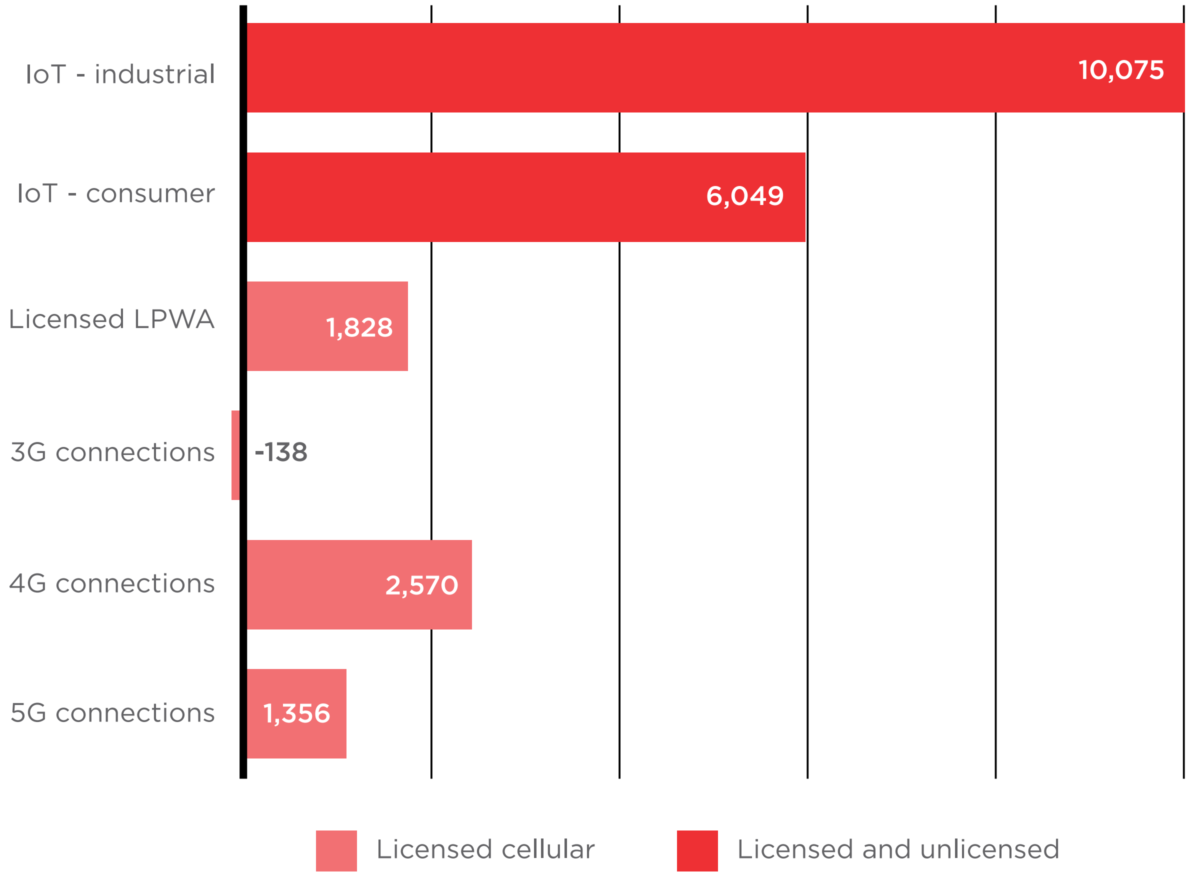
Mobile operators are under pressure to meet capacity demand while containing costs and launching new offerings in highly competitive mobile services markets. They now compete with web-scale companies like Amazon, Facebook and Google that offer similar, even more innovative, services at a far lower cost base and with agile development environments that speed time to market. Another case in point is Google Fi, which now has wide availability on mobile phones.

Until proven revenue streams emerge for IoT and 5G, overall growth outlook for Telcos is conservative

Operators are already feeling the pinch. According to strategy consultancy CIMI Corp., 2017 was to be the first year when the cost-per-bit surpassed revenue-per-bit for many operators. The basic business problem for network service providers therefore is that their networks must now be built to support low revenue per bit services. That has important implications, assuming flat or declining ARPUs and subscriber growth, for the amount of capital that can be spent on networks to support the expected number of customers, average revenue per account and the amount of stranded assets. Operating costs remain an ongoing issue, as the cost per customer is high and getting higher, as competition shrinks the market share any proficient provider can expect to obtain.

