5G RAN DIVERSIFICATION: BALANCING THE TRADE-OFFS OF MAKING 5G A WORKING REALITY

As the rollout for 5G infrastructures expands, mobile network operators are modifying the existing infrastructure, adding what's needed to support the higher throughputs, greater device density and lower latency we'll need to run advanced 5G use cases, now and in future.

Operators have done this kind of work before, moving cellular from 2G to 3G and 4G, but this time it's different. 5G is more than just an overlay on the previous generation – it's a seismic shift that brings fundamental change at every level. Preparing for 5G operations means having to deal with new technologies and new techniques, from recently opened bands of unfamiliar spectrum and complex active antenna architectures to virtualization and machine-learning algorithms.

At the same time, the goal of infrastructure investment has taken a turn. Where the traditional focus, in place for roughly 30 years, has been on coverage, and trying to find the lowest cost per square kilometer serviced, the initial focus for 5G shifted on capacity, and trying to find the lowest cost per gigabit delivered.

As the 5G rollout continues, the current focus is on the optimal balance between 5G coverage and 5G capacity. What used to be a network dominated by high-power macro cells, is becoming an intricate mix of technologies used to deliver capacity where it's needed most.

The complexities of deploying this kind of heterogeneous network are offset by the fact that the cellular service becomes more flexible, making it easier to meet changes in demand and support new use cases while managing costs. To understand the economics of these investment decisions, it's useful to review what makes 5G different and, as a result, more challenging to deploy.

THREE WAYS 5G IS DIFFERENT

Three things that set 5G Radio Access Networks apart from previous generations are 1) where in the wireless spectrum it operates, 2) the antenna structure used to transmit and receive signals, and 3) the transition to a more software-based approach to managing and optimizing operation.

- **New Spectrum**

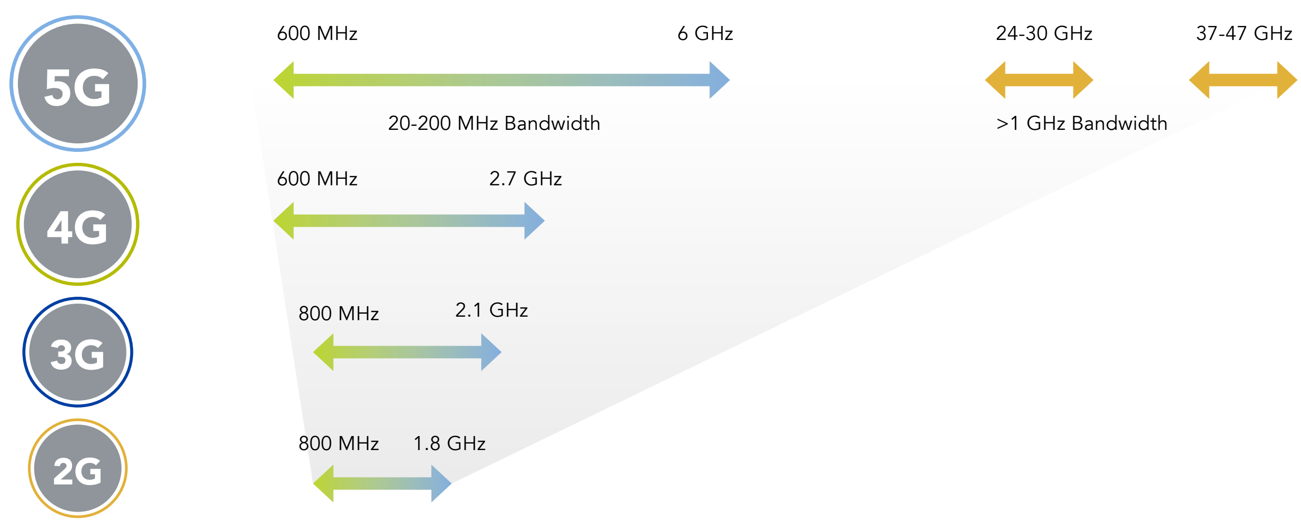
  As shown in the diagram, 5G extends the existing cellular spectrum to include the area between 2.7 GHz and 6 GHz, and adds a completely new part of the spectrum, above 25 GHz. This new portion of the spectrum, known as millimeter wave (mmWave), was previously reserved for other services, such as medical imaging, microwave remote sensing, and radio astronomy. It will enable ultra-high bandwidth and ultra-low latency use cases in 5G, but presents a steep learning curve for engineers used to working below 6 GHz.

