5G Is Rapidly Approaching, What Must Cable MSOs Do To Capitalize On This Business Opportunity

A Technical Paper prepared for SCTE•ISBE by

Jon Baldry
Metro Marketing Director
Infinera
125 Finsbury Pavement, London, EC2A 1NQ
+44 7766 146 440
jon.baldry@infinera.com

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Introduction

Over the last year there has been a dramatic shift within the wireless industry in terms of 5G preparation. As the 5G standards have solidified, many wireless operators have shifted their transport network mindset from "4G transport that can evolve to 5G" to "5G-Ready now". This has had a major impact on how wholesalers, and particularly cable MSOs who plan to sell transport services to wireless operators, need to address the market opportunity.

The most significant advance in wireless transport standardization over this period has been the additional clarity around the eCPRI standard and the performance demands this puts on the transport network. In 5G the underlying transport infrastructure moves from a collection of dumb pipes, albeit high performance pipes, to a highly dynamic network supporting:

- Even higher demands on performance – Low latency, synchronization and higher capacity demands are a given with 5G.
- Multiple transport functions integrated into a single network – The network must support legacy 4G infrastructure in parallel to new 5G Fronthaul I (low-split), Fronthaul II (high-split) and backhaul in a X-haul/any-haul environment.
- Network slicing and support for virtualization of mobile infrastructure – dynamic movement of 5G resources around the network to support Multi-access Edge Computing (MEC) and fog networking requires dynamic transport that is SDN controlled and cloud-optimized. Network slicing at all layers will also play a critical role in supporting this environment.

To address these challenges, MSOs need networks that are flexible and open, and offer high performance now. Some wireless operators are already testing wholesale networks for key 5G performance metrics, such as eCPRI synchronization requirements, to prepare themselves for 5G.

This paper will describe the challenges associated with 5G and show how MSOs must evolve their transport services to adapt and grasp the exciting opportunity that 5G presents to the industry. This paper will address the issues, challenges and opportunities associated with the fiber-based footprint and services. Cable MSOs may well also be able to utilize DOCSIS-based services over the coax plant to augment the capabilities outlined in this paper to extend services further into access networks.

Content

1. 2018, The Year That 5G Arrives

2018 is undoubtably the start of the eventual 5G onslaught with initial 5G services hitting the street in numerous countries. With the rush to be local leaders in 5G there is considerable variety around the services currently labeled as 5G. Most, but not all, conform to the latest 5G New Radio (NR) standard which is the new air interface for 5G. This means that any 5G NR compliant device should be able to connect to the network and deliver mobility services. This is of course very early days for 5G and initial 5G services over the next couple of years will focus on high speed broadband services, essentially higher speed offerings of the 4G services we enjoy today.

But 2018 also sees the next stage of standardization in 5G. The initial non-standalone (NSA) 5G standard was completed in late 2017 and focused on utilizing the existing 4G/long term evolution (LTE) radio access network (RAN) and core to deliver enhanced mobile broadband (eMBB) services. 2018 will see the completion of the next stage of 5G standardization, the standalone (SA) variant, which utilizes the new 5G RAN and core network, as shown in Figure 1.