Something must give. Operators cannot carry on with business-as-usual and expect to meet surging bandwidth demand, compete with web-scale rivals and prepare for a 5G future. The cost-per- bit model must change, revenue generating services must be explored and revenue must be protected from fraud and hacking. But their traditional Network Equipment Provider partners, also themselves burdened by legacy business models, are struggling to deliver the required innovation, flexibility and agility that operators require to remain competitive and profitable. It is not an exaggeration to speculate that the survival of some wireless operators and traditional Network Equipment Providers is in question.

Connections growth between 2017 and 2025

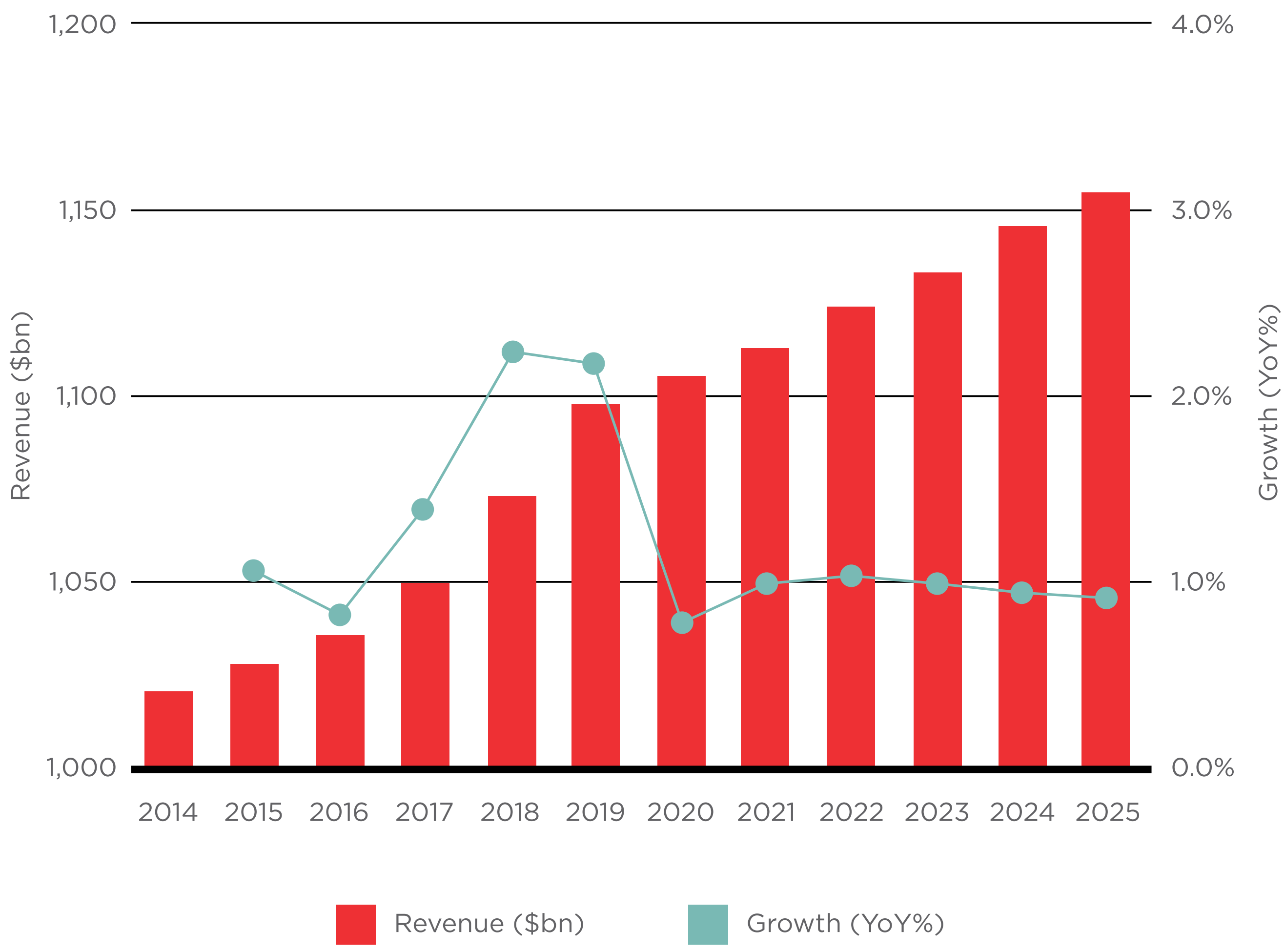


Source: GSMA Intelligence

This looming market reality is one catalyst for implementing Network Functions Virtualization (NFV) and Software Defined Networking (SDN).

