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When 5G is ultimately introduced in five years, SDN, NFV and Carrier Aggregation will be widely adopted. Base station resources will be pooled in centralized locations and the RF channels will be dynamically assigned and routed to the cell sites for transmission to users. That instantaneous RF resource assignment will require a real time, low latency and high capacity transmission front haul network for RF routing to the cell sites. Backhaul connectivity from the cell sites to the core must be of equal speed and quality in order for voice, data or video sessions to be successfully completed. Our keynote is playing a leadership role in the PCIA Innovation & Technology Council, and he will argue that fiber front haul and back haul to all of cells, data centers and application centers will be required for the smooth evolution from 4G to 5G technologies.

Fredric J. Morris
Editor-in-Chief,
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Plotting a migration course to network virtualization

by Pravin Mirchandani, CMO, OneAccess Networks

This article will examine the role of virtualization technology as it stands today – focusing on NFV, which offers the greatest opportunity for US carriers in the short term – and how it relates to current and future business opportunities. Ultimately it will share OneAccess' perspective on how carriers might move forward, step by step, in a pragmatic manner, to reap measurable returns within a realistic time frame.

Pravin Mirchandani joined OneAccess Networks as Chief Marketing Officer in 2011 and currently leads the product strategy, product management and corporate communications functions for the company. Pravin has developed the company's innovative SDN / NFV strategy based on service migration which has been described it as 'one of the most technically advanced globally' by some of the world's biggest operators. Mirchandani is an internationally recognized thought leader and regular speaker on the subject of SDN and NFV.

Pravin has over 25 years' experience working in key roles in major telecom equipment manufacturers and software vendors including Bay Networks, Nortel, Orchestream and Codima Technologies. Before joining OneAccess, Pravin was CEO at Syphan Technologies UK, an innovative organisation providing security services to managed service providers.

Pravin Mirchandani is a graduate of both the University of Edinburgh and the London School of Economics.

As local exchange carriers across North America seek competitive advantage in their next generation business service portfolios, the much-hyped trends of Network Functions Virtualization (NFV) and Software Defined Networks (SDN) have come under increasing scrutiny.

For US carriers, the potential benefits of this technology are indeed substantial, and given the exponential growth in the volume of their customers' traffic, as well as its increasing volatility, some combination of NFV and SDN adoption may soon become a pre-requisite for viability within this burgeoning marketplace.

Yet while promising far greater service agility at potentially much lower cost, NFV and SDN still remain elusive goals for the majority of established service providers. To date, one of the chief reasons for this has been the difficulty in creating a realistic migration strategy from where they are today.

Investments in existing network infrastructure, as well as in Operations and Business Support Systems (OSS / BSS), has all but ruled out a simple rip-and-replace approach, and with each of the major networking vendors advocating slightly different and often incompatible roadmaps to NFV and SDN, the pathway forward is far from clear.

This article will examine the role of virtualization technology as it stands today – focusing on NFV, which offers the greatest opportunity for US carriers in the short term – and how it relates to current and future business opportunities. Ultimately it will share OneAccess' perspective on how carriers might move forward, step by step, in a pragmatic manner, to reap measurable returns within a realistic time frame.

Why NFV?

For NFV, the products and technology already exist to deliver substantial benefits in five key areas:

Capital and operational cost savings

EMC and NFV: Modernize then Transform with Evolvable Infrastructure

by David V. Hudson, General Manager, Telecom Transformation Group, EMC Corporation

Since announcing the creation in 2015 of a Network Functions Virtualization Technology Group to supply NFV solutions to the Communication Service Provider (CSP) market, EMC has made a great deal of progress, introducing two highly differentiated platform offerings – one focused on NFVi and one on Telecom Analytics – and is embarking upon an ambitious go-to-market with the Federation of companies that includes EMC, Pivotal, RSA, VCE, VMware and Virtustream.

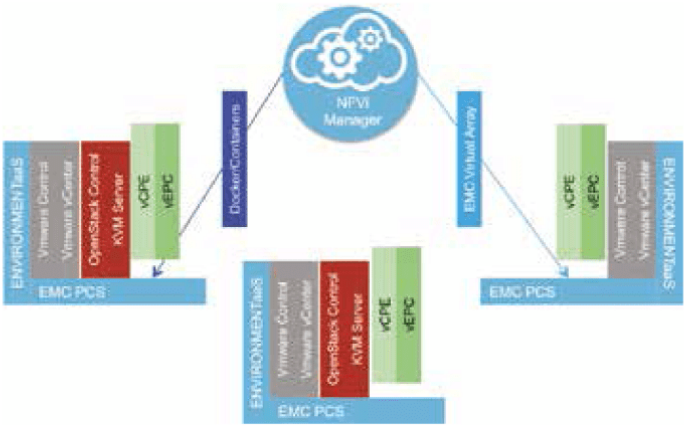
The EMC Telecom Transformation team, has spent 2015 talking to CSPs of all sizes around the world and has learned a number of important lessons. And the lesson that has had the greatest impact on helping us to formulate EMC's NFV strategy is that there is value in taking a gradual approach to NFV implementation, initially virtualizing one or two VNFs as a first step on the journey to NFV. While CSPs can choose to dedicate enormous resources to embark on broad, multiyear transformation projects, CSPs can also approach the transformation more pragmatically and step by step.

By EMC's definition, a pragmatist is an operator that seeks to test the waters with "VNF-in-a-box" architectures that feature a number of distinguishing characteristics. The first characteristic is an NFVi architecture that must be customizable yet simple. Operators want to be able to size and configure NFVi platforms to suit specific workload requirements. Whether virtualizing customer-premises equipment or the evolved packet core, operators are intimate with the requirements of their network and subscriber base and want to be able to customize their solutions with the right amount of compute, networking and storage. At the same time, these operators want the deployment and management simplicity typically associated with a turnkey converged infrastructure system.

EMC's approach to NFVi offers the best of both worlds, by providing a set of common building blocks that can be composed to support custom workloads at the factory before being shipped to the customer, while also providing the capability for the customer to auto-deploy their environment, going from bare metal to workload-ready in a simple, repeatable manner. And EMC simplifies management of the running environment with automated collection, correlation and analysis of system telemetry at every layer of the NFVi stack.

Another characteristic that is important to pragmatists is carrier-grade availability and disaster recover. In the mobile and telecom marketplace, customer satisfaction is tied to availability of the network and the voice and data services it delivers. CSPs are under particular pressure to keep their services "always on" in distributed operational environments that can often be harsh and unpredictable. In the traditional world of telecom, systems and system components were engineered from the ground up to meet or exceed "five nines" availability and reliability, resulting in highly engineered and expensive proprietary systems. In the new world of virtualized, commodity components, carrier-grade has to be redesigned – this time, not at the component level, but throughout the distributed environment, with resiliency built across multiple systems and across multiple sites. This is the approach taken by EMC, which has adapted its industry-leading enterprise technology to the telecom world so as to distribute functionality across the network and eliminate single-points-of-failure, providing active-active failover, continuous availability, and workload consistency across sites.

EMC's NFVi delivers this customizability, simplicity, carrier-grade availability, and distributed operational capabilities, in a platform that is built on three pillars: an abstracted commodity hardware layer, virtual infrastructure capable of hosting multiple services, and advanced management and orchestration with real-time and predictive analytics.



But meeting pragmatists' requirements is only part of the EMC value proposition to CSPs. Filling out EMC's vision for transformational NFVi is the belief that infrastructure should be future-proof. This means that instead of choosing a single operating environment and becoming beholden to its unique set of tools and capabilities over time, an operator should be able to adapt to rapidly changing innovations without having to do a rip and replace of its initial investment. In the four years since ETSI began defining the standards for NFV, the industry has seen the technology landscape expand to include proprietary technologies from vendors like VMware, open source innovations from the OpenStack community, and a growing variety of virtual machine technologies that include hypervisors, containers and unikernels. In order to take advantage of this rapidly evolving technology landscape, an operator's infrastructure should be able to evolve along with it.

An evolvable infrastructure stack should allow for dynamic stack composition and re-composition, and allow for any combination of NFV operating environments and any combination of VNFs, services and applications to be collocated on a common, scalable, cloud architecture. EMC makes the evolvable NFVi stack possible with EMC NFVi Manager management and orchestration technology designed to allow the automated creation, monitoring and management of service environments on a standard underlying infrastructure stack called the EMC Provider Cloud System (PCS). The combination of EMC NFVi Manager and EMC PCS enables operators to run NFVi as an "environment-as-a-service", using blueprints and templates to dynamically define, deploy and manage custom multi-personality NFVi environments.

EMC has come a long way in one year and is excited by the opportunity ahead. If you will be in Barcelona between February 22nd and 24th for Mobile World Congress 2016, EMC will be joining VMware to showcase our NFVi capabilities and our Big and Fast Data Analytics capabilities. We invite you to join us at Hall 3, Stand 3K10 in the Fira Gran Via in Barcelona. And if you won't be there, we invite you to stay up-to-date throughout the year and reach out to EMC for more information at http://www.emc.com/emctelco/

The most obvious cost savings will eventually come from simple economies of scale. Because production volumes for commoditized, off-the-shelf server blades are generally an order of magnitude greater than those for dedicated networking devices, carriers should eventually see a corresponding reduction in CAPEX.

When considering the current processes involved in the deployment of networking hardware, from ordering, shipping and rack allocation, to final installation and configuration, it is easy to see how OPEX could fall dramatically once these are replaced by the point-and-click instantiation of virtual network functions (VNFs). Freed from the costly and lengthy validation cycles for deploying new hardware, new VNFs can be 'spun-up' within minutes, and fully tested and deployed within a matter of weeks or even days.

Performance and scalability

Another indirect advantage of NFV comes from the idea of function decomposition. Since a VNF may be decomposed into sub-parts which are themselves VNFs within the NFV infrastructure (NFVI), some interesting implications arise for performance and scalability.

This is because the function of a given network element can be implemented not only by a single corresponding VNF, but also by multiple parallel constituent VNFs. Conversely, implementation of the functions of multiple network elements can be consolidated into a single VNF, as with a multi-function virtualized gateway for example. This splitting of business services into individual component services can then facilitate transactions, increase scalability, and enable the creation of new, higher performance service bundles.

Service agility

Service agility refers to the speed and ease with which new services can be planned, tested, deployed and billed. Today, using the current operator model in which physical networking components have to be selected, tested, validated, and then integrated into the operations and business support systems (OSS/BSS) framework, is a journey which takes between 12 months and two years or more. NFV on the other hand, since most of the processes take place through centrally managed software, has the potential to shrink this journey to a matter of weeks.

Service customization

With increased agility come many interesting new possibilities for service differentiation including the ability to design, test and deploy brand new customized services tailored to specific customer needs. Within a virtualized infrastructure, spare resources can be temporarily set aside for such trials with little or none of the cost overhead that would prevent equivalent physical trials from reaching economic viability.

Migration Challenges

For the majority of incumbent local exchange carriers (ILECs) however, a number of challenges, both practical and cultural, will need to be overcome before the full range of NFV benefits can be realized.

Unless investment in existing network infrastructure is close to being fully amortized, outright replacement is unlikely to yield a satisfactory return. Migration to NVF may therefore have to proceed at the natural pace of equipment refresh cycles.

This means that VNFs will almost certainly have to co-exist with existing physical network components and CPE, meaning that orchestration of the NFVI will have to integrate, or at least run in parallel with, current management systems.

One of the biggest issues is ensuring a migration path for legacy voice components. All VoIP may be desirable in the long run but customers also face equipment refresh constraints.