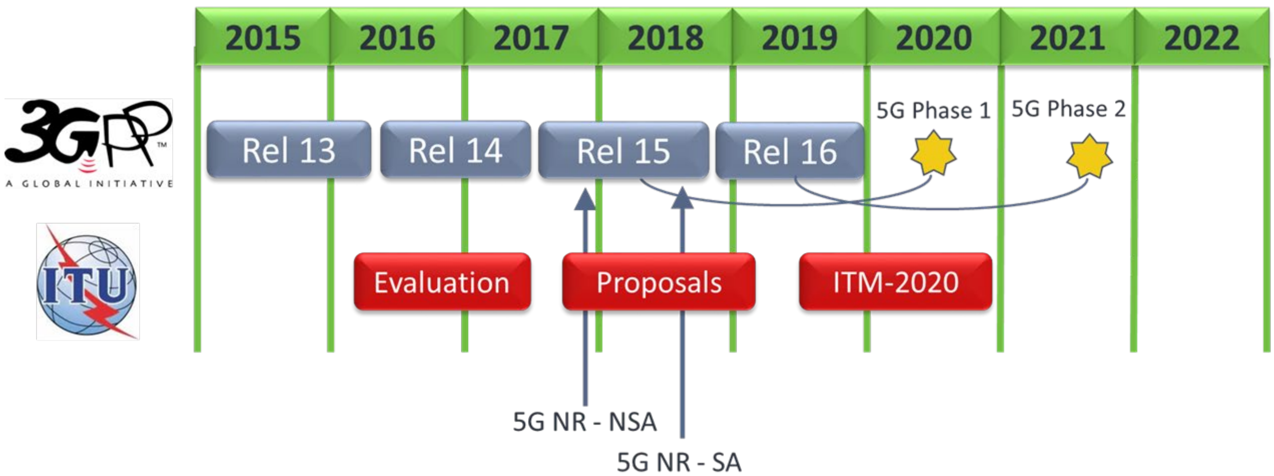


Figure 1 - 5G Standardization timeline[2]

Ultimately 5G offers the potential for a wide range of services beyond eMBB and these will fully utilize the capabilities of the new 5G network, both RAN and core. Key to these new capabilities will be significant advances in the mobile transport network connecting the RAN to the core. It will however take many years for the full portfolio of envisaged 5G services to fully rollout, but transport networks need to be 5G-ready now to avoid unnecessary and traffic impacting upgrades in the future. This will enable support for all the envisaged services when mobile operators are ready and any new killer apps that we haven't yet considered that can utilize the high performance that 5G has to offer.

2. The Cable MSO 5G Opportunity

Given an ideal world, many mobile operators would like to build their networks with their own fiber or dark fiber from other operators. This would give them total control of their network, but it has many challenges. The cost of building a dedicated fiber network would most likely be overly onerous even if the high cost of new 5G licenses wasn't also taken into consideration. Digging new fiber isn't an option when alternative fiber from wholesale operators exists and is only an option to push fiber deeper into access networks to support new cell sites. Some dark fiber providers will provide dark fiber to mobile operators in some geographies but in others with differing market dynamics, wholesale operators will offer wholesale services rather than dark fiber.

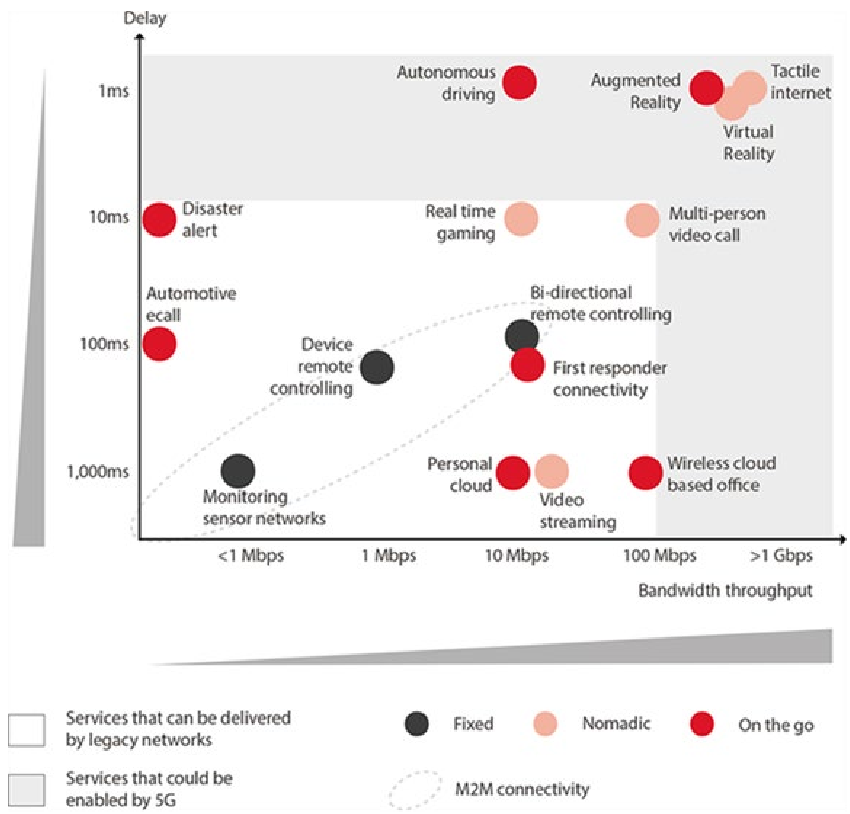
The 5G standards foresee a world where network resources are shared and once the initial rush to grab local headlines with early 5G services in over, network operators will look to use their capital carefully to build unique capabilities when it gives differentiation and to use lower cost shared resources when it doesn't.