To prosper in the 5G era, wireless operators must build cost efficient, flexible, and agile networks to deliver innovative services and grow the top and bottom lines. The new model for wireless network economics is founded on dramatic savings in capital and operating expenditures through the deployment of distributed cloud native architectures that foster new service models, standard open interfaces and rapid innovation – each of which is imminently achievable. The technology shift marks a distinct departure from a traditional telco mindset to web-scale deployments and speeds, including fundamental changes in how operators engage with suppliers as they adopt new and innovative software licensing models.

Projected growth in global mobile revenue



Source: GSMA Intelligence

The Need for NFV and SDN-Cloud Native Software

The vision for Network Functions Virtualization (NFV) was established by 13 of the world's largest telecom network operators in a white paper published in 2012. It proposed a radical transformation in the way that networks are built and services are delivered to achieve cost savings in capex and opex as well as accelerate service development and time to market. Virtualization enables CSPs to deploy software-based network functions on general purpose hardware, rather than install proprietary appliances every time they need a new network function, service or application. As originally envisioned, the benefits of NFV all boil down to cost savings, deployment flexibility and service agility.

While substantive progress has been made in a relatively short time, the promised cost savings and agility have not yet materialized for most CSPs. In a recent Heavy Reading survey that tracked virtualization deployments, 64% of the CSPs surveyed said they did not expect capex related to virtualization to level off or decline until 2020 or later, and most CSPs said they expected to see opex savings in the next three to five years.

There are many reasons for NFV's as-yet unfulfilled promise: inadequate support for automation, complex integration with legacy systems, immature Management and Orchestration (MANO) systems, not enough incorporation of SDN programmability principles, just to name a few. The fundamental issue is that for the most part, the Virtual Network Functions (VNFs) themselves are not natively designed for high-performance cloud environments. Early VNFs were simply proprietary software that previously ran on customized appliances. The software wasn't rearchitected for virtualized environments. Today, most VNFs are built upon existing software code and modified to run in virtual machines (VMs) on general purpose hardware. But VMs have serious limitations in terms of scalability and resource utilization.

VNFs that are designed for cloud environments overcome the operational challenges of VMs, which require significant manual intervention. Cloud native software design leverages containerization, stateless processing and microservices to create VNFs that use compute resources efficiently and reliably. Rather than just scaling up or down, native VNFs scale out to spread the capacity load across available compute resources. Also, native VNFs allow dynamic service chaining and can be instantiated rapidly, reducing the time it takes to launch new services and applications.

Native VNFs achieve the flexibility, scalability and operational efficiency promised by NFV. Ultimately NFV will transform mobile networks to achieve web-scale, full service automation and enable Platform-as-a-Service (PaaS) offerings. The result will be programmable mobile networks that leverage telemetry and analytics, automatically scale and self-heal, as well as deliver the highest service assurance. These capabilities can change the economic equation for mobile operators, significantly lowering the overall cost- per-bit and leveling the playing field to compete with web-scale cloud rivals Facebook, Amazon, Netflix and Google (FANG).