Finally, as with any sea-change in business practice or philosophy, NFV will undoubtedly meet some level of cultural resistance. Some will doubt that virtualization can deliver the same 'five-nines' availability claimed for today's carrier networks. Others may be concerned about the security implications of having so much of their business built upon remotely configured software.

De-composing software functions provides flexibility and scalability but it's much easier to point a single trouble-shooting finger at a monolithic appliance that doesn't work rather than several fingers towards multiple components and vendors.

Building a Migration Strategy

For US companies that do feel confident enough to make the transition, significant benefits await. For service providers however, it is prudent before embarking on any migration to NFV to properly assess an organization's readiness by asking the following four questions:

1. What is the life cycle status of current network components? Clearly unless large parts of the network are due for a refresh, this may not be the optimal time to migrate.

2. What new services are planned? Since the biggest advantage to be gained from NFV is increased service agility, it makes sense to start any migration strategy with a focus on the new services that are being planned.

3. Will available VNF solutions support the planned services with the level of interoperability required? Whether considering pure software or hybrid solutions, they must be able to fully integrate with the existing infrastructure and come together under a common management umbrella.

4. What strategy to adopt concerning legacy voice? If all VoIP is unrealistic, then there must be a decision about how to bind voice interfaces (PRI, BRI, T1/E1, FSX, etc.) into next-generation management systems.

5. How What is the minimum level of orchestration required for deployment of new VNFs? Spinning up new VNFs and interconnecting them ('service chaining') so as to deliver a service is only half the battle, and while full integration of next-generation management systems with the existing BSS / OSS may be unrealistic in the first phase of migration, it is nevertheless important to determine precisely how much compromise on this important aspect would be acceptable.

Putting Migration into Practice

Service providers can now make the move from classical OSS to next generation IT systems with the help of specialist telecoms vendors, like OneAccess Networks. With so much variation in the approaches taken by the various participating vendors, the following checklist is a useful barometer for assessing which are best positioned to support migration to NFV:

• Is the architecture sufficiently open to allow full virtualization and guard against vendor lock-in? While x86-based architecture may not be suitable in all situations, solutions based on an open OS such as Linux should prove more adaptable to future requirements.

• Do they already provide support for open virtualization frameworks in order to keep down costs and ensure the greatest future interoperability?

• Do they support the NETCONF network management protocol with some form of parallel API for legacy management interfaces?

• Are all management objects, both data and voice, defined using a common data model such as YANG, so that ultimately all network services can be brought under the same management umbrella?

• Often overlooked, what is the software licensing scheme proposed? One of the benefits of virtualization is flexibility but this can be severely hampered by inflexible key management systems or software that is tied to a specific environment.

Conclusion

As the virtualization ecosystem has advanced it has become increasingly complicated and difficult to navigate. Whilst specialist vendors such as OneAccess are there to lend a hand, carriers must chart a path through this environment according to their own respective commercial objectives, and overall appetites to migrate quickly. Nevertheless, there are key underlying considerations that all carriers would benefit from building into their migration roadmap:

Enable native NETCONF on physical as well as virtual CPE so that all components can be brought under a common next-generation management umbrella.

1. Insist on openness and interoperability and avoid in particular management approaches that rely on proprietary mechanisms or extensions.

2. Look for a level of pre-integration to reduce the burden of integration, e.g. deploy white box-CPE with pre-integrated middleware to host VNFs.

3. Ensure parallel support for classical management APIs as well as next-generation ones to facilitate service migration.

4. Don't forget about legacy voice: one way to approach this is to look for equipment with TDM interfaces that also supports NETCONF.

5. When building new virtualized services, gather the experts together: your own as well as from the respective vendors. Network virtualization technology is still in many respects immature and requires experts to interact with each other to isolate and resolve the inevitable teething and integration issues.

6. Be both pragmatic and smart. Some level of compromise is inevitable but make sure that choices made don't block future evolutions or lead to vendor lock-in.

While it is up to each service provider to chart their own migration course to network virtualization, if they adhere to the above considerations and build them into their strategy, they will can embark on the migration process confident that they are both keeping their options open in a rapidly evolving market, and establishing safeguards that will keep them in control of their new virtualized infrastructure in the future.

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User beware: SS7 spoofing and the rise of signaling fraud in Next-Gen Networks

by João Albergaria Resende, Vice President Product Development, WeDo Technologies

How does SS7 spoofing happen? This type of fraud can take place from anywhere in the world. Recognized vulnerabilities of an SS7 network allow for an intruder without sophisticated equipment. Using a Linux-based computer and a publicly available SDK for generating SS7 packets, fraudsters can determine the subscriber's location, hack into calls and chats, and collect personal data to steal money and valuable information, or just disrupt communications. Since WhatsApp doesn't store previous chat history, fraudsters can't access past conversations, but they are able to impersonate the account holder to gain access to private or sensitive data from other people they know.

João Albergaria Resende, VP Product Management, WeDo Technologies

Before joining WeDo Technologies in 2001, Joao spent four years at American Management Systems (AMS) in various development and program management roles. He now leads product development at WeDo Technologies. João Resende has over 15 years of experience in Software development and in the telecom industry. He holds a MBA from INSEAD and a master's degree in Computer Sciences from Universidade do Porto in Portugal.

With all the advances in technology, most of us would be surprised to learn that telephone networks – both mobile and fixed - were never designed to be secure. They were created as a 'trusted' environment that was designed to facilitate global interconnections. Unfortunately there are hackers around the world who are constantly exploring how to identify and take advantage of new and existing security gaps. Today there are vulnerabilities in networks that allow hackers to read texts, listen to calls and track mobile phone users' locations. For this reason, mobile operators and fraud management companies fight a never ending battle to minimize the impact of fraud – against themselves and their customers.

Even with these threats, we typically think that when communicating through encrypted services like WhatsApp, Viber, Facebook and others, our messages and conversations will remain secure forever. But that's not always the case. In fact, in today's all-IP world the risks are higher than ever. As reported by Forbes Magazine this past May, someone could steal your mobile identity without your knowledge, and start impersonating you-messaging or calling people through these supposedly secure apps without your knowledge or consent. Or commandeering your Facebook page to make calls, comments and posts - posing as you. This type of fraud is called SS7 Spoofing. And when it comes to the future, the problems won't stop with messaging apps. The rise of 5G and millions of new IoT sensors will drive additional risk of theft. According to Gartner, by 2020, a black market exceeding US$5 billion will exist to sell fake sensor and video data for enabling criminal activity and protecting personal privacy.

Blame it on the 70's

Lots of things can be blamed on the 70s; the global oil crisis, the Watergate scandal, disco, and now apparently, cybercrime. SS7 spoofing stems from a security flaw in Signaling System 7 (SS7), an international standard that defines how network elements exchange information over a signaling networks.

SS7 Spoofing

SS7 (and other signaling protocols) are really at the heart of every network. It was developed way back in 1975, only two years after the very first mobile call was made. The problem is that it has never been updated to account for advancements in mobile technology or the rise of cyber-crime.

SS7 is used by over 800 network operators around to world. It allows them to exchange information needed for transmitting calls and text (SMS) messages between each other, and to ensure correct billing. It also allows users to roam internationally. It's a critical technology for keeping the world connected, but it has its flaws.

How does SS7 spoofing happen?

This type of fraud can take place from anywhere in the world. Recognized vulnerabilities of an SS7 network allow for an intruder without sophisticated equipment. Using a Linux-based computer and a publicly available SDK for generating SS7 packets, fraudsters can determine the subscriber's location, hack into calls and chats, and collect personal data to steal money and valuable information, or just disrupt communications. Since WhatsApp doesn't store previous chat history, fraudsters can't access past conversations, but they are able to impersonate the account holder to gain access to private or sensitive data from other people they know.

Because apps often use SMS authentication to identify users, fraudsters don't have to bother trying to break the app's encryption. Instead, they can leverage loopholes in the SS7 protocol which allows an attacker to intercept incoming SMS messages, which are then used by the apps to identify users. To do this, the fraudster simply uses SMS to request and create a 2nd 'shadow' user account without the owner's knowledge. Once this is completed, they can impersonate the account holder - sending and intercepting messages without the owner's knowledge.

Security issues within SS7 were first uncovered by researchers at a hacker conference in Hamburg, Germany in 2014. These systems continue to be used both by governments and criminals for snooping, and the fraud can be targeted against subscribers and service providers. While SS7 spoofing may be seen as an intrusion or inconvenience for most of us, it is a real threat to government officials, public figures, business executives, and certainly victims of stalking or domestic abuse.

Next-Generation Networks and new signaling protocols

New protocols can help improve the efficiency and performance of telecom networks, but they also bring increased risks to a network's security and privacy because they add another layer of complexity that can be infiltrated. For next-generation networks such as 4G and 5G, signaling in the evolved packet core is based on Diameter, with protocols that are different from those used in SS7. However many of the concepts used in the SS7 network environment are the same, and therefore share the same risks.
According to the GSMA, "Diameter is the fastest deployed network technology in telecommunications history". It is easier to access than SS7, and with more parameters, Diameter protocols provide a wealth of new opportunities for fraudsters to access sensitive network information, stemming from issues like the use of femtocells and new mobile operators that rely upon roaming interconnections. Plus, Diameter based networks need to have the ability to interconnect with legacy SS7 networks, which will be in operation for another decade or so. This causes additional complexities and avenues for fraud.

How do we stop it?

Networks are continuing to evolve at a faster and faster pace. And with technologies like NFV and SDN on the near horizon adding another layer of risk, one of the best ways to protect against these threats and stop SS7 and Diameter attacks (and other signaling flaws) is for network operators to continue their efforts in protecting their customers by constantly looking for real time fraud scenarios. For example, they should ensure they have the right firewalls and other IP security in place to guarantee secure connectivity to roaming partners. Modern fraud management systems can monitor for all types of signaling attacks. Forward-thinking mobile operators have already deployed these methods to protect their subscribers from this and other types of signaling fraud.

Moving to 5G is coming… but there is still life in LTE

by Phil Sorsky, International VP, CommScope

Phil Sorsky, international vice-president at CommScope, explains the key role Long-term Evolution (LTE) network still has to play in the 5G roll-out

Phil Sorsky, international Vice president of Service Providers, covering Europe, MEA and Asia Pacific, Phil is responsible for all business in the telecommunications space including mobility and fixed line.

Phil has more than 20 years of telecommunications industry experience, having worked for and made significant contributions to industry leaders such as Juniper Networks, Adobe Systems, Cisco Systems and AT&T. In his most recent position, Phil was Juniper's vice president of sales for the United Kingdom and portions of northern Europe, where he was responsible for sales, technical support and marketing. He is a graduate of the University of Birmingham in the UK.

The next wave in mobile innovation, 5G, is beginning to take shape. With subscribers demanding more bandwidth to stream videos and access peer-to-peer gaming and augmented reality apps, operators are under pressure to deliver a better experience.

The vision is smart

Looking ahead, new applications and services driven by the Internet of Things (IoT) such as self-driving cars and virtual reality, will need even greater speeds. Hundreds of times as many devices could be connected to networks, enabling smart buildings in smart cities.

With high network capacity and super-fast speeds, doctors may be able to perform surgery on patients remotely. Downloading entire movies may take seconds instead of minutes. Applications no one has yet conceived will be possible when wireless networks shift to 5G.

The question facing operators is undoubtedly how to find new ways to profit from their networks and how to successfully make the transition to 5G. Various organisations around the world are working diligently to help decide what 5G will look like.

They will need to decide what frequencies it will run on, how networks can deliver super low-latency speeds, how long IoT device battery life will need to be and how green 5G needs to be. This is no small feat.