5G creates an opportunity for cable MSOs to utilize their fiber and hybrid fiber coax (HFC) resources to extend any current wholesale mobile services. This is due to the increased pressure on mobile operators to fiber up an ever-growing number of cell sites with high performance transport. The economics of each mobile operator building their own dark fiber-based networks simply don't stack up. As mobile operators look towards wholesale operators, cable MSOs have a unique advantage in their service area due to their extensive fiber footprint that is often in the same places as the mobile operators 5G plans, residential and business areas. This local access fiber footprint asset will be expanded hugely over the next few years as distributed access architecture (DAA) rolls out pushing fiber deeper from the secondary hub to remote PHY devices. This converts access fibers from analogue optics to digital wavelength division multiplexing (WDM)-based optics, creating the opportunity for a multi-service converged interconnect network (CIN) supporting DAA, mobile and other services.

Key to this 5G wholesale opportunity for cable MSOs is the high performance that transport networks will require in the future. Offering differentiated high-performance services built on a multi-service platform will enable MSOs to provide high quality services with the better economics for both the mobile operator and the cable MSO.

3. 5G Services driving 5G Transport Network Revolution

To understand the requirements on the transport network we first need to consider the range of services that 5G will potentially bring and the requirements these put on the underlying transport network. The plans for 5G services cover a broad range of services from the Internet of Things (IoT), connected and self-driving cars, augmented and virtual reality plus those new killer applications that we haven't envisaged yet. These services require a radical change to the mobile transport network to support the new 5G radio access network (RAN) technology and supporting mobile core functions, enabling them to reach the bandwidth and delay/latency requirements shown in figure 2.



Source: GSMA

Figure 2 - 5G Services with Bandwidth and Delay/Latency Specifications

Existing LTE/4G networks already require high-performance transport to support advanced functionality such as coordinated multi-point (CoMP) and enhanced intercell interference coordination (eICIC). These features will also be used in 5G and require performance characteristics such as high network resilience and low latency to ensure operation. In some geographic regions, high-quality synchronization performance to allow the transport network to deliver frequency, phase and time-of-day synchronization to the cell site. In regions where 4G/LTE synchronization is delivered via other means such as GPS, it is envisaged that 5G cell sites will drive the requirement for alternative means of synchronization as small cells move into locations that aren't suitable to GPS, e.g. inside shopping malls, subway stations and deep within buildings.

From a transport network architecture perspective, 5G brings a radical rearchitecting of the network to support the higher bandwidth, lower latency and tighter synchronization between cell towers required for the envisaged new services. Capacity increases by at least a factor of 10, and the complete network latency is lowered by a factor of 10, from 10 to 1 millisecond. This will be achieved via a two-pronged focus on latency within the transport network and a migration of some of the compute and storage resources previously located in the core of the network out into the network closer to the end user via multi-access edge computing (MEC).