Virtualized RAN (vRAN) Dramatically Reduces TCO at the Edge

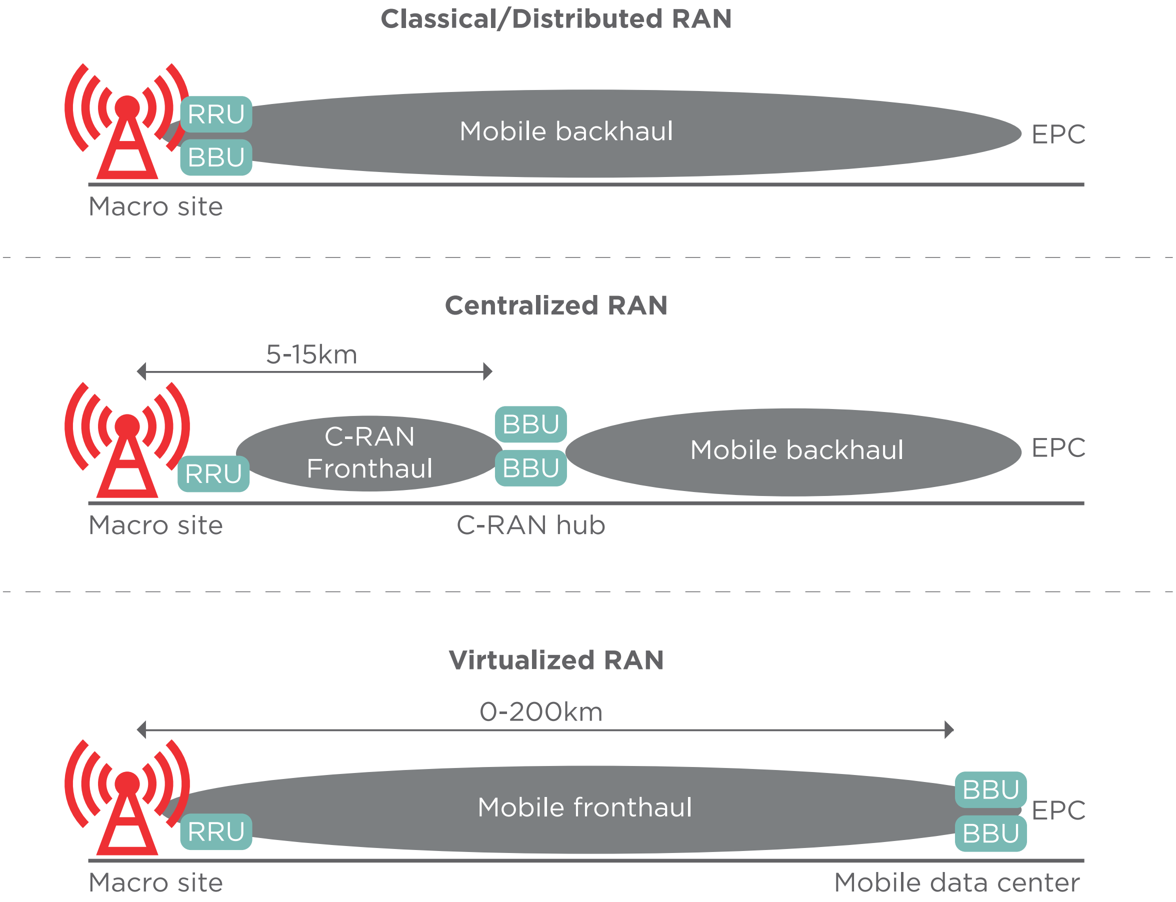
Virtualization fosters new architectures in the Radio Access Network (RAN) that enable mobile operators to dramatically improve performance and reduce costs. The RAN transformation features a fundamental architecture shift from traditional distributed/centralized models toward fully virtualized implementations, allowing operators to locate processing power flexibly and cost effectively where it is needed most.

What is Virtualized RAN?

There are three distinct types of RAN architecture: Distributed RAN (DRAN), Centralized RAN (C-RAN) and Virtualized RAN (vRAN). Most mobile networks today are built with a DRAN architecture, whereby the baseband unit (BBU) and remote radio unit (RRU) are located at the cell site, typically in a cell site cabinet near or at the base of the tower. The RRU is located either with the BBU in the cabinet or on the tower near the antennas and then connected to the BBU via fiber using the Common Public Radio Interface (CPRI) protocol to transport the digitized RF data. The cell sites are then connected to the Evolved Packet Core (EPC) via backhaul transport links.

In a legacy RAN architecture, BBUs are deployed in a central location – often referred to as a baseband hotel – while the RRUs remain at the cell sites. The distance between the central BBU site and RRUs can be between 5 to 15 kilometers and they are connected via CPRI-based fronthaul transport over fiber. The BBUs may control multiple cell sites and the baseband processing resources can be pooled. While collocating and sharing baseband resources improves network efficiency and reduces site costs, the benefits are often outweighed by the necessity for highly reliable, low-latency fronthaul transport that can only be delivered via expensive leased or owned fiber connections.