Defining the standard

With the first 5G standard targeted for release the second half of 2018, or even sooner depending on who you talk to, there is still much work to be done. Organisations, governments, academics and special interest groups are all working on the technologies that will eventually form the standard. Until then, 5G is still largely a concept.

The first networks built on the standard are due to be rolled out in 2020. The International Telecommunications Union (ITU) will formally determine what the next generation standard will be in terms of performance, with the 3GPP and ITU involved in the process. To meet that deadline, which will include the ITU requirements for 5G, other groups including universities and special interest groups will also need to give input.

Not enough spectrum

Regulators are already identifying the spectrum needed to support the initial 5G deployments. Every new standard demands more spectrum. If operators want to deliver more capacity, they will need more wireless spectrum to do it. According to industry analysts, there simply isn't enough spectrum left.

Much of the success of 5G will rely on optimising the use of spectrum. One solution could be to look at higher spectrum banks such as 6GHz, 28GHz and 3GHz. These higher bands allow data to be transmitted at a greater bandwidth, but the signal doesn't reach as far lower spectrum banks.

The rise of the millimetre wave

Instead of broadcasting signals in all directions using lower spectrum banks, higher spectrum banks could be used to send information directly where they need to go. This could be to a handset, router or base station for example. This approach, referred to as the millimetre wave, is one way to get more spectrum into LTE.

However, there have been atmospheric challenges in delivering the millimetre wave. Some reports are that a downpour could impact delivery – which isn't great for places like London. That said, many key players are investing in trailing the technology with some promising results.

Samsung, for example, has produced the first millimetre wave hardware. This 64-element adaptive array transceiver, which when operating in the 28GHz band, can handle over 16Gbps over 2km. Following its acquisition of millimetre wave research company Alpental Technologies, Google is also getting in on the game.

Small cells could boost performance

To address the lack of spectrum, the mobile industry can add more capacity by improving existing spectrum efficiency or rolling out more infrastructure. On the infrastructure front, small cell technology could be added to lamp posts or buildings to boost performance.

While they may have a reduced range compared to their larger counterparts, small cell technology is a valid alternative to adding more base stations in already densely populated areas. Small cells also have the benefit of needing less energy.

Another benefit of using small cell technology is that it offers the potential to turn the cells on and off as they are needed – something that can't happen easily with a large base station. To do this, however, would require a fundamental change to mobile architecture.

This change is something being considered for the 5G roll out. Sometimes called ultra-lean design, the 5G network would have the anchor remaining on while the small cells are shut down or awakened as as they are needed. This means less energy is used and also there is less interference – a viable methodology to optimise spectrum.

MIMO could drive spectrum

Multiple input, multiple output (MIMO) is another key technology contributing to 5G. Instead of one single antenna, MMO equipment could have tens or even a hundred or more antennas. The addition of more antennas translates into better data rates for users as gives operators greater spectral and energy efficiency.

MIMO can work particularly well alongside millimetre wave and small cell technology. Using small cells to offload traffic from base stations can decrease the distance between transmitters and users, resulting in lower energy use. Tiny wavelengths can allow for hundreds of antennas to transmit data more efficiently – and even has the potential to overcome issues due to rain.

With MIMO in place, beamforming, where the beam is directed towards the equipment that is meant to receive it, is possible. The result is better coverage due to more efficient throughput and reduced interference. MIMO is already being used as part of the LTE-A. But, with the arrival of 5G, its likely to be much more widespread.

Investment in 5G

Gartner predicts that there will be 20.8 billion internet enabled devices by 2020 – rising from 6.4 billion in 2016. Establishing the right technology will be critical to powering these devices, and reaping the benefits from IoT globally.

The U.S. 5G technology market is forecast to grow rapidly. The Federal Communications Commission (FCC) has already begun an assessment of the allocation of 5G frequencies. Companies including T-Mobile and AT&T in the use are talking about increasing bandwidth and performance by introducing 450 and 600Mbps networks – to boost existing 4G networks.

These types of initiatives are helping the industry to understand what it needs to deliver to make 5G a success. Aspects including bringing latency under one millisecond, greater energy efficiency than its predecessors, as well as being capable of delivering a 1Gbps downlink and multi-gigabyte in the future, are some of the capabilities outlined for the upcoming standard.

Years away

With the history showing new generations of wireless technology being introduced every 10 years, with 2G in the 1990s, 3G in the 2000s and 4G/LTW in the 2010's, this is no quick transition. Significant roll-outs of 5G networks are not reasonably expected until 2020. But, even then, it will likely be several years until substantial parts of operator's networks have converted to 5G.

Again, if we look at what has happened in the past, each generation's technology has lasted for 15-20 years. Sales of 2G equipment stopped around 2010 and 3G sales are only now on a downward slide. Following this trend, LTE equipment will continue to be sold throughout the 2020s. This means that LTW will remain the predominant wireless network technology sold for at least the first few years of the coming decade.

LTE improvements at the heart of 5G

With this in mind, LTE capabilities will ultimately experience incremental improvements on the way to 5G. To improve LTE, Cloud-RAN architectures, for example, can help operators reduce costs now with baseband unit pooling, and densified networks can add capacity where needed.

5G offers a way to make all sorts of exciting new technologies become reality. But ensuring there is no latency and the signal can't be lost, is paramount to its success. With innovations such as driverless cars on the cards, the implications of poor coverage could be paramount – even fatal.

Of course the industry is aware of the risks. This is one of the reasons that agreeing a standard is so critical. In the meantime, optimising LTE will be critical to laying the foundations for the introduction of 5G.

According to the GSMA, operators are spending $1.7 trillion on their LTW networks between 2014 and 2020. Naturally they will want to see a return on their investment. In theory, 5G will give mobile carriers new ways to drive revenues – and consumers will be more likely to part with their cash for the benefits that 5G brings.

The road to 5G will undoubtedly see improvements to LTE along the way. Virtualisation and optimisation, as well as centralised RAN and true Cloud RAN, offer both operating and capital expenditure savings for operators. LTE will continue to play a key role in delivering a robust 5G network. So while operators are focused on 5G, LTE will remain the workhorse of the wireless industry for many years to come.

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COMEXPOSIUM

The path to 5G brings new back office challenges

by Paul Hughes, Director of Strategy, Netcracker

No matter how you look at it, 5G promises a greater digitalization of everyday life. It also promises significant disruption of the status quo. As network performance metrics greatly improve, the potential impact from new and evolving business models may be sudden and unexpected. As a result, any operator who lacks the back office system flexibility will be forced to compromise on business and monetization models.

Paul Hughes is Director of Strategy at Netcracker Technology. Paul is responsible for all aspects of Netcracker's strategic initiatives across BSS/OSS and customer experience business lines, including customer, product and technology management, market direction and corporate communications and has over twenty years of telecom industry experience. Before joining Netcracker, Paul was Program Director for IDC's Storage and Data Management Services practice. Prior to IDC, Paul was Director of Marketing at Oracle Communications.

The demand for ubiquitous connectivity has driven wireless service providers to take drastic action around IT transformation in order to meet the ever-changing needs of their customers and their always-on expectations. 5G networks promise lightning-fast network capacity with the potential to displace other service delivery methods, in particular cable services. It also drives new opportunities for services, forcing the provider community to embrace the transformational challenges needed to support those revenue stream ideas well in advance of their actual launch. This creates a daunting challenge for providers to ensure that they deliver on the technology promises customers expect from them and be able to monetize these new services.

With all the expectations that come from such an increase in bandwidth, it's hard to deny that 5G should bring some exciting new services to the forefront. Soon, users will have the ability to stream or download 4K video to their handsets in a matter of seconds. New levels of digital automation will benefit hospitals, medical device companies, automobile and other highly automated industries. While these industries can all benefit from 5G's yet-to-be defined 'killer app,' mobile operators will likely treat the network itself as a new revenue resource, offering up network as a service based on speed, QoS and value for both B2C and B2B segments. Guaranteed levels of performance that help ensure mission-critical applications run smoothly can be contracted and priced based on service expectations, particularly in the B2B segment. Similarly, emergence of high bandwidth intensive consumer applications can also allow greater creativity in pricing, where high value, higher bandwidth applications and services can potentially be priced accordingly.

This will require an update to the back office and front office systems with the new capabilities available from the 5G network, including using network intelligence functions as a key aspect of every billing transaction. Higher network speeds and greater capacity translate into new service opportunities. Current 5G models show mobile operators splitting network bandwidth and resources based on service demands. Each of these network slices will contain network-based transactions that will create ratable and billable events. And each of these billable events will translate into revenue, either for the operator, or for the operator and service partner, and is intrinsically linked to the customer experience.

BSS at the core of new 5G service revenue

Mobile operators must be ready to transform their BSS if they are to rate and bill for a new wave of services and ensure that BSS infrastructure can support

whatever 5G business models are thrown their way. In fact, analyst firm Ovum expects spending on revenue management related BSS systems to grow by five percent to US$16.6 billion in 2020, much of this being driven by digital transformation and new service readiness.

5G cellular wireless networks are envisioned to provide higher data rates, enhanced end-user quality-of-experience (QoE), reduced end-to-end latency, and lower energy consumption. One of the key catalysts for 5G infrastructure will be the growing ecosystem of things around the end user, acting as a producer and consumer of data, as new terminals will be tuned to retrieve and generate information independently from the network infrastructure availability.

One example of a 5G revenue generating service comes from a water company in a drought stricken region that could leverage wireless sensors located on reservoirs and delivery infrastructure around its supply area to maximize water resources. The company would receive guaranteed network capacity from an operator to ensure each sensor remains wirelessly connected to a central management system. Through periodic data gathering, or on-demand updates, the utility would gain valuable insight into current reservoir levels, help discover or prevent water main breaks before they happen, identify leaks in the infrastructure, as well as link to smart meters to compare actual consumption with projected usage.

In this case, each download would be a billable event for the operator, yet the costs of services to the water company would likely dwarf that of a massive infrastructure repair or water purchase in case a reservoir capacity reached critical levels.

Another example could be a mobile operator partnering with a sports media company to provide 4K quality streaming of a sporting event. In this case, the streamed event would be given dedicated bandwidth and billed based on a flat rate price or by duration. Any delivery issues would trigger QoS discounts as part of the BSS policy management and ensure the billing system creates, rates and bills the transactions accordingly.

Potential revenue streams such as these demonstrate the importance of rating and billing flexibility that mobile operators need in order for 5G services to be both viable and profitable.

Taking the next step – plan now for the unexpected

Any operator that puts off BSS transformation will delay future service innovation and likely leave significant revenue opportunities on the table, so now is an excellent time to begin the process to ready the business, network and IT departments to ensure a seamless launch. First and foremost, do not invest blindly without a set plan that highlights the business models for future services. Creating a set of guiding principles around flexibility of business and revenue models for emerging 5G services will help to reduce the risk of potential technology bottlenecks that may lurk outside the network.

The reason for this is simple: What's been predictable in past networks becomes unpredictable with 5G. The days of using speed to attract new subscribers are over, as user penetration rates are over 100 percent in some regions of the world. 3G and 4G networks have now given the end user a taste of speed, and the benefits of speed and connectivity now mean one user may have multiple devices.

For most wireless operators, thankfully, unlimited data plans are largely a thing of the past. However, as 5G enable devices to consume data at even higher rates and in short order, speed becomes the value play. Wireless data billing will have to adapt to support a broader range of service plans, and ones that embrace real-time networks functions that can throttle usage, provide preferential bandwidth, and charge accordingly based on consumption.

The explosion in the number of devices connected to the 5G network will require real-time usage measurement, in what could resemble an energy/utilities model. All this usage must be charged and billed for based on the complexity and value of the interaction. Whereas data consumption from traditional services like email; internet and phone are all currently measured by the amount of data we consume, 5G shifts the model to become increasingly specific. Instead of billing for services, wireless operators will need to bill for interactions and value of interaction could be based on time, priority or other measurable units.