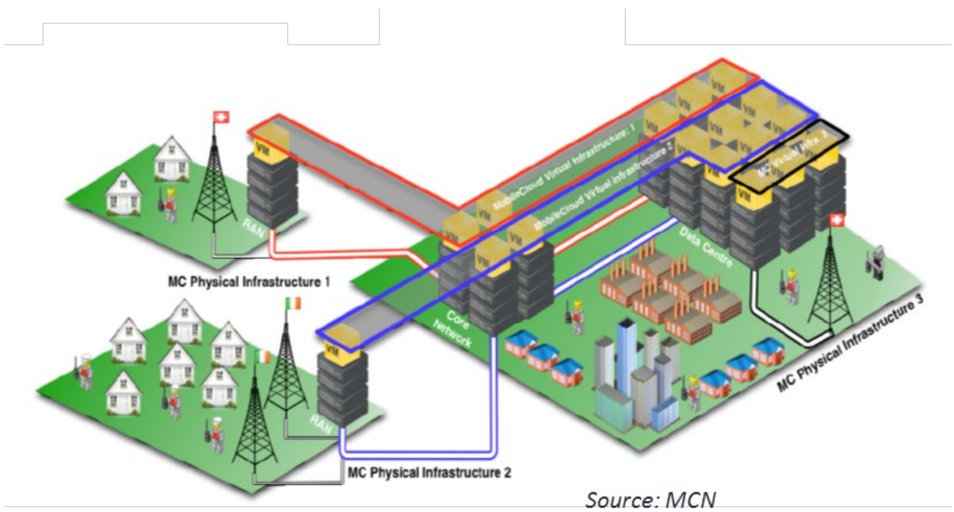


Figure 3 - Data Center Distribution to Support MEC

These MEC capabilities will also be virtualized software packages rather than the previous bespoke hardware platforms, which means the 5G network will become a collection of large core data centers and smaller edge/mini datacenters, as shown in figure 3. These data centers are able to move virtualized capabilities around the network and dial up or down the associated processing power. In order to support this fluid bandwidth and services environment, mobile transport networks will need to migrate from today's collection of effectively dumb pipes, albeit high-performance dumb pipes, to a dynamic network with tightly integrated control mechanisms to the wider 5G network.

One particular challenge for transport networks is that there isn't a single set of performance criteria and capabilities that are optimum for 5G. Figure 4 shows the International Telecommunication Union's radiocommunication sector (ITU-R) view of 5G services and clusters them around three core service types – eMBB, massive machine type communications and ultra-reliable and low latency communications. Each of these 3 focus areas requires differing transport optimization and therefore any

5G transport network will need to blend the technical requirements and economics of bandwidth transport to support these as best as possible.

