Cell Backhaul – Building The 5G-Ready Network of The Future, Today

A Technical Paper prepared for SCTE/ISBE by

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

Table of Contents

Title **Page Number**

List of Figures

Title **Page Number**

Introduction

5G promises huge advances in wireless technology, with its greater bandwidth and lower latency that enable a wide array of new services and applications. Radical changes will be required throughout the network, from handset design to the architecture deep into the core of the network. 5G will bring significant challenges to the transport network as well, and also adds a degree of uncertainty as the 5G standards are still under development.

Nonetheless, mobile operators and MSO-based wholesalers who provide them with mobile transport services want to be able to evolve seamlessly from today's 4G-based fronthaul and backhaul environment to a future 5G environment while addressing evolving transport network requirements, including:

- Even higher demands on performance – Low latency, synchronization and higher capacity demands are a given with 5G.
- Ethernet evolution – 5G fronthaul will migrate to Ethernet, creating a hybrid fronthaul/backhaul environment sometimes called midhaul or crosshaul (X-haul). But Ethernet needs to adapt to support this new environment.
- Seamless coexistence of 4G and 5G - Whereas the transitions from 2G-3G and then 3G-4G were totally separate networks, 4G doesn't go away with 5G. 4G infrastructure remains a key element in the new network, which must coexist with the new 5G infrastructure.
- Virtualization of key network resources - The move to a software-defined network (SDN)-controlled and cloud-structured environment will help facilitate support for mobile edge computing (MEC), fog networking and virtualization of key network resources.

To address these challenges, network operators need networks that are flexible and open, and offer high performance. This paper will describe the challenges associated with the migration to 5G and show how MSOs must evolve their transport services to adapt and grasp the exciting opportunity that 5G presents to the industry.

Content

1. Evolution from 4G to 5G

5G promises huge advances in bandwidth and network performance that will enable an array of new mobile services and applications. The terms "4G" and "5G" are quire broad and cover a range of releases within the plan of the 3rd Generation Partnership Project (3GPP), which is the global wireless standards group that unites the standards development activities of the primary seven standards organizations within the wireless world. As a generalization, the term 4G covers 3GPP release 8 which covered Long Term Evolution (LTE) through LTE-Advanced (LTE-A) in releases 10 and 11 to release 14 which will be standardized in 2017 and prepares the ground for 5G networks. The term 5G covers release 15 onwards which is designed to support the new 5G requirements. 5G standardization activities started in the 3GPP in 2017 and it is anticipated that Phase 1 of the 5G spec will be standardized in R15 in the 2^{nd} half of 2018 and Phase 2 will be concluded in R16 in late 2019-2020.

One key aspect of 5G networks is the of co-existence with 4G infrastructure. This differs from previous network transitions where 3G replaced 2G networks and 4G replaced 3G within a cell site once the network was upgraded. We therefore need to understand current 4G trends to understand how transport networks will be required to support 5G networks in the future.

1.1. Current advances in 4G

4G networks brought significant advances over 3G networks and have continued to evolve since the introduction of the Release 8 standard in 2008 and the first commercial LTE services 12 months later by Telia Sonera in Stockholm and Oslo. The standard has evolved from R8 through to R14 with many advances including the extension from macro cells so a variety of small cell options and the inclusion of additional advanced functionality such as enhanced intercell interference coordination (eICIC) and coordinated multipoint (CoMP). These capabilities have enabled LTE/LTE-A networks to extend to heterogeneous networks (HetNets) containing overlapping cells of various sizes simultaneously working together to support each end user devices in a coordinated manner.

The ability to support better simultaneous interaction between multiple cell sites will be critical in future 5G networks as 5G cells will be smaller than current 4G cells, so more cells will be needed to provide coverage and this will create a mix of coverage from new 5G cells and “legacy” 4G cells. To put the relative sizes in perspective, if 4G cells are measured in kilometers then corresponding 5G cells will be measured in hundreds of meters.