For example, take an IoT model of water or waste management, where sensors are placed through an infrastructure to measure flow, pressure, and provide valuable data that helps maintain efficiency and reduce the threat of leaks. This set up for testing and measurement could be done at specific times to help reduce costs and burden to the network (similar to the Time of Usage model in utilities). An operator would rate each transaction based on the time it was measured. A waste management provider would endure higher prices during peak hours if a problem arose and sensors started to generate data to provide greater insight into the problem. Another example would be a consumer 5G service that offers lower 4K video streaming pricing during off peak hours. This interaction would allow the end user to make the choice on when to stream, which could result in different rates for data usage during peak times vs. off-peak hours. As part of the pricing, any degradation of service would also be tracked, and discounted accordingly.

No matter how you look at it, 5G promises a greater digitalization of everyday life. It also promises significant disruption of the status quo. As network performance metrics greatly improve, the potential impact from new and evolving business models may be sudden and unexpected. As a result, any operator who lacks the back office system flexibility will be forced to compromise on business and monetization models. Any compromise on the operator's part will no doubt be a boon to the end user, as inflexible billing systems will likely force an operator to offer simplistic usage plans. Regardless of the approaches taken for managing the service aspects of this newfound bandwidth and network flexibility, one solid piece of advice should be heeded by everyone: Don't overlook your billing systems until it's too late.

"The Future of 5G and its big Connectivity challenges"

by Jeff Gudewicz, VP Product Development, Wilson Electronics, LLC

Although many operators are talking about the impending implementations and possibilities of 5G, the reality is that the formal specifications for 5G have not yet been fully drafted and agreed upon. It is currently estimated that the actual implementation and rollout of true 5G services will not occur until at least 2020

Jeff Gudewicz is vice president of product development at Wilson Electronics, LLC since joining the company in 2013. Wilson Electronics designs and manufactures broadband cellular signal boosters for a variety of applications including both mobile and indoor solutions. In this role he is responsible of managing all engineering, R&D and Product Line teams to execute product roadmaps. Jeff has more than 20 years of experience in the RF and wireless industry through various positions in engineering and product management.

Prior to joining Wilson he worked as Director of Business Development at RFMD Inc., a semi-conductor company specializing in components for RF and wireless applications world-wide.

Gudewicz has a B.S. from Southern Illinois University and his MBA from Regis University. When not building cool products with the great team at Wilson, Jeff can be found enjoying the great outdoors in Colorado.

In today's world, streaming videos and consuming large amounts of data have turned from a novelty to a necessity. Can you imagine navigating to a new place without your phone? What about taking a road trip without being able to use your favorite streaming service? While we currently experience the faster data rates on our mobile devices using 3G, 4G and LTE, 5G wireless would bring our mobile devices to the next level. Unfortunately, the evolution of 4G to true 5G wireless is still years away from reaching consumers' hands, but we nevertheless can see the potential it could bring.

Let me explain. The word evolution brings to mind the popular image of the evolution of man. This evolution of man image isn't much different than the evolution from the brick or bag phone to the advanced devices we now utilize today. Consumers are just now in the past year starting to enjoy the benefits of faster speeds and better coverage of 4G LTE. As devices evolve into a more complex and evolved state, our wireless standards must follow.

In the cellular communications industry, few things are as enthralling than having a new wireless standard. New standards eliminate previous limitations and open the doors to new opportunities for businesses and consumers. Such is the case with the evolution from 4G to 5G. This evolution will bring about very exciting change, but it isn't without its challenges. As the 5G standard becomes adopted across the globe, consumers, carriers and businesses can expect to confront barriers, including the adoption of formal specifications, the rollout across carriers, and management of signal attenuation.

Although many operators are talking about the impending implementations and possibilities of 5G, the reality is that the formal specifications for 5G have not yet been fully drafted and agreed upon. It is currently estimated that the actual implementation and rollout of true 5G services will not occur until at least 2020. At this time, there are many considerations underway. In July 2016 the FCC approved spectrum in the microwave bands of 28GHz, 37GHz, and 39GHz. These much higher frequency bands are needed in order to achieve the allowable channel bandwidth required to reach the data rates, which will be 1000x higher than those of today's 4G LTE speeds. Recently, telecommunications companies T-Mobile and Ericsson have demonstrated trials with download speeds over 12 Gbps and latency (the time it takes for data to travel between source and destination) at under 2 milliseconds (ms). Next, the carriers need to incorporate all of this into their own build-outs. It will be an exciting time.

When the time comes for the rollout of true 5G, people will be able to see the technology across a broad spectrum of areas in day-to-day life from the home and on the road to right in consumers'

Why 5G and platforms go hand in hand

by Barry Graham, Senior Director, Agile Business & IT program, TM Forum

Platforms are both driving the requirements of 5G and will provide the underpinning technology that will allow companies to capitalize on the opportunities it offers.

Barry Graham has over 20 years' experience in Telecoms having held senior positions including head of Product Management at Motorola and Acision, and most recently JDSU (now Viavi), having been part of the executive team of startup Arieso, which was acquired by JDSU.

Barry Graham is now the Programme Director for the TM Forum's Agile Business and IT program, helping members transform their businesses to meet the challenges of today's new technology and ever changing business environment.

5G is not fully defined yet, but powerful trends are driving the urgent push for it, even before standards are agreed. First, the Internet of Things/Everything (IoT/E – the latter includes people), which is becoming an inherent part of so very many sectors that analysts are predicting billions of devices will be connected by 2020.

As outlined in a paper by Professor Ian Brown of Oxford University in 2015, IoT/E spans different scales of deployment:

Individual – typically spans smartphones and wearables used by individuals, where the intended audience for the data is likely to be the user themselves, perhaps their immediate friends and family, or maybe a bank (for mobile money apps) or their employers for work-related use.

Community – includes connected cars, health devices and smart homes, linked to intelligent transport systems, remote alarms and heating systems, blood pressure monitors and so on. The data will be about speed, distance, airbag, crash locations, heart rate, blood pressure and diet, among other things. The audience for that data will be the doctor and other healthcare givers, car insurance companies, police, social networks, wider circle of friends.

Society – meaning large systems like smart cities and smart grids, that rely on smart electric, gas and water meters, and traffic monitoring. The data will be based around consumption and billing, and traffic flow data. The audience for the data is regulators and authorities, utilities and other citizens.

It also involves four different kinds of communications models: back-end data sharing; device-to-gateway; device-to-cloud; and device-to-device.

All of these will have to be catered to by 5G.

The platform revolution

The second terrific force driving 5G is the rapid rise of platform-based businesses. Over the last 20 years, and at an accelerating rate, they have and are reshaping established business models globally. By becoming a platform player, Apple, which almost went out of business in 1997, is now the world's most valuable and profitable company.
Platform businesses scale very fast by exploiting the network effect, whereby a product or service becomes more valuable as more people use it, because the more people use it, the more people they tell about it and more people join in. Hence Airbnb, not yet 10 years old, is worth US$30 billion, based on the valuation from its last round of funding in September – surpassing the value of Hilton Hotels, founded just shy of a century ago.

Another key characteristic of platform businesses is that they can morph or grow by leveraging their assets in new ways, and indeed, by design they are highly modular and componentized to give them this agility; their systems and processes can be reconfigured, recycled and replicated very quickly. For example, Uber is planning to spend half a billion dollars developing its own maps (using cameras in its cars) because Google Maps aren't detailed enough for its future business model of using driverless vehicles for all kinds of deliveries, not just passengers.

Last, but not least, all successful platform businesses are built around customers – indeed Uber and Netflix, among others, were triggered by their founders having bad experiences – and ensuring they have a good experience every time.

Boom – 5G meets platforms

These household-name examples offer just a glimpse of future requirements and business possibilities: Imagine what could happen when the agility, speed and scale of platforms is combined with the agreed requirements so far for 5G, which include:

- Enhanced Mobile Broadband (eMBB) – successive generations of access technology have increased capacity and throughput, and reduced latency, and 5G will be no exception.
- Ultra-reliable and low latency (uRLL) – although a key goal of LTE was to reduce latency, 5G takes this to a whole new level of sub-millisecond targets, opening a new world of applications.
- Massive Machine Type Comms (mMTC) – existing systems were designed for one device per subscriber and relatively large data volumes, and so cannot support billions of devices or their different demands, such as consuming dramatically less power (10-year battery life) and passing tiny amounts of data efficiently.
- Network slicing to provide what each service requires – that is, commoditizing connectivity and making it possible to offer network as a service in much the same way that cloud providers have commoditized compute and storage infrastructure as a service.

This is a demanding set of requirements and likely there will be more design goals put on the table before they are narrowed down. After all, the ICT world surrounding 5G is changing as fast as the network, and we cannot anticipate all the new applications and user needs that will emerge between now and the initial deployments of 'standardized' 5G, never mind throughout the lifecycle of the technology.

5G will help to realize a completely new world for consumers and vertical industries. Operators must be ready for the technical challenges of managing this and also to capitalize on the new opportunities it creates.

Managing complexity, monetizing services No one company can address all the challenges and opportunities alone – the complexity will be greater than ever. Partnerships and ecosystems – enabled by platforms – are the key.

Take autonomous, self-driving cars as an example. They promise fewer fatal accidents, less traffic congestion, more navigable cities and environmental benefits. However, features like cooperative collision avoidance demand ubiquitous, totally reliable communications – way beyond what we have today. Moreover, vehicle and municipal sensor information will need to be exchanged in real time between perhaps thousands of cars in the same area, overcoming many potential sources of signal obstruction.

The ecosystem is complex and includes car manufacturers, city authorities, traffic signal manufacturers, communication service providers, traffic data providers, other drivers and more. These partners all need to be able to exchange data and information instantaneously to provide a safe and pleasant experience for the user.

In the midst of such complexity, platforms allow the delivery of digital products and services between producers and consumers, and hide the complexity from them. Through open, standard architectures and APIs, new partners can be on-boarded quickly and new services assembled almost instantaneously and super-fast, reliable connectivity – without human intervention, which is far too slow – is a critical part of this.

How to be 5G-ready

TM Forum's pioneering member companies are engaged in a number of programs to help service providers and other companies prepare for the transition to 5G and make the most of it when it arrives. One example is our groundbreaking work and research on the orchestration (including automation) of services running on hybrid (combined physical and virtualized) and virtualized infrastructure. Many other efforts are focused solely on virtualized infrastructure.

Another is our suite of standardized, open (that is, available for use by everyone without charge) application program interfaces (APIs), which has been endorsed by nine of the world's largest network operators – Axiata, Bharti Airtel, BT, China Mobile, China Unicom, NTT-Group, Orange, Telefónica and Vodafone – in their quest become platform-based businesses, by making select assets available to third parties.

To give you some idea of their combined reach, scale and scope, Vodafone has operating companies in 28 countries or territories, plus with partners operates in 52 more. China Unicom and China Mobile between them have more than a billion mobile subscribers.

The nine telcos have been joined by nine major equipment vendors, which will deploy these APIs in their products and services, as mandated by the nine network operators.

A third is working to define the necessary components of an open platform architecture that can support ecosystems with the necessary agility, speed and scale. Here one of our proof-of-concept Catalyst projects is looking at automating drone flights as a platform-based service that uses 5G network slicing to ensure redundancy and quality of service, in a project championed by Vodafone.

The Operations Center of the Future work is all about the processes and business aspects of platforms, and the Forum has a long established pedigree in both. Our Business Process Framework (part of our central Frameworx suite of templates, guidebooks, best practices and much, much more) has been a huge success for network operators all over the world, and has been constantly evolved by them to meet new market needs.