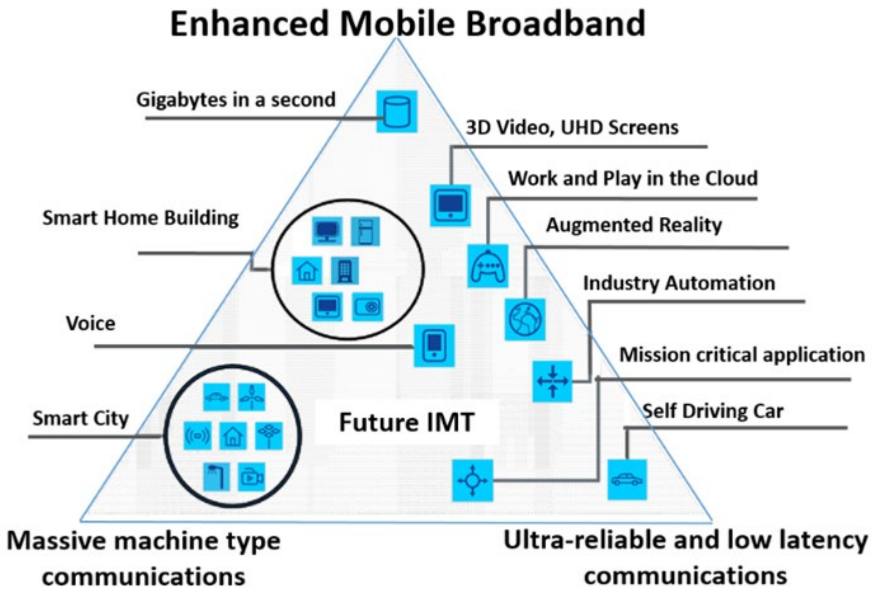


Figure 4 - 5G Services by Focus Area, source ITU-R

4. Introducing X-Haul

Today 4G/LTE networks use a fronthaul and backhaul architecture to support communication between the remote radio head (RRH), the baseband unit (BBU) and the core network. In many cases the RRH and BBU are collocated so only backhaul is required. In other cases networks have started the migration to the cloud-RAN (CRAN) architecture[3]. Here BBUs are clustered together a maximum of 20 kilometers from the RRH to better support capabilities such as CoMP and eICIC. Essentially from a transport perspective these are two separate networks with the fronthaul network using common public radio interface (CPRI) for RRH to BBU traffic and backhaul using Ethernet for BBU to core. They can however run over a common packet optical physical network to share fiber resources with a packet optical platform that supports both networking types on a wavelength by wavelength basis.

In 5G, this will be required to migrate to a new X-haul architecture, with Ethernet-based backhaul necessary to support the required higher performance for 5G, and fronthaul migrating from CPRI to an Ethernet-like enhanced CPRI (eCPRI) network. This new architecture builds a common network for both traffic types and eCPRI itself comes in high-split and low-split options to give fronthaul-like or backhaul-like performance to match the requirements RRH to distributed unit (DU) or DU to centralized unit (CU) traffic, as shown below.