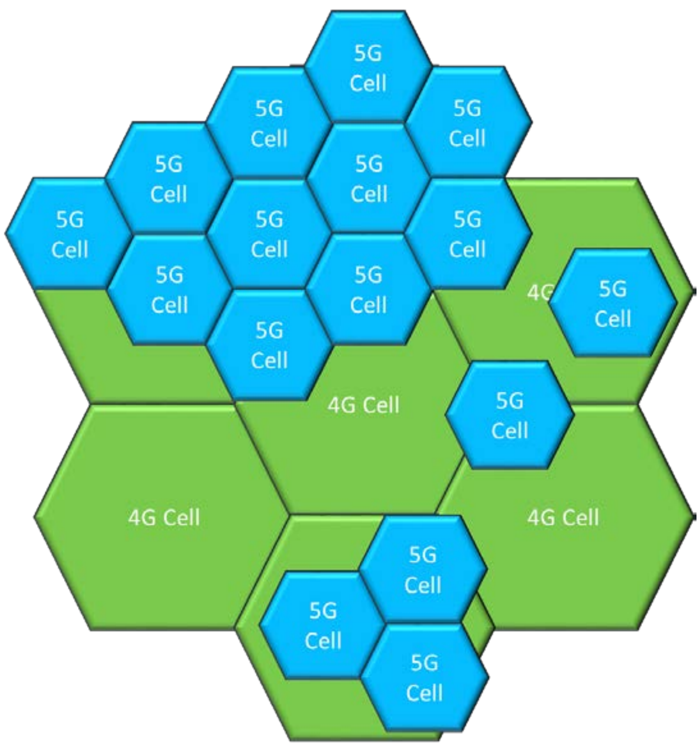

Figure 1 - 4G and 5G Cell Coexistence. Source: Infinera

1.2. Migrating to Cloud-RAN Architectures

A significant trend within wireless networks in recent years has been the adoption of centralized-RAN and cloud-RAN architectures, both commonly abbreviated to C-RAN. These architectures take advantage of the migration of the interface between the remote radio head (RHH), which connects to the antennae, and the baseband unit (BBU), which creates the radio frequency (RF) signal that each antennae/RRH transmits, from coaxial cables to fiber optics. This was initially done to reduce power consumption and cost but also then created the opportunity to move the BBU out of the cell site to a centralized "BBU hotel" where several BBUs could be co-located. The connectivity between the BBU and RRH then requires a new mobile fronthaul network which uses a protocol called common public radio interface (CPRI) to carry a digitized version of the analogue RF signal between the BBU and RRH. Some deployments use a very similar protocol called open base station architecture initiative (OBSAI).

In the C-RAN architecture the BBU still requires a backhaul link to provide connectivity to the evolved packet core (EPC) network, known as the S1 interface, and BBU to BBU connectivity over what is known as the X2 interface.

The migration of the BBU to a BBU hotel creates the initial step in this architectural shift with a centralized-RAN where the BBUs are centralized in a single location. This reduces power and space requirements in the cell site and makes BBU to BBU communications via the X2 interface easier, thereby assisting in advanced functionality such as CoMP or eICIC.

The next step in the architectural shift is to consolidate these collocated BBUs into a single larger BBU that can work across a collection of RRHs and cell sites to create a true cloud-RAN. This may be a larger BBU with the processing power to consolidate several BBUs or more likely a virtualized BBU (vBBU) in a network functions virtualization (NFV) environment, which effectively turns the BBU hotel into a mini data center.

Adoption of C-RAN varies around the globe, which Asia taking the early lead. There are two primary reasons for network operators:

1. Network economics and environmental reasons. The first C-RAN deployments that required mobile fronthaul networks were largely driven by economic reasons. This is well documented in the China Mobile Research Institute's white paper "C-RAN - The Road Towards Green RAN". In these cases, there was a clear economic business case centered around reducing power and space requirements in the cell site as BBUs were moved to the BBU hotel. This had the additional benefit of overall power consumption reduction which led to a reduction in the carbon dioxide footprint of the network.
2. Preparation for LTE-A and 5G. While the business case outlined above works in some regions of the world, due to differing economic and commercial factors it hasn't really been viable in some regions such as North American and Europe. These regions are therefore behind Asia in terms of C-RAN and fronthaul deployments but many operators in all these regions are now looking at C-RAN and fronthaul as a mechanism to support some of the advanced functionality introduced in LTE-A and 5G that need better real-time coordination between cell sites.

1.3. New advances in 5G

Future 5G networks have the promise of considerable improvements in network performance with a drop of latency from 10 milliseconds to 1 millisecond and an increase in throughput to support services in the order of 1 gigabit per second. To support these performance advances significant changes will be required in the overall architecture of the network. The first change to consider is the "cloudification" of the mobile network. 5G will require sophisticated coordination between cell sites and will therefore require a C-RAN like architecture where the BBU hotel is essentially a mini data center. One of the principals of the 5G network is to allow the network to offload functions from simpler wireless devices that can then preserve battery life or enable more complex operations on simpler, lower-cost hardware.