What is Virtualized RAN? Open Interface Software on Open Market Hardware



Source: Mavenir

vRAN overcomes the limitations of traditional RAN by leveraging virtualization. The vRAN architecture comprises virtualized BBUs (vBBUs) running on general purpose hardware in mobile data centers, or at cell sites, or other network-edge data centers and RRUs located at the cell sites. Virtualization enables new functional splits in the RAN elements, which relaxes the requirements for fronthaul transport and increases the distance that the vBBUs can be located from the cell site to up to 200 kilometers. The functional split allows operators to use Ethernet-based fronthaul and removes the dependence on proprietary and costly CPRI-based fiber for fronthaul. The vBBUs can be implemented alongside virtualized EPC (vEPC) elements in a mobile data center, which triggers further cost savings by eliminating the need for backhaul transport and improving latency.

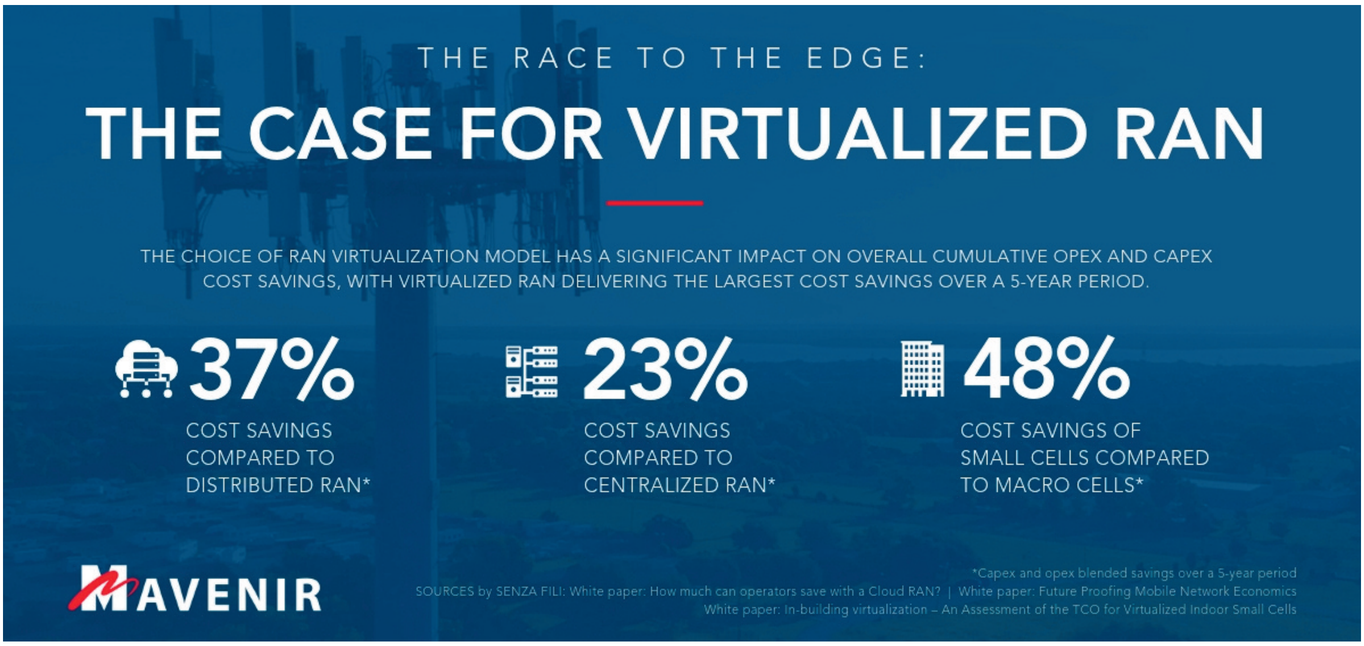
A set of total cost of ownership (TCO) studies developed by Senza Fili Consulting illustrates that significant cost savings can be achieved from a vRAN deployment over a five-year period in a typical real-world scenario in a high-density area. The model compares the TCO of a DRAN, C-RAN and a vRAN greenfield network, covering the RAN to the EPC. The network model is based on 100 macro cells, 200 outdoor small cells and 250 indoor small cells. The DRAN deployment assumes backhaul transport while the vRAN deployment assumes non-CPRI-based fronthaul.