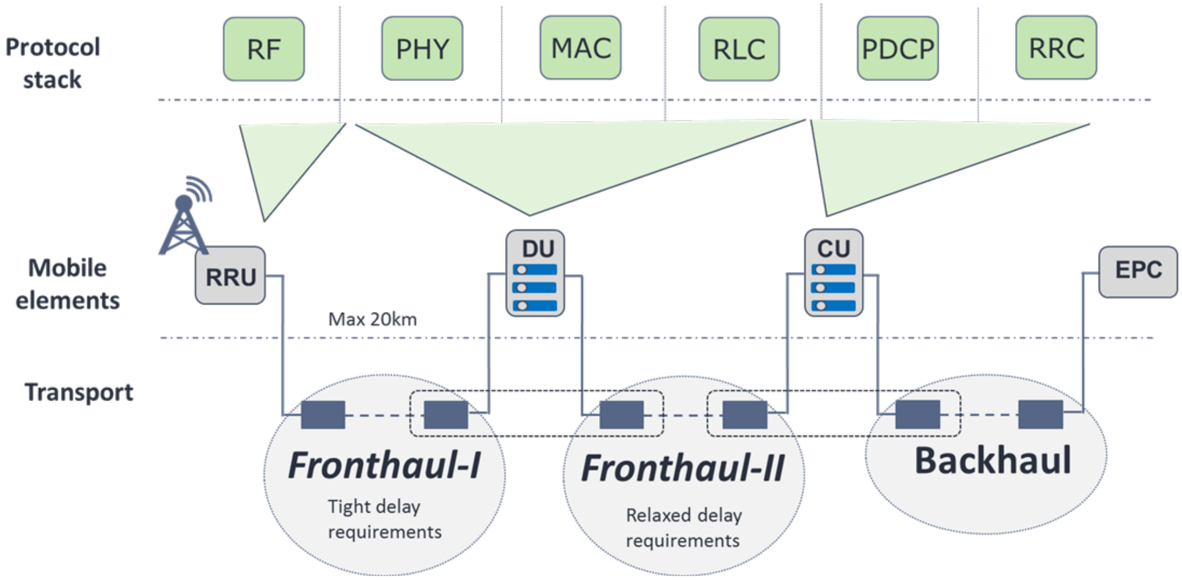


Figure 5 - Fronthaul and Backhaul Evolution For 5G

To support this range of traffic options over a common network, packet-optical-based mobile transport networks will be required to support Ethernet and eCPRI traffic over a combined any-haul/cross-haul/X-haul network, ensuring that each traffic type is supported with the specific performance requirement.

4.1. X-Haul Performance and Architecture

Transport performance is important in many packet-optical networks where Ethernet or IP functionality is required but the service still requires layer 1 like characteristics. Mobile and particularly 5G is a good example of one of these scenarios. These transport performance characteristics include low latency, low jitter (ideally zero) to give layer 1 like constant latency through any particular route through the network and for those networks where high-performance synchronization is delivered to the cell site via the transport network, then high quality synchronization is also required through the network. This includes frequency, phase and time-of-day synchronization.

As an example, LTE-A/4G features such as CoMP and eICIC already require tight synchronization performance of +/- 1.5 microseconds for phase synchronization, so 3 microseconds total budget. The recently completed eCPRI specification[1] reduces this to 65 or 130 nanoseconds for the highest 5G performance services such as beamforming multiple input multiple output (MIMO), roughly a 30-fold improvement in synchronization performance for the network as shown in figure 6. This high level of synchronization performance is only really needed once operators are ready to implement the most demanding 5G RAN features, to support the most demanding 5G services such as the ultra-reliable and low latency communications shown earlier in figure 4, and this is currently viewed to be a few years away yet.

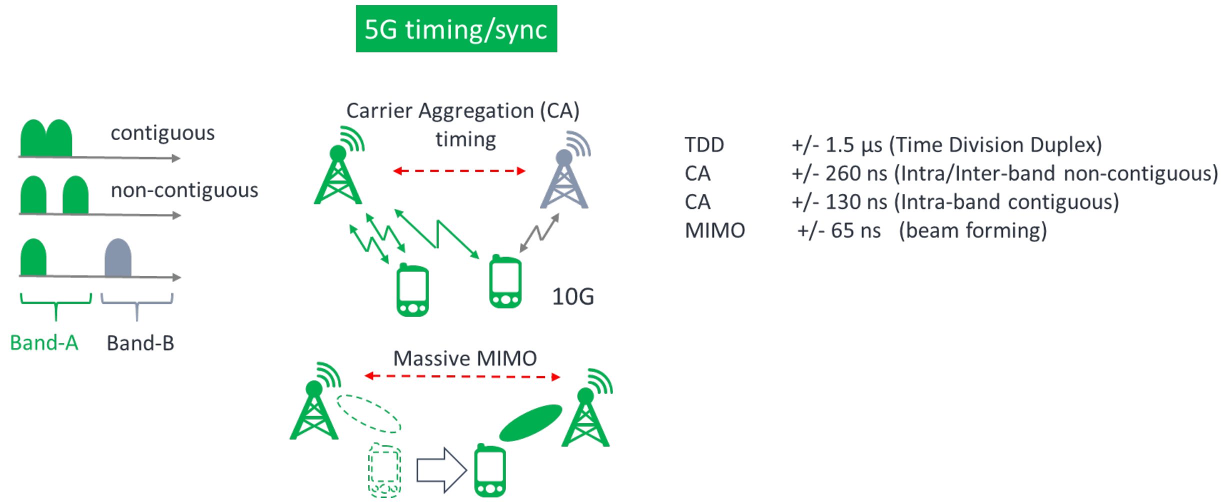


Figure 6 - Demanding Timing and Synchronization Requirements For 5G

But synchronization performance is not something that can be added later via software upgrades as it relies on key design decisions embedded deep in the hardware and software architecture of the platform. 5G-ready mobile transport networks need to be ready for everything 5G RAN will throw at them, without the need for a future network upgrade to fix substandard synchronization performance. So, for cable MSOs to prepare true 5G-ready mobile transport networks, they need to strongly consider the need this high level of performance now. This level of network synchronization is tough to achieve but it is possible in today's 5G-ready networks.