Customer centricity and data analytics are also a great focus of attention in the Forum, and again a suite of proven tools is available to help.

In conclusion

Platform-based businesses are driving the need for 5G, but will 5G will also allow them to expand and innovate services in ways we haven't even thought of yet. While we cannot predict exactly what is going to happen, the trick is to ensure we are as ready as we can be to take advantage of market opportunities, partnerships and technology. Within the TM Forum's collaborative development projects, some of the companies that will be leading players in the 5G world have already made majors steps towards achieving their goal.

Yamal-300K' Eastern Campaign

by Gazprom Space Systems

Two and a half years ago the Russian operator Gazprom Space Systems replenished its orbital constellation with a new satellite Yamal-300K.

The satellite was launched from the Baikonur cosmodrome and put into the 90'E slot on the geostationary orbit. After the successful launch of Yamal-401 satellite into the same orbit slot, and moving all the customers from Yamal-300K to the new satellite, Yamal 300K started planed relocation into the other orbit slot 1835'E. this position is located over the Pacific Ocean, and enables coverage over the Russian Far East, Korea, Japan and other South East Asian territories; and as far as Alaska. These regions have good market prospects and, because of this, Gazprom Space Systems made a decision to extend its business eastwards and arranged this "Eastern Campaign".

The satellite in its new designation is interesting for the Russian as well as international customers. Gazprom Space Systems experienced it already at the stage of preliminary sales. One of the Yamal-300K beams perfectly covers the Russian Far East and attraction the attention of, for example, Russian mobile operators concerned about the creation of backhaul infrastructure for their cellular networks in the region.

The steerable beam of the satellite is ready to serve any region of the South East Asia, Australia, New Zeeland and the waterlocked states of the Pacific Ocean. However, the most attractive coverage, in our opinion, is provided by the wide shaped beam of Yamal-300K that covers the north of the Pacific Ocean with its intensive aeronautic and maritime traffic and the big transport hubs on the coast.

Recently, Gazprom Space Systems essentially renewed and extended its satellite assets. Launch of the three high power satellites results in the 3.5 time growth of the satellite capacity amount in 2015 in comparison to 2012. Nowadays satellite flit of the company is rather young (the average satellite age is less than three years).

The company markets 30% of Yamal satellites capacity outside Russia. In particular, one of the new satellites Yama-402 55'E has achieved prominence on the markets of Africa and the Middle East, and Yamal-202 49'E has already been successfully working for Asian markets for more than ten years.

In Russia, Gazprom Space Systems is not only a satellite operator but also a service provider and system integrator. The key element of the company's ground infrastructure is the Telecommunication Centre in Stchelkovo near Moscow, from where the satellite constellation is controlled, and where the main ground assets to provide services are concentrated (hub, up-links, NOC and so on). From this place the company also controls wide scale satellite communication earth stations network placed in the Russian regions.

Concerning further business development, along with the plans to create new own satellites, Gazprom Space Systems also searches for new business models. The company relies on cooperation with the other satellite operators to build and use orbital assets. Joint efforts with the other operators help to resolves increasingly frequent collisions connected with the overcrowding of the GEO.

Cooperation allows us to share the risk of financing capital-intensive satellite projects. The idea to create joint satellites, or hosted payloads, has become ever more popular. During those periods when our large investments are impeded, similar solutions provide operators with the opportunity to gain business traction.

While similar business ideas are waiting for their implementation, the business project "Yamal-300K' Eastern Campaign" has already started.

5G infrastructure for agile new services

by Kin-Yip Liu, Senior Director of Solutions Architecture and Segment Marketing, Cavium

5G promises not just significantly better throughput, latencies, and efficiency than 4G, but also ground-breaking new services like e-health, tactile Internet, lifeline communication, and massive IoT connectivity. 5G radio access technologies, e.g. millimeter wave, provide major physical (PHY) layer enhancements especially in throughput. To support the new services, the rest of the mobile infrastructure needs paradigm-shifting enhancements. This article examines technologies for next generation mobile infrastructure and how they enable agile deployment of new services. These technologies include NFV, SDN, intelligent front-haul, edge computing, and network slicing.

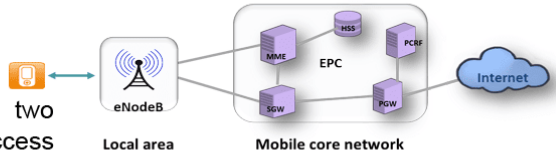
Kin-Yip heads Solutions Architecture and Segment Marketing at Cavium. He and his team analyze industry trends, system architecture, standards and requirements for NFV, SDN, mobile infrastructure, cloud, datacenter, security and storage applications, and develop solutions for customers. He has been at Cavium for 9+ years working in both technical and marketing roles. Prior to joining Cavium, he worked at Intel for 17 years, designing and architecting various processor families which targeted servers, networking, and infrastructure markets.

5G complements 4G, and enables ground-breaking services. These services impose highly diverse requirements for the mobile infrastructure. E-health and lifeline communication require very reliable connections. IoT requires massive connectivity very cost effectively. Tactile Internet and e-health require excellent latency. Fixed broadband requires significantly higher throughput. Service providers plan to create and deploy new services with excellent agility and efficiency.

Mobile infrastructure overview

Mobile infrastructure involves two primary components: radio access network (RAN) and mobile core. RAN covers the local area to a user. RAN comprises of basestations, or eNodeB in LTE terminology. Mobile core, or Evolved Packet Core (EPC) in LTE terminology, resides in the operator's core network. There are much fewer EPC nodes than eNodeBs, and EPC nodes are far away from individual users.

User equipment (UE) like phones and tablets connect to nearby eNodeBs. Every millisecond, an eNodeB schedules which connected UE's can communicate data, at what bandwidth, and the radio parameters to use in order to optimize spectrum utilization and quality. An eNodeB also relays wireless traffic between UE's and EPC. eNodeB's communicate with EPC over the backhaul which is typically secured by IPSec protocol. EPC, with access to individual users' billing and subscription plans, establishes wireless connections, enforces policies, and connects wireless user traffic to the Internet.



NFV and SDN

To improve efficiency and to enable agile services deployment, service providers are adopting NFV and SDN.

Most of today's deployed network equipment is implemented as purpose built appliances. Each appliance is a self-contained software-plus-hardware implementation designed and tested to meet its features and performance specification. Typically it has its own management and user interface. As such, operators need to maintain each appliance separately. Moreover, when an operator plans to add new features, it usually requires waiting through the development cycle of the next generation equipment which may take years. NFV (Network Function Virtualization) is architected to eliminate these inefficiencies by separating the software and hardware portions of purpose-built network appliances, and by utilizing centralized management and orchestration (MANO) for services and network functions. Moreover, by using industry standard platform software and APIs (application program interface), NFV prevents vendor lock-in.

Datacenter infrastructure provides virtualized compute, network, and storage resources which represents the hardware for NFV applications. The functionality of individual purpose-built appliances is implemented as virtualized software applications which adopt standard APIs and virtualized platform software including hypervisors, containers, and agents of virtualized infrastructure managers like OpenStack.

As a result, new services and functionality can be introduced via application updates or adopting applications from other vendors, while utilizing the same datacenter infrastructure.

SDN (software-defined networking) centralizes the control of the networking infrastructure. Operators can manage, virtualize, and re-configure the network dynamically and efficiently.

Virtualized and disaggregated mobile infrastructure

Adopting NFV, the mobile infrastructure comprises of virtual network functions (VNFs) for eNodeB, various EPC nodes, security, routing and traffic management, all running on datacenter infrastructure. In addition, new subscriber services are applications or chains of multiple network functions and/or applications. All of these virtualized software run on the same datacenter infrastructure with on-demand resource provision. When certain physical hardware becomes inoperable, network functions and applications can migrate to other working hardware. Reliability is achieved by ensuring that such migration completes timely, as opposed to over-engineering hardware to achieve extremely low failure rate. Since datacenter infrastructure is virtualized, the physical infrastructure may span multiple datacenters and geographical locations. NFV provides business continuity when nature disaster impacts certain geography or physical sites.

SDN enables disaggregating the mobile infrastructure by separating control and data processing. In addition to the improved efficiency from centralizing control, disaggregation enables dynamic scaling of control Vs. data processing resources for much better elasticity and resource utilization. For example, massive IoT and machine-to-machine (M2M) connectivity calls for more control processing to manage the large number of connections. On the other hand, IoT throughput may be low. A virtualized and disaggregated mobile infrastructure can dynamically scale up control processing resources and scale down data processing resources to optimize cost effectiveness dynamically.

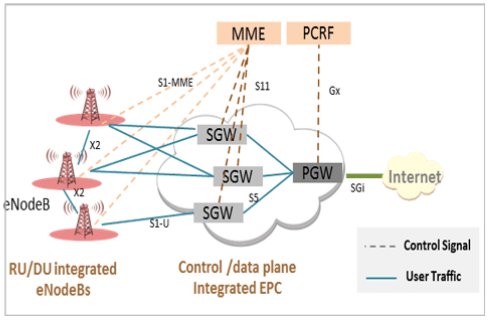


Figure 2: Traditional wireless infrastructure

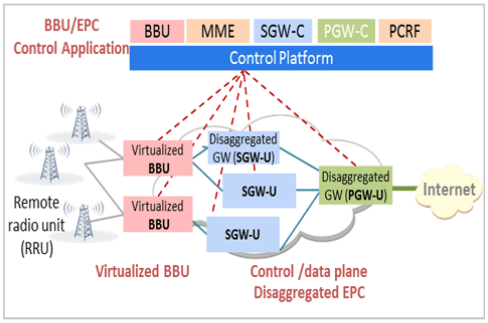


Figure 3: Virtualized and disaggregated wireless infrastructure

Intelligent front-haul

eNodeBs get virtualized by migrating most or all of the baseband processing (vBBU, virtualized baseband unit) from individual eNodeBs to centralized datacenter infrastructure. As a result, only the antennas and radios, which are remote radio units (RRU) exist at cell sites. The switch fabric connecting RRUs and centralized vBBUs is the front-haul.

This C-RAN (cloud or centralized RAN) approach boosts reliability and throughput by using CoMP (Co-ordinated Multi Point) and carrier aggregation; these are LTE-A features. Specifically, multiple eNodeB's service the same user traffic flow concurrently from different angles and individually optimized radio parameters in a coordinated manner. For example, with CoMP, multiple eNodeBs each focuses at the target UE using beamforming technique to optimize the overall wireless connectivity. Even if some of the eNodeB connections encounter interference or environment related issues, the user traffic gets communicated reliably with great throughput from the overall system perspective. With C-RAN, vBBU centrally processes baseband and radio parameter management of many RRUs. As such, CoMP can be implemented efficiently and delivers effective gains.

Nevertheless, C-RAN poses major front haul challenges in terms of bandwidth and latencies. With 5G throughput and adopting massive MIMO (multiple input multiple output), radio data for just one 100MHz sector may require >100Gbps to 200Gbps front haul bandwidth. Moreover, front haul fabric incurs extra latency. Only in dense urban areas where lots of fibers exist can the required front haul bandwidth and latency be supported.

To maximize deployment opportunities, it is possible to reduce the front haul bandwidth and latency requirements substantially by partitioning the processing between RRU and vBBU. By performing a portion of the PHY layer processing in RRU, the front haul bandwidth requirement can be reduced by >20 times. By processing the real time portion of the LTE protocol in RRU instead of vBBU, latency tolerance can be improved to even 10 milliseconds without materially impacting the quality of data communication. The trade-off is that CoMP gains tend to get reduced when more of the LTE protocol processing is done in RRUs as opposed to centralized vBBU. Industry standardization is in progress to specify several split options between RRU and vBBU in LTE protocol processing for front haul, and the software API.