The TCO model shows a weighted total reduction of 37% deployment and operational costs over five years, derived from a 49% savings in capex in the first year, and an annual 31% savings in opex over the full period. The capex savings are mainly due to the virtualization of the BBUs and vBBU pooling, which allow for the use of lower-cost COTS hardware and less of it. Since pooling vBBUs utilizes compute resources more efficiently, less hardware is needed.

Opex savings are derived from reduced maintenance routines, power and operations savings resulting from centralized vBBU locations that are cheaper and easier to access and operate. With less equipment needed to be located at cell sites, lease costs are reduced while operators also benefit from faster and more flexible deployments. Another key cost factor in the vRAN deployment is fronthaul. If the model assumed CPRI-based fronthaul, the opex savings would only have been 11% over five years, rather than 31%.

In a vRAN deployment, vBBU multiplexing dynamically allocates baseband resources to RRUs– reducing BBU capacity requirements by greater than 50%. Operationally, this allows operators to dynamically scale capacity where it is needed in the network during peak busy times or scale down during quiet times. The capability allows operators to move capacity to where users are as they move around the network, thereby improving the network performance and reducing costs.

vRAN significantly reduces TCO compared to traditional DRAN and brings the flexibility, scalability and cost savings of network virtualization to the mobile network edge.



Virtualized Networks Enable New Business Models

While RAN virtualization is leading to centralized approaches in the radio network, virtualization in the wireless core allows key functions to be distributed toward the network edge. Together, virtualized RAN and virtualized Packet Cores (4G vEPC & 5GC) provide unparalleled flexibility for operators to deploy network intelligence more effectively to not only improve network performance and customer experience, but also create new revenue-generating services and applications that were previously not possible with traditional network architectures.

A key feature of a natively designed 4G vEPC that enables new business models is Control and User Plane Separation (CUPS). As the name suggests, the control and user planes are separated to allow the different functions to scale independently, which gives operators more flexible deployment options and better tools for coping with increasing volume and dynamic variations of network traffic. With CUPS inherently designed into the vEPC, operators have more granular scalability across different functions, which avoids overprovisioning and allows operators to increase capacity in lock step with demand across consumer mobile broadband services and IoT device connectivity.

Component disaggregation in the wireless core is not only a lever for optimizing networks today, but also a fundamental principle of the 5G network architecture. Since the user plane functions can be distributed to the network edge closer to users, the architecture greatly reduces round trip time so that it's possible to support low-latency services, as envisioned by 5G ultra-reliable, low latency requirements. Initiatives such as ETSI's Multi- access Edge Computing (MEC) have developed a variety of use cases enabled by distributed edge intelligence – including augmented reality, IoT or video caching - creating new business models for wireless operators.

By disaggregating the core network functions, the vEPC also supports another key 5G principle, network slicing. vEPC instances distributed across the network can be subdivided into multiple network slices. Each slice can be dedicated to a specific service, user or quality of service (QoS) by assigning different parameters to each slice. Network slicing is the foundation for a wealth of new pricing and service models.

vEPC with CUPS also enables mobile operators to serve sectors that have previously been cost prohibitive to serve, such as the enterprise market. The vEPC can scale up or down to support networks of any size as well as a variety of use cases, including private LTE networks, public safety LTE, or dedicated core network for NB-IoT deployments.

With the availability of new shared spectrum, such as the 3.5GHz Citizens Broadband Radio Service (CBRS) in the U.S., and new technologies that leverage unlicensed spectrum coupled with a small-scale vEPC that can be deployed on premises, any enterprise can operate its own LTE network. The vEPC and vBBU combined with indoor small remote radio heads connected over Ethernet cabling, enable enterprise private LTE networks that are more cost effective than current Distributed Antenna Systems (DAS). According to Mobile Experts, on- premise CBRS small cell networks enable a 68% cost reduction compared to DAS networks.

