The Evolution to 5G

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5G wireless technology is coming rapidly, but mobile network operators (MNOs) have billions invested in 4G networks, and those networks will, in many cases, form the basis of 5G networks. So how do 4G networks evolve to support 5G? We know that 5G will deliver about ten times the throughput of 4G, and that it will likely use higher frequencies, but how do we get from 4G to 5G? In this article, we'll look at the fundamental changes that will occur during the transition from 4G to 5G.

Network Densification

If 5G is really going to deliver speeds that are ten times or more faster than 4G, simple physics dictates that the best way to drive higher network capacity within a given spectrum footprint is to have more base stations within a given area. MNOs began densifying their networks with 3G and 4G technologies by increasing sectorization and adding distributed antenna systems (DAS) and small cells. The ongoing densification effort involves macro sites, indoor areas, metro cells and small cells, and it's crucial that the MNOs be able to acquire new sites for this infrastructure.

Site Acquisition

Site acquisition has long been a problem for operators, and it is an issue that will persist as operators look for even more space on which to build and implement their 5G networks. There has been a lot of debate about how providers can get better access to sites. It is imperative that all internal and external mobile network stakeholders work together in order to construct an effective blueprint that makes rolling out 5G network sites a more streamlined process. Efforts to streamline zoning and standardize leasing costs are welcome reforms that will help speed deployments.

Spectrum

Operators will also densify their networks by adding more bandwidth and spectrum. One approach to deploying 5G will be repurposing low-band spectrum (such as 850Mhz) as a coverage layer for 5G. 5G will also be deployed in the 600 MHz band in the US, which has superior propagation characteristics and building penetration. To support higher throughputs, the operators will utilize mid-band and high-band spectrum.

The 2.6 and 3.5 GHz bands are emerging as global 5G bands, which will be used for both indoor and outdoor, fixed and mobile applications. 3.5 GHz is currently available in all regions and has decent propagation characteristics with a good amount of bandwidth. It likely will be a global roaming band for 5G.

Higher bands in millimeter waves above 6 GHz will also be used, but as these higher frequencies don't reach very far, they will largely be deployed on small cells and other local antennas that are close to users. Given the limited availability of clear, unused spectrum in the traditional cellular bands (400Mhz to 2.5GHz), new spectrum bands need to be brought into the mix and lightly used spectrum must also be considered.

One of the greatest barriers to the rollout and adoption of 4G services was the ability of governments to quickly free up spectrum. When it comes to 5G, this barrier cannot exist if the concept of a ubiquitous 5G network is to become reality. Regardless of regulators' ability to allocate new spectrum, spectrum will always be a finite and costly resource for mobile network operators. Therefore, technologies such as massive MIMO antenna architectures (which derive more capacity from a given amount of spectrum) will also be critical.

Virtualization

In order to more efficiently and cost-effectively control the swaths of spectrum in 5G networks, MNOs will need to virtualize their infrastructure. Centralized Radio Access Networks (C-RANs) will be the precursor to Cloud Radio Access Networks (also C-RANs). Centralized Radio Access Networks form when MNOs move baseband processing units (BBUs) from the bases of cell sites to centralized BBU pool locations serving multiple sites. In the 5G architecture, the BBU functions are split into two parts: the CU (central unit), which handles the upper-layer, non-real-time functions, and the DU (distributed unit), which handles the lower-layer real-time functions. This allows MNOs to move the DU closer to the user to reduce latency (Figure 1).

Centralized RAN reduces the amount of equipment needed at each individual cell site and presents a host of other key advantages. Operators have options about where they put DUs in the network. If they move the DUs closer to the edge of the network, they obtain lower latency. If they centralize the DUs, they have more latency but can optimize the network more effectively by minimizing interference within a group of sites. 5G gives MNOs the option to support a much more diverse set of use cases that determine whether to use a centralized or distributed approach, trading off between performance and costs.

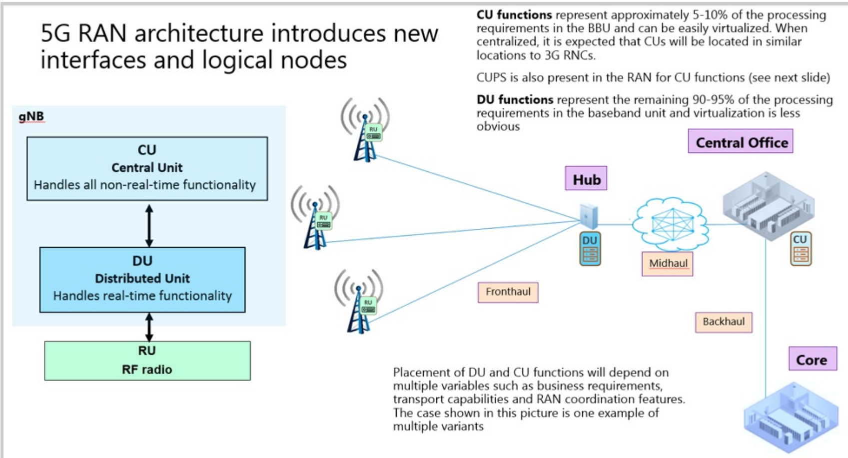

Figure 1: 5G architecture divides the baseband processing unit (BBU) into two parts.