Having 5G-ready levels of synchronization and low-latency performance now can offer cable MSOs competitive advantages today for wholesale mobile services. It has been shown that high quality sync can also help improve existing 4G services. Results from the field have shown that network performance can improve at the handset level with up to 80% better download speeds, 40% better upload speeds and a 40% reduction in latency when backhaul is migrated to packet-optical with high quality sync performance.

One further consideration for any wholesale operator is the ability to support multiple sync domains on a single transport network. Assuming sync as a service is applicable to the end customers then any wholesaler needs to build a network that can support multiple sync domains over the same common infrastructure to enable the economic advantages of a shared network. If the platform used can't support multiple sync domains in parallel, then each new mobile end customer will drive parallel packet-optical platforms per end mobile operator customer with very little economic gain.

4.2. 4G/5G Coexistence

In previous mobile generational upgrades, the move from one generation to the next was a completely new network from edge to core. However, for the migration from 4G to 5G, 4G doesn't go away in the same way that previous generational changes did, in fact 4G infrastructure plays a critical role in 5G. Much of the 4G standardization over recent years was done to enable 4G to support 5G. 4G networks already adequately support today's levels of video streaming, internet browsing, etc., which means new 5G infrastructure should focus on supporting new high-performance services. This is one of the key drivers for CoMP where a 5G device will communicate with multiple cells in parallel to support multiple services or to overcome issues introduced by the new millimeter wave technology needed for 5G. This is one of the primary drivers for high performance synchronization between cell sites.

5G will also use millimeter wave technology to provide the required higher RAN bandwidth, but this comes at the cost of reach and vulnerability to blocking or reflections from objects such as buildings, trees and metallic objects such as cars or production line machinery in in-building networks. Consequently, 5G cells will be smaller, meaning we'll need a lot more of them and it will take a very long time for 5G to reach the same coverage as 4G, if it ever does. If 4G cells are measured in kilometers, then 5G cells will be measured in hundreds of meters, as shown in Figure 7.

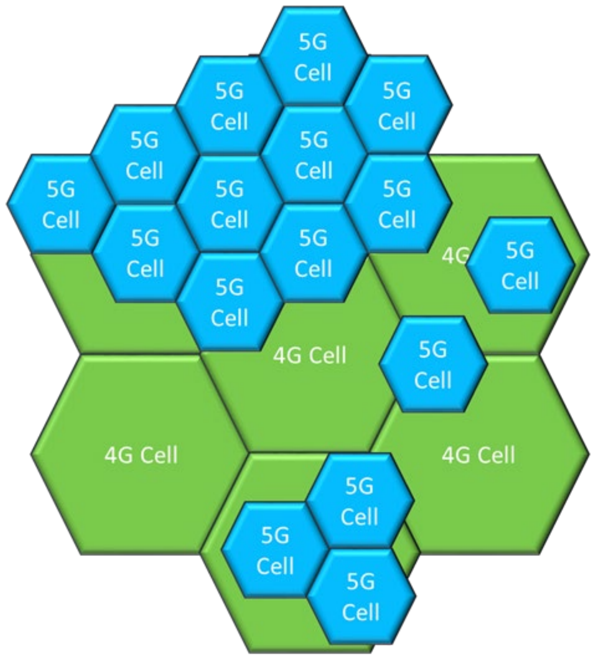


Figure 7 - 4G and 5G Cell Coverage

The result of this co-existence is that any MSO wholesale services for 5G need to consider the hybrid 4G/5G scenario and potentially continue to offer 4G fronthaul and backhaul services in addition to 5G X-haul, ideally over the same packet-optical platform.