As the private LTE use case shows, vEPC with CUPS offers a more cost-effective way to provide enterprise compute services and allows new players to enter the market. Now, mobile operators have an opportunity to devise new ways to serve enterprise customers. The combination of vRAN and vEPC is not exclusively a 5G opportunity. Both will be critical to enabling operators to derive the benefits of 5G but they also have applications in the 4G era. An example of this is Media Breakout, which enables video traffic to be offloaded from the core.

The scale of the challenge facing operators is demonstrated by the enormous increase in projected network consumption. Research firm iGR has reported that the mean bandwidth for each macrocell in the US in 2018 is just over 428 Mbps and, by 2022, it estimates this figure will grow to 763 Mbps, an increase of 78%. To keep

up with this demand, mobile operators have to add more capacity to the macrocell itself, the backhaul and to the evolved packet core (EPC).

iGR estimates that approximately 80% of mobile data traffic today is video. If, for example, 32% of the total traffic (as 40% is encrypted of the 80%) was broken out, the load on the backhaul and EPC can be reduced by that amount. A mobile operator is not going to remove current capacity from the network because of this potential saving but instead will be able to extend the time before additional capacity needs to be added. This means that local breakout will extend the current macrocell backhaul and EPC capacity by 25.6 months.

To quantify the potential benefits of local breakout, iGR modelled four mobile operators in different regions of the world. In the US, total savings over the five-year period are US$546m for a mobile operator with 50 million subscribers. In Germany, a mobile operator with 30 million subscribers would see total savings of nearly €189m (US$227m) over the five-year period.

In Australia, an operator with 10 million subscribers could save AS$106m (U$80m) over five years from local breakout. And in India, a mobile operator with 150 million subscribers could save Rs38,764m (US$596m) over five years.

Open Interfaces are Imperative

To make the virtualized, programmable and software-defined network a reality from the core to the edge, open interfaces are vital in all parts of the system. Open application programming interfaces (APIs) unlock the flexibility, manageability and cost savings that operators require by breaking open the proprietary stronghold that legacy vendors have on networking equipment and software. Open APIs prevent so-called vendor lock-in by giving operators more choice of suppliers. Open interfaces also drive innovation by allowing more companies and startups to participate in the development of vRAN and vEPC solutions, creating a broad, competitive ecosystem.

Industry momentum is building for open interfaces in mobile networks, as evidenced by initiatives such as the ORAN Alliance, launched in February 2018, which brings together the xRAN Forum and the C-RAN Alliance. Other organizations in this area include: Mobile Central Office Re- architected as a Datacenter (M-CORD) and the Open Network Automation Platform (ONAP).

The ORAN Alliance, which counts many leading operators among its members, is working on decoupling control and user planes in the RAN, building a software stack that operates on COTS hardware and publishing open northbound and southbound APIs. Its xRAN specification was released in September 2018.

Importantly for vRAN implementations, the group is working on an industry imperative, open fronthaul specification that will support interoperability between RRUs and vBBUs from different vendors as well as address future use cases and a variety of deployment scenarios. The goal is to establish a fronthaul spec that is vendor agnostic and interoperable.

The work of the ORAN Alliance dovetails with the edge computing efforts of the open source M-CORD project, which AT&T, Google, SK Telekom and Verizon are leading to create an open reference solution for software-driven 5G architectures. The two groups are working together to create an open reference implementation for xRAN within M-CORD. That is, M-CORD will embrace and implement the ORAN Alliance's standard APIs, which broadens the applicability of both group efforts across the industry.

In another key open source project at the Linux Foundation, ONAP is addressing Management and Orchestration (MANO) issues by creating a framework for policy-driven software automation of VNFs. With a community of major network operators, vendors and software providers, the group continues to gather industry support for its efforts to provide a neutral automation platform for SDN and NFV implementations.

Led by some of the world's largest operators, the impetus for driving open interfaces is strong. While building consensus and creating frameworks takes time, the progress achieved by these groups show keen commitment to break from proprietary legacies.

> "The RAN industry is about to see significant transformation"
>
> **John Baker of Mavenir**

Disrupting the Traditional Network Equipment Provider Model

A recurring theme in discussions with wireless operators about NFV and SDN migration is their frustration with traditional Network Equipment Providers for not moving fast enough to deliver native VNF solutions that run on COTS hardware in a standard way. While operators have always been focused on driving suppliers to lower price, the transition to virtualization and software-based networking puts unprecedented pressure on vendors by forcing them to disrupt their own legacy business models. The traditional, largest telecom equipment vendors – Ericsson, Huawei and Nokia – may one day be the subject focus of compelling business case studies illustrating how companies can either embrace disruption to reinvent themselves or succumb to disruptive forces.