In addition to saving on hardware costs, the C-RAN model can create significant savings in terms of power, cooling and site leasing costs. In Asia, the first region to successfully deploy C-RAN commercially, China Mobile has seen savings of 30 to 60 percent in total cost of ownership by deploying the C-RAN architecture.

Network Function Virtualization

A large part of the work to define 5G relates to a new architecture for the operators' core networks. The primary goal of this architecture is to allow operators the ability to quickly and easily roll out new services. To accomplish this, the network architecture will take advantage of new networking paradigms such as network function virtualization (NFV) and software-defined networking (SDN). Operators will use these and advanced analytic tools for the core network in order to automatically optimize their networks under policy control.

Cell Virtualization

Cell virtualization extends the concept of virtualization beyond the core network and onto the airwaves. Inside buildings, cell virtualization will enable MNOs to manage multiple radio points within the footprint of a single cell. The result is the elimination of inter-cell interference while providing high capacity. C-RAN-enabled cell virtualization also gives operators the ability to re-use spectrum, enabling more dynamic and efficient use of this scarce and costly resource.

Network Slicing

5G networks are being architected to support diverse use cases by implementing a set of "network slices" that may serve different customers with different Quality of Experience (QoE) characteristics. These network slices are virtual instances running on a common infrastructure and may be sharing common resources such as computing, storage, and connectivity.

Optimization

MNOs must optimize their networks to support 5G. One goal is saving tower real estate by adding and consolidating antennas. For this, operators will use high-density antennas, perhaps compressing three 6-port antennas into one 18-port antenna to create room on the crowded tower for new antennas.

Massive MIMO

Massive MIMO (Multiple Input-Multiple Output) antenna architectures will be used with mid- and high-band spectrum to deliver an enhanced mobile broadband experience. The term massive MIMO is typically used when the number of antenna elements is equal to or higher than 64. As higher frequencies are used, the size of antennas decreases and hence it is feasible to fit tens or hundreds of them in a planar array within a reasonably small area (as small as the palm of a hand). By controlling each antenna or a group of antennas individually, it is possible to steer beams toward the desired direction on a per-UE (user equipment) basis.

Time Division Duplexing

5G will also likely include a significant role for Time-Division Duplex (TDD) modes. TDD and Frequency Division Duplex (FDD) are both full-duplex transmission technologies. TDD spectrum is a better fit than FDD for massive MIMO, because the reciprocal nature of the uplink and downlink make it easier to perform channel estimation as part of the beamforming process.

Interference Mitigation

Like the journeys to 3G and 4G, the RF path will be critical in the arrival of 5G, as will be the need for a high Signal to Interference Plus Noise Ratio (SINR) to ensure a robust data service. SINR has become increasingly important as the demands for high-speed data increase. The quality of the RF path is always mission-critical in a wireless network; the level of noise and interference strongly determines the data throughput. To this end, operators must focus on ensuring a clean RF path.

Wavelength Division Multiplexing (WDM)

Passive WDM optical components can have a significant impact on the efficiency of fiber fronthaul/backhaul networks. The incorporation of wavelength division multiplexers reduces the amount of fibers in the network, decreasing both the footprint and the investment cost of network rollouts. In existing networks, these components allow capacity upgrades at a relatively low cost without additional construction work.

Mobile Edge Computing

To service low-latency use cases, cloud-computing capabilities are needed at the edge of the mobile network. Mobile Edge Computing (MEC) architecture is being integrated into the 5G vision. MEC involves many smaller data centers distributed closer to the cell sites, forming an edge cloud where intelligence can be placed closer to devices and machines (Figure 2).

Figure 2: 5G networks will use Mobile Edge Computing to move intelligence closer to devices and machines.

The Road to 5G

As we have seen, moving from 4G to 5G requires myriad changes and upgrades. In general, networks will become much denser, spectrum management and virtualization will be crucial, and optimizing the network by moving parts of the radio infrastructure to the edges of the network will also be essential for supporting 5G in the future.