Mobile and multi-access edge computing

Service providers typically own many central offices (CO's) near subscribers. The industry trend is to update CO's with datacenter infrastructure. NFV applications, e.g. vBBU, and new services can be deployed in these re-architected CO's with agility. The close proximity to subscribers greatly improves latency and user experience.

With NFV, EPC nodes don't have to reside at the operator's core network. For subscriber traffic that can be serviced locally, vEPC running at a local CO can complete the wireless infrastructure processing and chain the subscriber traffic with local services. This improves latency and customer experience substantially as compared to having to send data to the far-away core network and over the Internet. In addition, bandwidth efficiency improves significantly by eliminating unnecessary data traffic between CO and core network.

In addition to mobile wireless, datacenter equipped CO's readily support other access technologies. For example, residual and enterprise broadband and access equipment can be virtualized and deployed using the same infrastructure. Moreover, subscribers using different access technologies can all access the same services which are deployed at the network edge (e.g. in CO) or in the cloud. Multi-access edge computing enables excellent user experience and new services deployed at network edge.

Network slicing

A virtualized and disaggregated mobile infrastructure provides dynamic deployment of services and resource provisioning. To cope with the diverse requirements of 5G services, the end-to-end mobile infrastructure can be orchestrated dynamically into logical slices that are individually optimized for the various services that are active at the moment. For example, a logical slice of the network can be optimized for highly reliable connections with reserved bandwidth. Another logical slice can be optimized for massive number of connections with just best-effort bandwidth provisioning.

Conclusions

5G promises not just a next generation wireless technology, but also many ground-breaking new services. New technologies including NFV, SDN, intelligent front haul, edge computing, and network slicing fundamentally upgrade the end-to-end mobile infrastructure to fulfil the 5G promises and to deliver brand new services with unmatched user experience.

Dense networks lay the commercial foundations for 5G

by David Orloff, Chair, Small Cell Forum

5G will take radically new approaches to addressing the pressing need for mobile capacity, with architectures that make hyperdense networks affordable and deployable. Qualcomm, for instance, envisages a 1000x increase in mobile traffic by 2020, which could, in extreme cases, merit up to 1,000 very small cells per square kilometre.

David Orloff is currently the Chair of Small Cell Forum, having represented AT&T on the board since 2013. He is also AT&T's Director of RAN Product Introduction group with responsibility for delivery of RAN Infrastructure products and functionality including Macrocells, Consumer Femtocells, Outdoor and Indoor Metrocells, and Mutli-Standard Metrocells. He supports the strategic direction for new technology and novel network implementations managing the vendor relationships for product introduction into the AT&T network.

David has over 20 years if experience in the communications industry with leadership roles including Indoor RF Systems, Macrosystem RAN delivery, Small Cells delivery, and RAN optimization.

David Orloff has a BS, Electrical Engineering from the University of California, Davis and joined AT&T in 1996.

There are extremely high hopes for 5G and its impact on business and society. As wireless connectivity increasingly underpins almost every commercial and leisure activity, each generation of standards has affected more sectors of society, more deeply. With 5G, that process will intensify because the new networks will not just be about faster mobile broadband, but about millions of previously unconnected objects in the Internet of Things.

The problem with such an all-embracing vision is that 5G can mean different things to different people, especially in this phase when most of its technologies have not yet been clearly defined. This is a digital version of the Jain parable of the blind men and the elephant. Each man's view of what an elephant was depended on the piece of the animal he touched. In 5G, each industry sector similarly has a a selective view of what 5G is. To a broadcaster it is a fat pipe rushing ultra-HD movies to eager customers. To an energy supplier it is a low cost, low speed connection to thousands of smart meters. To a logistics firm it is a low latency, ultra-reliable way to fly delivery drones.

And so on. The challenge is to support all these very different network behaviors on one infrastructure, and that will require a road to 5G which can unify all the different views of the elephant in one flexible platform. Fragmentation is a real danger when so many interest groups and applications are involved, but it would risk disastrous delays and technology dead ends, severely reducing the hoped-for benefits for businesses and consumers.

In fact, while 3GPP will not publish its first standards for 5G radio until late 2017, this platform is not just about the radio. Unlike previous generations, the broader architecture is more important because the 5G network needs to address so many requirements. Many pieces of that architecture are already evolving within 4G networks, and there is gathering consensus about several key enablers of 5G.

For mobile operators, it is important that they can support those enablers now, evolving their networks step-by-step according to their business model, and putting in place a bridge to 5G which will not require a big bang upgrade in the early 2020s. Each step will need to be justified by the additional revenues and efficiencies it delivers.

Many of those justifications will come from delivering services to newly connected groups, from cities to cars to remote villages. As the network evolves from 4G to 5G, it will need to be able to support all these parties efficiently from a unified underlying fabric of standards and interfaces.

At the heart of this fabric are small cells. In their early days, small cells were just useful tactical devices to fill gaps in the mobile network. Now, they are inherent in many of the developments which are enriching current mobile networks and services, and will be essential to 5G.

Small Cell Forum, the industry body representing operators, vendors and other stakeholders in this sector, recently announced two work streams for 2016-2017, which will tie together all its technical and commercial work into a comprehensive roadmap from 4G to 5G. The work streams are:

- Deploying Hyperdense Networks
- Enabling Digitized Enterprise

These reflect the two most fundamental characteristics of 5G on which all interest groups can agree.

One, 5G will take radically new approaches to addressing the pressing need for mobile capacity, with architectures that make hyperdense networks affordable and deployable. Qualcomm, for instance, envisages a 1000x increase in mobile traffic by 2020, which could, in extreme cases, merit up to 1,000 very small cells per square kilometre.

Two, the business cases which will justify the cost of deploying 5G will not generally relate to consumer mobile broadband, but to enterprise and vertical services, including the IoT. Many industries have been deeply underserved by mobile networks to date. Of course their employees use mobile communications and some commercial processes are shifting to the smartphones, but 5G promises far more – optimized connectivity and specialized services for each vertical's specific requirements and core activities. This is where the bulk of the incremental revenues for operators, integrators and cloud providers will come from in 5G.

Small Cell Forum is taking a lead in the quest to create a unified platform to deliver these goals, because hyperdense networks and many enterprise/IoT systems will be dependent on small cells. Some of the key enablers of 5G, which are included in its roadmap, are:

- High frequency spectrum bands, which can support very high data rates over short distances.

As operators start to run short of spectrum, they need to harness underused bands in order to keep driving up capacity and quality. Frequency bands above 3 GHz have been sub-optimal for mobile communications because they only support signals over a short range, which means large numbers of base stations are required to support broad coverage. With macrocells, that creates hefty additional cost, but small cells are sufficiently cheap and deployable to be an economic option in higher bands.

US operators, in particular, have taken the lead in tapping into spectrum in 3.5 GHz (with the new CBRS service) and 5 GHz (LTE-Unlicensed), and in conducting trials in far higher bands, such as 28 GHz and even 70-80 GHz, which are candidates for 5G. All these are inherently small cell bands and will be commonly used in enterprise environments and in the high capacity HetNet. In the unlicensed frequencies, new approaches to sharing spectrum with other operators and technologies will be useful preparation for 5G, in which many bands and many access networks are expected to be integrate

- Virtualization, which allows many base stations to share a central pool of network resources (baseband processing, storage, computing), so that those resources can be allocated flexibly where they are required at any one time, with a dramatic effect on costs and on users' quality of experience.

In many cases, operators are starting to support virtualized RAN in the small cell area first, perhaps to create a cluster of cells for an enterprise building, controlled from a single point. This provides a relatively low cost, low risk first step towards a fully virtualized environment in the 5G stage.

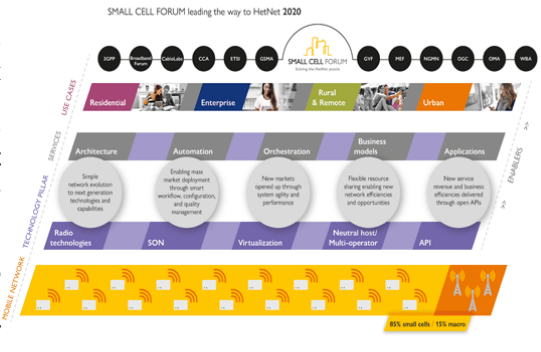
- Automation and self-optimizing networks (SON). With the large numbers of cells that will form dense 5G networks, manual configuration and tuning becomes impossible, especially as user expectations of network quality are rising. SON is a crucial enabler of 5G and the Forum has been

All these 5G enablers can be deployed now, at least in a first-stage way, and provided there are open interfaces, they can lay the foundations for future developments. One of these, of course, will be the 5G radio(s), which may, for many operators, be the final change once they have put a dense, virtualized, automated network in place.

That will then support further changes in the platform, which will enable yet more business cases and service providers. For instance, the concept of 'network slicing' will be important to enable 5G to address the needs of so many diverse user groups. This allows an enterprise or provider to request a virtual 'slice' of the network, for as long as it is required, optimized for the organization's particular needs in terms of performance, security and cost.

Small Cell Forum believes flexibility within a unified framework is the right way to allow each organization to proceed to 5G at the pace that suits their business. Our vision is that the future network must be characterized as a 'multi-x' environment – multi-technology, multi-domain, multi-spectrum, multi-operator and multi-vendor - and flexible enough to accommodate changing user needs, business goals and subscriber behaviors without the need to rip and replace.

This vision of a dense HetNet will be equally applicable in evolved 4G and in 5G, even while the technologies in the various layers of the network will develop and change to achieve even greater efficiencies and capacity, and to support new use cases and service providers in future.



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Spectrum sharing is bringing 5G to market

by Kurt Schaubach, CTO, Federated Wireless

The success of the U.S. “experiment” will accelerate the global convergence to deploying the first 5G systems in shared spectrum at 3.4-4.2 GHz. There was significant activity around the world within the last year.

Kurt Schaubach brings 25 years of wireless industry experience to Federated Wireless where he plays a key role in developing technologies and new business strategies to create the next-generation architecture of broadband wireless.

Previously, Kurt served in various engineering roles at the National Rural Telecommunications Cooperative (NRTC), NextWave Wireless, LCC International, and Southwestern Bell. He has also served as a technology consultant to wireless network operators, equipment manufacturers, and semiconductor suppliers.
Kurt was a founding member of a publicly traded wireless broadband and multimedia software company and led the acquisition and integration of two wireless infrastructure companies.

Kurt has been active in spectrum development, management, and policy matters throughout his career. He currently serves on the Commerce Spectrum Management Advisory Committee (CSMAC) and has spoken at the International Symposium on Advanced Radio Technologies (ISART) events, among many others.

Kurt received his B.S. and M.S. in Electrical Engineering from Virginia Tech.

In the U.S., less than one-quarter of spectrum is available for commercial mobile service with most spectrum allocated to radar, satellite and fixed link usage. Given the time and expense required to clear legacy systems, the best and most efficient path to 5G will be to use shared spectrum. In April 2014, the FCC issued a Report and Order to make the 3.5 GHz band available for commercial use. This band, deemed by the FCC the Citizens Broadband Radio Service (CBRS) band, was required to have a shared model to protect incumbents from interference free operations while making the band available to commercial users in a tiered access model. This sharing is done via a Spectrum Access System (SAS) and enables mobile broadband to operate in band with a variety of incumbent federal radar, fixed satellite and fixed links. Leveraging the SAS to share spectrum around the world could effectively triple mobile broadband spectrum.