The traditional Network Equipment Provider business model is based on selling dedicated hardware appliances and licenses for the software that runs on them. This transaction is too restrictive for today's networking needs because the hardware provides an inflexible, minimum amount of capacity that can only be expanded by purchasing additional equipment. Operators also become locked into supplier relationships due to the need for ongoing hardware maintenance contracts. And the entire process of procuring, designing, integrating and deploying network equipment is too slow and stifles innovation.

With the adoption of standard open interfaces, NFV and SDN changes the traditional supplier business model from hardware contracts to software licenses. Rather than purchasing dedicated appliances for a specific amount of capacity, mobile operators will buy software licenses and pay for what they use in the network. Traditional Network Equipment Providers are struggling to adapt to new software licensing models.

Pure software vendors that are not burdened by legacy hardware businesses are well positioned to deliver the native virtualization solutions that mobile operators require. But it is not easy for operators to extricate themselves from long-term supplier relationships. Since mobile operators are not going to rip out entire networks overnight and replace them with virtualized implementations, they will depend on their existing suppliers of legacy equipment during the transition.

But the financial incentives for moving just one network element to software are overwhelming. In equipment purchase prices, typically 10% is for maintenance services. CSPs can implement the same function in an overlay virtualized network for less than what they are paying in maintenance costs for the equivalent network appliance. The implementation of a VNF in the mobile network would pay for itself within one year. Whether it's instantiation of vBBUs in a vRAN deployment or implementing vEPC, mobile operators will reap the cost saving benefits of NFV one VNF at a time.

Without the constraints of legacy business models, new software vendors are poised to disrupt the supplier landscape and take market share from Network Equipment Providers. With software assets that are natively designed for cloud environments, the new breed of software supplier can deliver the innovation, agility and costs savings that mobile operators need to survive.

Summary

- Open standards and interfaces are achievable
- OpenRAN ecosystem in formation
- Reference architecture
- Not a revolution – need Carrier adoption
- RAN is an edge service
- Moving the core to the edge allows great cost savings against declining ARPUs
- Virtualized RAN = Open Interfaces on COTS hardware

Conclusion

With all the moving parts operators face during transformative periods, balance and timing are critical considerations. Operators must balance the needs of their traditional operations with the need to transform to new technologies and new operational and business models.

The launch and migration towards NFV signifies a recognition among leading network operators that their legacy business models are not sustainable and that they need to change their cost-per-bit assumptions and revenue generation capabilities. Five years on, the quest for new network economics is more urgent as the costs of keeping up with traffic demand outpaces service revenue growth. Wireless operators have been let down by their traditional suppliers whose legacy business models are not aligned with their goals.

To survive and thrive in the 5G era, there are five critical factors for success:

1) Native software solutions for NFV and SDN;

2) vRAN for reducing TCO;

3) Distributed core networks for fostering new business models;

4) Support for standard open interfaces;

5) Disruptive solution providers.

Nimble, independent Network Software Vendors are redefining mobile network economics by delivering end-to-end virtualized solutions from the core to the edge, and are poised to challenge the traditional Network Equipment Providers and help operators of every type succeed and deliver shareholder value.

Mavenir is the industry's only 100% software-based, end-to-end, Cloud Native Network Software Provider, redefining network economics for Communication Service Providers (CSPs). Our innovative solutions pave the way to5G with 100% software-based, end-to-end, Cloud Native network solutions. Leveraging industry-leading firsts in VoLTE, VoWiFi, Advanced Messaging (RCS), Multi-ID, vEPC and vRAN, Mavenir accelerates network transformation for 250+ CSP customers in over 130 countries, serving over 50% of the world's subscribers. We embrace disruptive, innovative technology architectures and business models that drive service agility, flexibility, and velocity. With solutions that propel NFV evolution to achieve web-scale economics, Mavenir offers solutions to CSPs for revenue generation, cost reduction and revenue protection.

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