However, 5G networks will take the cloud model one step further with mobile edge computing (MEC) where a shared compute resource as placed at the edge of the mobile network, most likely in the same location as the vBBU. There is a very similar but subtly different architecture called fog networking where the cloud of compute and storage resources are distributed between a range of data centers from the vBBU location at the edge of the network, centralized core data centers and other mini data centers in other intermediate locations. MEC and fog will enable the network to provide a better user experience and also can optimize the network resources to match the performance requirements of the application with low latency applications using resources closer to the user and more latency tolerant applications using lower cost centralized resources elsewhere in the network.

The 5G architecture also utilizes network sliceablity to create dedicated pools of network resources to create separate domains over the same physical infrastructure. Sliceablity will enable applications to sit above a sliced control plane and sliced forwarding plane as if they were discrete networks with differing performance metrics. Operators can therefore carve out a slice of the network dedicated to a function, such as supporting autonomous vehicles, knowing it has the necessary resources, or for a network to be logically shared between multiple operators.

To support the trends outlined above 5G will be built using software-defined networking (SDN) control and NFV will play a major role in the optimization of the network. 5G networks will leverage the structural separation of HW and SW, as well as the programmability offered by SDN and NFV.

2. Protocol changes required for 5G mobile transport

In order to support the performance improvements and architectural changes required for 5G, the mobile transport network will undergo significant changes. Firstly, fronthaul and backhaul will merge into a single midhaul or crosshaul (X-haul) network that will be able to support fronthaul-like and backhaul-like transport over a common network. This will require adaptions to the current Ethernet standards to support this new environment, such as the ability to understand and respond to the latency sensitivity of traffic. Standard Ethernet switches traffic and makes decisions over which packets to forward or store based on the priority information so work is currently underway to add the ability to consider latency sensitivity to this decision making to ensure that applications needing lower latency can be prioritized correctly. This is known as time-sensitive Ethernet.

In parallel to this standardization work, the 3GPP has proposed a model covering the possible blending of fronthaul and backhaul capabilities with eight options for functional split between the processing in the distributed unit (DU) that will replace the RRH and the central unit (CU) that will replace the BBU in a fronthaul scenario supporting the vBBU and other NFV functions. At one extreme, there is a fronthaul-like split, which is essentially the transmission of a digitized version of the analog RF signal. This results in minimal processing in the DU at the cell site, but will have latency limits similar to CPRI based fronthaul today and requires significantly more bandwidth than other options. At the other extreme, there is Ethernet-like transmission and there are also many possible options between the two extremes. 3GPP is discussing how to take this model forward.

In addition to the changes in the protocol that mobile transport networks will be required to support, the changes to 5G performance will also have a knock-on effect to synchronization and latency requirements.

While the exact details are yet to be determined, it is clear that these performance parameters of the transport network will become even more critical than they are today.

3. Requirements for 5G-Ready mobile transport

As you can see, we are currently in pre-5G period of uncertainty. We understand the big picture of how 5G networks will be architected but we don't know the exact details yet and we won't for some time. This creates a challenge for wireless operators and wholesalers such as cable MSOs who sell connectivity services to wireless operators. These operators need to be able to continue to deploy backhaul services today and many are evaluating adding fronthaul services to support advanced LTE-A capabilities and to prepare the ground for 5G. But everyone wants to avoid the situation where fronthaul and backhaul deployments are quickly obsoleted as 5G is standardized.

Network operators therefore need flexible equipment for mobile fronthaul and backhaul that has the ability to support CPRI or Ethernet today and can be updated in the future via a software upgrade to support 4G cell sites that will be upgraded to support a mixed 4G and 5G environment.