Spectrum sharing decreases time to deployment

By supporting the continued operation and evolution of incumbent systems, spectrum sharing avoids many of the political and capital issues that hamper band-clearing actions, enables mobile broadband systems to quickly access additional spectrum and significantly increases the amount of spectrum available. For instance, it took approximately seven years from NTIA identification for initial LTE deployments at 3.5 GHz with spectrum sharing for radar and other systems. But two decades will pass before access to the 1.3 GHz band will be possible, as the existing radars must first relocate to another band. Spectrum sharing has a role even when a band has been designated for clearing by creating a transition period during which both incumbents and new entrants may access the spectrum. Such an approach was adopted in AWS-3, which most federal systems will vacate over the next decade, but a sharing regime allows LTE systems to access the band now.

The Spectrum Access System simplifies and accelerates spectrum sharing

Spectrum sharing becomes complicated when multiple incumbents share spectrum with multiple entrants as:

1. Each incumbent has unique protection requirements
2. Efficient incumbent protections may require coordination across multiple new entrants
3. Different incumbents will have different abilities to support the coordination and information sharing needed for spectrum sharing
4. New entrants may require process or technology changes to support the sharing agreements
5. Incumbents and new entrants will want to continue to evolve their systems. Consider that within the same band, each country has different incumbents and

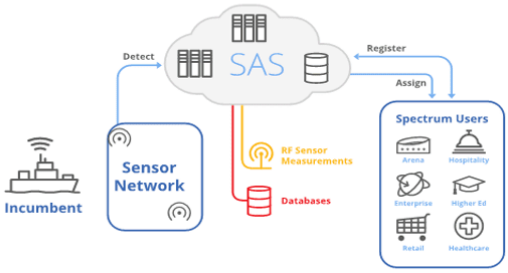
and deployment rules so the preceding issues are multiplied when looking to deploy 5G globally.

The Spectrum Access System (SAS) solves these problems.

The SAS concept was first proposed in the 2012 President's Council of Advisors on Science and Technology Report to the President on Realizing the Full Potential of Government Held Spectrum to Spur Economic Growth. The report referred to the SAS as an "information and control clearinghouse for band-by-band spectrum registrations and conditions of use and allow non-Federal users to access underutilized spectrum in Federal bands." Through actions taken by the FCC, the Wireless Innovation Forum and the CBRS Alliance to permit and standardize spectrum sharing at 3.5 GHz, the SAS has become a general purpose spectrum sharing service. The SAS will enable millions of 4G and future 5G systems access to broadband spectrum – up to 150 MHz – while a multidue of Fixed Satellite Service (FSS) sites, legacy fixed wireless systems, and military radar installations on land and at sea continue to operate as before. Plus the SAS enables mobile broadband-style deployment at 3.5 GHz, including access similar to licensed and coordinated unlicensed access.

SAS-enabled spectrum sharing at 3.6 GHz

The SAS leverages real-time sensing and database information to enforce varied and hierarchical spectrum sharing regulations, rules and practices to determine spectrum availability and assign spectrum to individual radios (called CBSDs at 3.5 GHz) or networks of radios in real-time. Illustrating the variety of incumbent protections, the SAS protects some users with exclusion zones, some based on their sensed presence from dedicated sensors via dedicated RF sensors called the Environmental Sensing Capability (ESC), some based on aggregate interference to specific locations, and others based on aggregate interference to service areas (e.g., Priority Access Licensees). Accurate information is critical to spectrum sharing and the SAS. The SAS leverages a diverse set of sources, including online databases, dedicated sensors (ESC), measurements reported from managed devices and messages from protected users reporting interference. Protocols are defined for coordinating operations with other spectrum controllers (SAS-SAS), for exchanging grants and information with individual devices (SAS-CBSD) or with a proxy for a collection of devices to provide partial obfuscation (SAS-CBSD proxy), and for adjusting timers when closer coordination is required to accommodate variable incumbent activity.



What SAS-enabled spectrum sharing means for equipment manufacturers and service providers

With a cloud based implementation providing spectrum-as-a-service, the SAS enables any wireless network running any wireless technology to operate anywhere spectrum sharing is allowed. The devices won't be encumbered with any of the regulatory or policy complexity as long as the network is capable of performing the following tasks:

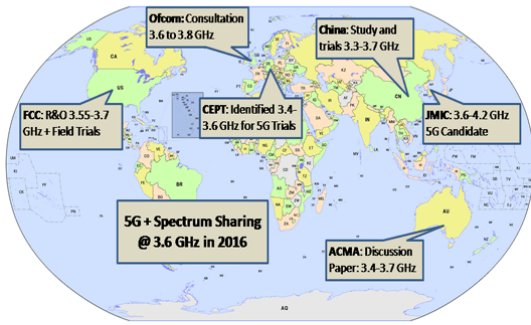
- Report the location and installation information for cells so the SAS can perform interference estimate calculations. The locations of lower power mobile devices (e.g., UEs) are modeled statistically.
- Formulate and transmit a time-limited request for spectrum to the SAS. The SAS authorizes a set of allowable values and the network reports back, which are actually used to free back up spectrum resources for other networks.
- Correctly tune to the reported current spectrum use
- Regularly report observations of spectrum use to the SAS. This can be as simple as RSSI measurements or as sophisticated as signal classification results.
- Otherwise satisfy general transmission requirements that may not be configurable, e.g., out-of-band emissions or ACLRs that might be part of a transmission mask

The standard for communicating with the SAS (SAS-CBSD) was published by the Wireless Innovation Forum in December 2016 as document WINNF-16-S-0016, with numerous field trials based on the draft standard conducted throughout 2016. While this standard was developed to capitalize on the 3.5 GHz opportunity in the U.S., its extensibility will enable rapid deployment around the world and in other spectrum sharing bands as they become available.

Spectrum sharing in 3.4-4.2 GHz will enable the first worldwide 5G band

The success of the U.S. "experiment" will accelerate the global convergence to deploying the first 5G systems in shared spectrum at 3.4-4.2 GHz. There was significant activity around the world within the last year.

- Japan and China are conducting early 5G trials in at 3600-4200 MHz and 3400-3600 MHz, respectively.
- In Europe, the Radio Spectrum Policy Group and the European Conference of Postal and Telecommunications Administrations identified the band 3400-3600 for initial 5G deployments.
- Australia (ACMA) published a Discussion Paper as a step towards Mobile Broadband Spectrum Sharing from 3400-3700 MHz.
- The United Kingdom (Ofcom) issued a Consultation considering the 3600-3800 MHz band for mobile broadband with sharing with FSS and fixed services.



Seizing on the opportunity offered by spectrum sharing, in the ongoing Spectrum Frontiers proceeding, the FCC proposed spectrum sharing in virtually every band considered - 24, 28, 32, 37, 39, 47, 50, 70 and 80 GHz. Similar bands for mobile broadband sharing have been proposed for consideration by the ITU at WRC 19 with the intent of global harmonization of 5G spectrum sharing bands.

Federated Wireless is at the forefront of SAS-enabled mobile broadband spectrum sharing

Successful spectrum sharing requires buy-ins from a diverse set of communities, including incumbents, OEMs, carriers and regulators so that the interests of all parties are addressed. Federated Wireless is currently leading and actively contributing to several groups to advance spectrum sharing, including the following:

- Wireless Innovation Forum, which is a technology neutral group creating standards for shared spectrum access, particularly focused at 3550-3700 MHz
- CBRS Alliance, which focuses on promoting and certifying LTE use in the 3550-3700 MHz band
- 3GPP, which recently designated 3550-3700 MHz as Band 48 and is pursuing complementary device technologies in LTE-U and Licensed Assisted Access (LAA)

I invite readers interested in modernizing and increasing spectrum availability for 5G to participate in these organizations.

Moving to 5G: Spectrum as a shared resource: Light-licensing models for 3.5 GHz band open new ways to deploy and operate wireless networks

by Monica Paolini, Senza Fili

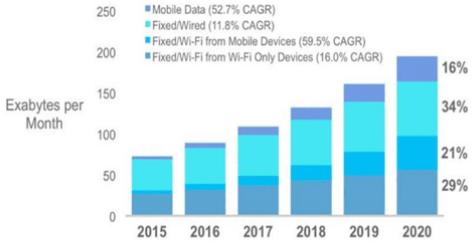
The gradual transition to 5G is the introduction of new frameworks for spectrum allocation and use – regulatory work for the 3.5 GHz and millimeter wave (mmW) bands has started already and will continue in parallel but separate from 3GPP standardization. At the same time, the use of high-frequency bands in new regulatory regimens is going to be a defining element of 5G, and it will bring a massive increase in RAN capacity, with a combination of more efficient air interface and more extensive spectrum reuse.

Monica Paolini, PhD, is the founder and president of Senza Fili. She is an expert in wireless technologies and has helped clients worldwide to understand new technologies and customer requirements, create and assess financial TCO and ROI models, evaluate business plan opportunities, market their services and products, and estimate the market size and revenue opportunity of new and established wireless technologies. She frequently gives presentations at conferences, and writes reports, blog entries and articles on wireless technologies and services, covering end-to-end mobile networks, the operator, enterprise and IoT markets. She has a PhD in cognitive science from the University of California, San Diego (US), an MBA from the University of Oxford (UK), and a BA/MA in philosophy from the University of Bologna (Italy).

Despite the impressive number of slide decks explaining what 5G is, we still do not know for sure what it will encompass when the standardization work will be completed. What is becoming increasingly clear, however, is that 5G will be larger than previous Gs – it has a wider scope that can change the way we deploy, operate and profit from mobile networks. It will be a toolbox from which mobile operators and other service providers will choose different elements to deploy, at different times. It is unlikely that operators will turn on 5G on a specific date, but it will be a incremental process that is starting already.

An example of the gradual transition to 5G is the introduction of new frameworks for spectrum allocation and use – regulatory work for the 3.5 GHz and millimeter wave (mmW) bands has started already and will continue in parallel but separate from 3GPP standardization. At the same time, the use of high-frequency bands in new regulatory regimens is going to be a defining element of 5G, and it will bring a massive increase in RAN capacity, with a combination of more efficient air interface and more extensive spectrum reuse.

Today, spectrum allocations for public access are mostly for license-based cellular bands and for unlicensed technologies like Wi-Fi today, and LAA in the future. Cellular bands excel at providing coverage across the operators' footprints, but Wi-Fi carries much more traffic (50% of the worldwide fixed and mobile IP traffic by 2020, compared to the 16% of cellular.

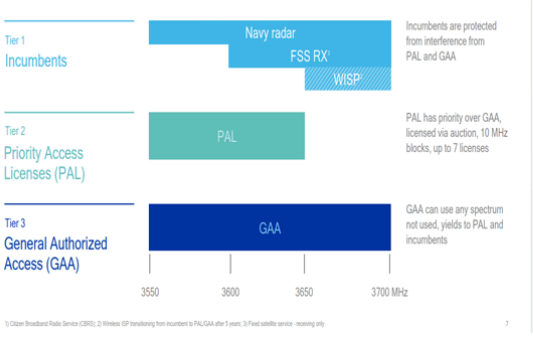


This is astonishing if we consider that this traffic is all carried through the 2.4 GHz and 5 GHz bands in unlicensed environments where interference is difficult to control. A more intensive spectrum reuse coupled with low-cost and easy-to-manage equipment have been the foundation for Wi-Fi adoption and a stunning (and largely unpredicted) success in regulation.

Regulatory work at the FCC in the US for the 3.5 GHz Citizen Broadband Radio Service (CBRS) band and in the 2.3 GHz band in other countries goes even further to combine the flexibility of Wi-Fi deployment and use, with some protection for those – service providers, venue owners, neutral hosts – who invest in the infrastructure and operate it. The expected outcome is an increase in spectrum re-use compared to cellular bands, which translates in higher wireless capacity.