4.3. Multi-Service Edge Computing

We discussed the introduction of MEC earlier in this paper as a means to help mobile operators reduce network latency for services that require latency performance that is better than current 4G services. To achieve this goal, compute and storage resources are moved from the core datacenters to locations closer to the edge of the network and the end user. These will then run virtualized functions needed for 5G and provide local content or data caching. Essentially the cloud moves closer to the user and is spread around the network, hence this is sometimes referred to as fog networking. From a transport network perspective this drives several requirements:

- SDN control and orchestration – As transport networks will need to dynamically dial up and down bandwidth to match the requirements of the network, open SDN-based application programming interface (API)s will be required. These will allow bandwidth within the network to respond to the overall requirements of the 5G network.
- Highly flexible networking – bandwidth adjustments throughout the network from the cell site to the core need to utilize technology that allows for dynamic use of bandwidth on demand.

- Network slicing – This is a concept introduced in 5G where resources can be sliced to carve out a segment of the network to specifically serve a function, application or customer. Slicing will be done at both the transport and control planes enabling a shared resource, the network, to support either multiple mobile operators, multiple industry segments with specific performance parameters or perhaps multiple applications within a carrier or segment.

MEC and network slicing will be driving forces for SDN control and orchestration of the transport network bringing open APIs to the control plane and the ability to slice both the data plane and the control plane. Mobile operators will need to encompass wholesale services within their plans, requiring cable MSOs offering wholesale services to tightly align with their control and orchestrion platforms.

Conclusion

2018 is the ideal time for cable MSOs to reassess their approach to wholesale mobile services. Over the last 12 months 5G standards have matured considerably giving much more clarity on the exact requirements of the mobile operator. In addition, cable MSOs are currently planning their own fiber deep DAA networks that will push fiber and WDM-based packet optical technology deeper into the access creating the opportunity for a multi-service CIN to also support mobile wholesale services.

Cable MSOs who sell connectivity services to mobile operators must consider transport equipment that enables them to roll out 4G fronthaul and backhaul today but that also has the flexibility to migrate to the hybrid X-haul network of the future, supporting 5G X-haul concurrently with remaining 4G fronthaul and backhaul. This requires highly scalable and high-performance transport with low latency, zero jitter and high-quality synchronization to enable the cable MSO to differentiate their services in what will be a very competitive access market.

Lastly 5G will drive considerable changes into the overall transport network architecture with SDN control and orchestration, MEC and fog networking coming to the fore.

Mobile operators have a huge task ahead of them as they race to win in 5G and cable MSOs who can simplify their transport requirements leaving them to focus on the new 5G services that the public is eagerly anticipating have a lot to gain.

Abbreviations

API	Application programming interface
BBU	Baseband unit
CIN	Converged interconnect network
CoMP	Coordinated multi-point
CRAN	Cloud or Centralized RAN
CU	Centralized unit
DAA	Distributed Access Architecture
DU	Distributed unit
eICIC	Enhanced intercell interference coordination
eMBB	Enhanced mobile broadband
HFC	Hybrid fiber coax
ITM	International mobile telecommunication
ITU-R	International Telecommunications Union, Radiocommunications Sector

LTE	Long term evolution
LTE-A	Long term evolution - advanced
MEC	Multi-access edge computing
MIMO	Multiple input multiple output
NR	New radio
NSA	Non-standalone
RAN	Radio access network
RRH	Remote radio head
SA	Standalone
WDM	Wavelength division multiplexing

Bibliography & References

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2 - *IMT for 2020 and beyond;* ITU-R

3 - *C-RAN - The Road Towards Green RAN;* China Mobile Research Institute