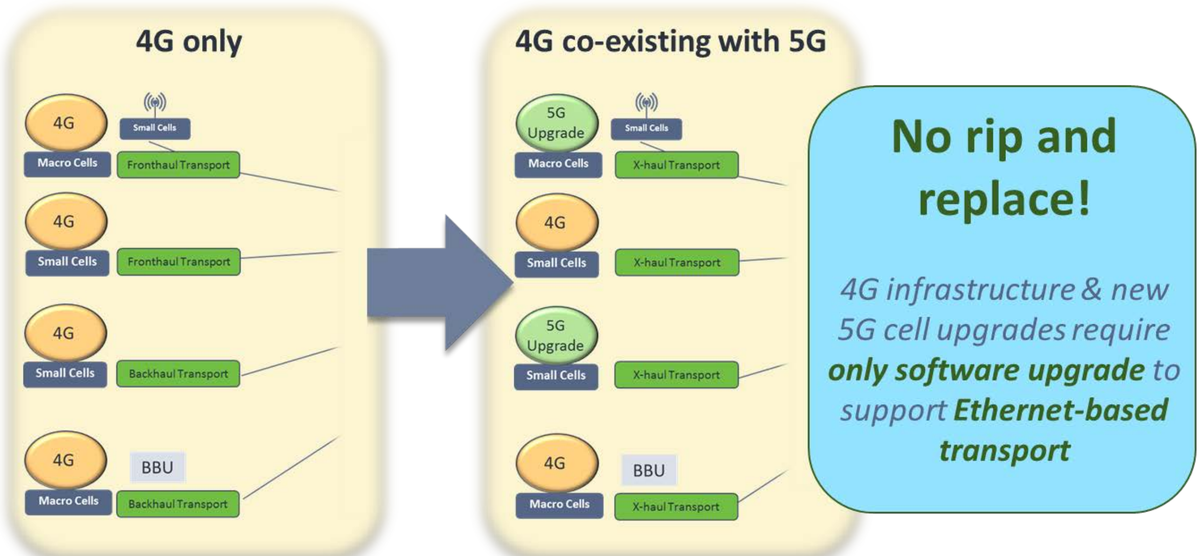

Figure 2 - Upgrade scenario that avoid"rip and replace". Source: Infinera

These systems are FPGA-based and allow for very flexible support of network protocols such as CPRI, OBSAI and Ethernet. By using FPGAs it is possible in the future to add new protocol framing to support the new variant of Ethernet that will be required for 5G via an in-service field upgrade. This means the operator can reuse the fronthaul hardware in a 5G network and avoid the need to rip and replace hardware.

5G will require new mobile transport hardware in all new 5G sites and any site performing layer 2 aggregation and switching but many current 4G cell sites can support fronthaul and backhaul services today and provide a smooth migration to 5G without the need to replace cell site mobile transport hardware.

Conclusion

The migration to 5G will require improvements to the overall network infrastructure in terms of performance, features and bandwidth. These improvements will drive new fiber builds, and fiber upgrades to an ever-growing number of cell sites, creating significant opportunity for cable MSOs and other wholesale operators to capture significant share of cell backhaul and fronthaul services for 4G and 5G mobile networks. For example, cable MSOs could create significant competitive advantage addressing current and potential cell fronthaul and backhaul services as they look to rearchitect their networks to support remote PHY, which is very well suited, from both performance and bandwidth perspectives, for these requirements.

A key consideration for the MSO community is how they can take advantage of the migration to 5G with managed services instead of simply providing dark fiber to wireless operators. While wireless operators will possibly take the initial view that their own network built using dark fiber from numerous sources, such as cable MSOs, is the best way forward, the MSO community should challenge this with a value proposition built around better network economics and performance. Wireless operators should focus their resources on differentiating their networks and services against their competition rather than all building "me-too" transport networks in parallel. The architects of the 5G standards already anticipate that network sharing will be key to 5G and are building support for this into the standards and architectures with capabilities such as network slicing.

MSOs should take advantage of the physical resources of fiber, HFC and real-estate and their field force to take away the pain of scaling networks from 4G to 5G with the massive proliferation of cell sites in geographies where all wireless operators will require transport. In these areas transport is a cost the wireless operators will all need to bear but not will gain competitive advantage by building their own.

Better economics can potentially be achieved by managed services from MSOs based on sharing a common MSO-based network between multiple wireless operators or taking advantage of other network transition projects such as packet-optical based remote-PHY transport to support wireless over a common infrastructure. In both these cases network slicing can potentially provide the wireless operator with the SDN-based control they desire without the need for them to build their own dark fiber based network. A further consideration is can the MSO also combine their network assets with their field force assets to enable the wireless operator to avoid the need to drastically increase their own field force to deal with the explosion of cell sites that 5G will require.

MSOs who can build a business case for business services instead of dark fiber should carefully consider future 5G requirements for both fronthaul and backhaul services to ensure future 5G migration can be accommodated as much as possible within current hardware to provide investment protection and to minimize network reengineering. Careful consideration should also be given to network performance in areas such as low latency and synchronization performance as means of differentiating the MSOs managed service performance against their own competitors.

Abbreviations

BBU	baseband unit
CoMP	coordinated multipoint
CPRI	common public radio interface
C-RAN	centralized or cloud radio access network
CU	central unit
DU	distributed unit
eICIC	enhanced intercell interference coordination
EPC	evolved packet core
FPGA	field-programable gate array
HetNet	heterogeneous network
LTE	long term evolution
LTE-A	long term evolution – advanced
MEC	mobile edge computing
NFV	network functions virtualization
RAN	radio access network
RRH	remote radio head
SDN	software defined networking
vBBU	virtual baseband unit

Bibliography & References

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