In the US, the FCC (FCC Rules Part 96)

established CBRS in the 3550-3700 MHz frequency band with a three-tiered use model.



- Grandfathered Wireless Broadband Access for incumbent licensees (e.g., military, satellite, WISPs), who can use the band with protection from interference from other users (3650-3700 MHz).
- Priority Access Licenses (PAL) for licensees who acquire right to use 10 MHz channels for three years through an auction (3550-3650 MHz).
- General Authorized Access (GAA) is available to any entity, provided that the use of the band is registered with and approved the Spectrum Access System (SAS), on a shared basis – i.e., there is no protection from interference (3550-3700 MHz, except for channels used by Grandfathered Wireless Broadband Access and PAL licensees).

The attractiveness of PAL is limited by the three-year limitation. Operators have a longer time horizon for deployments and may feel that their investment is not sufficiently protected.

Most interest is for the GAA model that can trigger new deployment, operation, and ownership models, because it is crucially different from both the licensed and unlicensed regimens.

Unlike licensed models, GAA spectrum use is open to any entity that has physical access to a location. The entity does not need a license or to be a service provider. Physical access is also required for licensed-band deployments (e.g., operators need to have access to a cell tower), but in that case real-estate owners cannot use the spectrum, benefit from coverage, and can extract rent from the cellular infrastructure, so they typically facilitate licensed deployments. With GAA, real-estate owners compete with mobile operators and other service providers in using the CBRS spectrum. Like with Wi-Fi, allowing a mobile operator to deploy its own infrastructure may result in interference and real-estate owners may decide to block or limit deployments from mobile operators. This is a common occurrence with Wi-Fi.

Unlike unlicensed models, GAA does not allow occasional use of the CBRS band. For instance, users cannot use their mobile devices or routers to act as mobile or temporary access points. As a result, within a stadium, the owner is protected against interference from unknown sources, unlike Wi-Fi, that everybody can use wherever they go, both to receive and transmit.

These differences from established spectrum use regulatory frameworks creates the potential for stronger role – in terms of control and investment – for real-estate owners. But does this means that mobile operators and other service providers will stay out of CBRS – as they initially did with Wi-Fi? I do not believe this will happen, because service providers fulfill an essential role that real-estate owners are not equipped to take on – provide reliable and consistent service across locations and integrated across wireless interfaces. But the relationship between real-estate owners and service operators is bound to change – and this can happen in ways that will benefit both, and will improve the subscriber experience. And this change is already underway, as operators rely more on Wi-Fi offload using venue-based and residential Wi-Fi infrastructure, and plan to use LTE in unlicensed bands, and residential users and venue owners take a larger role in providing access.

Then, what should be expect the 3.5 GHz band in the US and the 2.3 GHz band in other markets to be used for? These bands are well suited for small-cell densification deployments, both in indoor and outdoor environments, as they allow network operators to move beyond interference-prone co-channel deployments in which macro and small cell layers share the same spectrum channel, and use the 3.5 GHz/2.3 GHz spectrum exclusively for small cells.

This approach not only eliminates the need to manage co-channel interference, but it encourages neutral host deployments, in which a third party deploys and operates a network that is shared by multiple service providers. The neutral host may be a third party, as it frequently is in DAS deployments, a venue owner, or a mobile operator, which provides access to multiple service providers. Venue-owners generally like this model as it allows them to meet their visitors' expectation that they will have access to any service provider. Mobile operators have learned from DAS deployments that neutral host models can work, but they need to become comfortable that they do not have direct control over the RF access. Neutral hosts can provide sufficient transparency and performance KPIs to ensure that service providers get the RAN access they are paying for.

Venue owners are more and more willing to pay for the infrastructure, too. The advantage is that they can choose how to deploy the infrastructure, provide access to multiple operators, monitor performance, and have a say in which services operators support. In turn, this lifts the capex burden from operators, which continue to struggle on how to deploy outdoor or indoor small cells in mid-size venues.

Shared-access regulatory frameworks in the 3.5 GHz and 2.3 GHz bands do not only provide more spectrum, but they have the potential to push the Wi-Fi/cellular integration model further, change ecosystem roles, and establish new models for sharing cost and ownership of the wireless infrastructure.

The role of satellite: Telecom dinosaur or key enabler for the leap to 5G ?

by David Howgill, Founder & President, Huckworthy

The satellite industry is promising vastly expanded bandwidth, affordability comparable to high availability ground networks, global coverage, seamless integration for both 4G today and 5G/IOT in the future, and even the possibility of spectrum sharing – to a wireless industry desperately in need of affordable global capacity. The potential behind these developments, added to the fact the industry has now proven itself as an effective technology and delivery partner in the 4G LTE arena through it's new high capacity global payloads, make the satellite industry less the perceived dinosaur that it has appeared to be for some years and more the shining light of a wider telecommunications industry desperately in need of rapidly scalable, affordable and robust global capabilities. I therefore suspect that satellite is back to being the sector to watch, and will be a cornerstone of effective IOT by enabling hybrid 5G networks.

David Howgill, Founder and President of Huckworthy in Washington DC, has spent over 23 years managing applied technologies in the international telecommunications, AV and security industries.
Huckworthy is a certified HUBZone Small Business and DOD Mentor Protégé Program participant under The Boeing Company, bringing disruptive technologies and methodologies to market in the satellite, wireless, AV and energy sectors. Huckworthy's partners include some of the largest governments and civilian companies in the world - along with some of the smallest startups.

David also serves as Global VSAT Forum's Chief of Wireless Initiatives, and Chairman of the British American Business Association's Small Business Group.

The satellite and wireless industries have long lived separate, occasionally confrontational, but ultimately complementary lives. Satellite has provided the wireless industry with immediate bandwidth in the hard to reach nooks and crannies of a globalized world, while wireless has brought much needed new bandwidth demand to a satellite industry facing increased competition and waning broadcast reliance.

The wireless industry is in the thick of rolling out global 4G LTE networks and the industry, and media, are roiling at the prospect of the further dramatic increases in bandwidth and network infrastructure requirements that will come with 5G. These two events could not happen at a better time for the satellite industry.

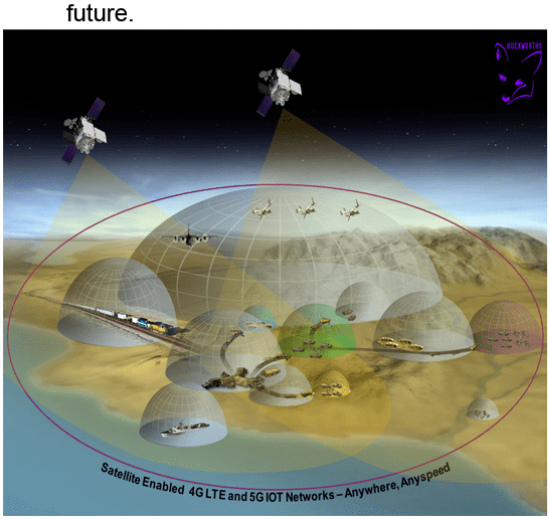
Advances in satellite, hub/modem, eNodeBs and EPC technologies already allow 4G LTE carrier and private networks to be easily and affordably deployed over satellite links with high speeds and low latencies maintained through a mixture of acceleration and seamless engineering. Satellite companies including Viasat, Gilat, Hughes, Comtech, SES, Intelsat and Huckworthy have all successfully deployed advanced networks to enable cellular to reach the furthest parts of the globe while maintaining the speeds expected in an advanced network, and containing the operating costs to ensure carrier and client viability.

With this new growing cadre of 4G LTE satellite enabled mobile networks successfully deployed by the wireless carriers and government agencies globally, attention is now turning to how –

and whether – satellite can cope with, or perhaps enhance, the jump to 5G in the coming years; a jump that is due to exponentially increase the demand for bandwidth and stretch spectrum to its current known limits.

Luckily the wireless industry and satellite industry are, by coincidence more than design, on the same page for this switch up. The satellite industry plans to deploy literally thousands of new low latency and high capacity satellites in the next few years. By complementing existing capabilities with new low earth orbit constellations, the industry will be able to deliver more speed, power and affordability than ever before; while deploying smaller terminals than ever – making the next generation of satellite networks simple to deploy and able to seamlessly handle the scaling for IOT devices under 5G far more effectively than any fixed ground architecture will be able to. In the lead up to this, the Global VSAT Forum (GVF) continues to provide constant leadership and updates to the satellite industry through the Connectivity, Cellular Backhaul and High Throughput Satellite series of Roundtables, while also providing the insight of where these technologies can best be applied, from carrier networks to global transportation and energy networks, or military and government deployments.

Continued perceived differences between the satellite and wireless industries now often derive from the fact that the satellite industry's traditional reserved and active spectrum has been identified as a potentially potent force for and 5G and IOT on the ground, with multiple wireless bodies seeking to take over or share the spectrum. The latest technology advances and resulting filings* (*notably by Boeing in filing for a new potential 2000+ Satellite LEO Satellite Constellation earlier in 2016) have now put the satellite industry back in the driving seat for these issues, showing a willingness to explore spectrum sharing in the future – allowing a future with not just satellite enabled and enhanced IOT, but an ecosystem in which satellite is potentially seamless in both its ability to deliver and its affordability. That is the birth, and inevitability, of a true wireless industry of the future.



So, in a nutshell, the satellite industry is promising vastly expanded bandwidth, affordability comparable to high availability ground networks, global coverage, seamless integration for both 4G today and 5G/IOT in the future, and even the possibility of spectrum sharing – to a wireless industry desperately in need of affordable global capacity. The potential behind these developments, added to the fact the industry has now proven itself as an effective technology and delivery partner in the 4G LTE arena through it's new high capacity global payloads, make the satellite industry less the perceived dinosaur that it has appeared to be for some years and more the shining light of a wider telecommunications industry desperately in need of rapidly scalable, affordable and robust global capabilities. I therefore suspect that satellite is back to being the sector to watch, and will be a cornerstone of effective IOT by enabling hybrid 5G networks.

These technological advances in the satellite side, and increasing need for ubiquitous bandwidth on the ground, may have gone unheralded in the public eye, but have certainly not gone totally unnoticed in the wireless industry. There is strong renewed interest in the sector and a new wave of investment beginning that will finally tie these two essential sectors together; so despite much coverage of Google and Facebook reportedly pulling back from satellite investment (Google invested $900M in SpaceX), 2016 saw Softbank joining Qualcomm and Virgin Group with a $1 billion plus commitment to the next generation high throughput OneWeb constellation – a clear sign that the largest wireless companies are expecting satellite to be key to their own future expansion. The remaining questions are "How long before others follow suit and jump on the satellite bandwagon?" and "How many satellites does it take to assuage a never ending thirst for bandwidth?" - the answers to which are going to make for a very exciting 2017 and beyond.

As a small business owner dedicated to delivering hybrid communications and sensor networks globally I have long enjoyed the benefits of being "satellite savvy" in a larger wireless world, adapting networks to the nuances of Satcom. With these developments, I now find myself far more consumed by the growth and technology opportunities that present to both industry and end-user alike as these two behemoths of the telecom industry slowly come together to provide a seamless future for the global wireless world – and the realization that these opportunities are now. I look forward to working closely with my wireless colleagues from all corners of the telecoms sector to make 5G the economic driver that it can be, to embrace a closer cooperation between satellite and terrestrial wireless, and I encourage my global colleagues from the satellite and wireless industries to do the same – because why struggle separately when we can thrive together?

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