- **New Antenna Configurations**

  5G makes use of active antennas, which are more highly integrated and more complex than the passive antennas traditionally associated with cellular. Active antennas require a sophisticated mix of hardware and software and make use of massive Multiple Input, Multiple Output (mMIMO), a technique that involves dozens (if not hundreds) of antennas working together to expand capacity within the same bandwidth. Working with so many antennas is a complex, compute-intensive task that requires careful optimization to ensure reliable, interference-free operation.

- **More Code**

  5G makes extensive use of virtualization, with more being done in the cloud, and often uses machine learning (ML) algorithms for optimized network management, orchestration in the core, traffic monitoring, and load balancing. A typical 5G base station has millions of lines of code, using software to add new features like support for more devices, increased capacity, and expanded coverage to accommodate more traffic. Heavy reliance on software changes how the network is deployed and operated as well as changing the security models.



5G adds new frequency spectrum

PUTTING 5G TO WORK IN LAYERS

Preparing the infrastructure for 5G operation involves adding different layers of coverage, each providing the capacity / coverage trade-off needed for a given area or use case. Unlike 4G that consisted of high-power macro cells complemented here and there by small cells, the 5G deployments consist of high-power macro cells, mMIMO cells, small cells, with mmWave bridging the gap between them.

- **High-power Macro radios**

  Servicing a wide area of about 25 km, traditional high-power macro cells mainly provide capacity in suburban and rural environments. Macro cells are big, high-powered base stations that live on towers, monopoles, and rooftops, and are sometimes made to look like giant trees. They typically use a passive antenna system and a simple Multiple In Multiple Out (MIMO) configuration for transmission that uses from two antennas (2T2R) to eight antennas (8T8R), sub 6 GHz..

- **Massive MIMO radios**

  Servicing a smaller area of about 1 km, mMIMO cells are used to provide capacity in urban environments that have a higher device density than suburban and rural areas. The high-power macro cell's passive antenna and radio unit are replaced with an active antenna system. The active antenna system combines each antenna transmission for beamforming, to steer the RF signal into a precise direction. Typical configurations use 32 antennas (32T32R) or 64 antennas (64T64R), sub 6 GHz

- **mmWave radios**

  Servicing an area of about 100 m, mmWave cells make use of the new spectrum above 24 GHz to provide capacity in urban environments with very high device density and to support Fixed-Wireless Access (FWA) towards houses.

  Working in the mmWave spectrum means exceptionally high bandwidth, made possible using hundreds of antennas in a mMIMO configuration (e.g. 256T256R), but because mmWave signals have a smaller wavelength, they don't travel as far, making mmWave limited to the most dense urban areas. mmWave will also serve as a backhaul for small cells and WiFi6/6E hotspots.

- **Small Cells**

  Small cells are backpack-sized, low-power base stations that provide targeted capacity in network "hotspots" complementing the macro RAN network configurations described above. Small cells are compact and lightweight, so they can be mounted just about anywhere, and they prevent 5G signals from being dropped in crowded areas, such as city centers or sports venues. Small cells provide a great flexibility of deployment thanks to their low price point compared to larger RAN solutions, and a smaller, quicker to install form factor. They need three things to operate – a permitted space for operation, power, and some kind of backhaul connection for transmission to the core network. Some use microwave for backhaul communication, others use fiberoptic cabling.

  In the United States, the Federal Communications Commission (FCC) says they expect small cells will soon account for 80% of new cell-site deployment due to, in part, more operators taking advantage of the newly available unlicensed 5G spectrum. The CTIA trade group, which tracks the US wireless communications industry, backs up the FCC's prediction, with a forecast that has small cells in the US growing from around 86,000 in 2018 to over 800,00 by 2026, largely driven by the need for 5G operation.

5G densification brings capacity in layers

FINDING THE RIGHT MIX: A WORK IN PROGRESS

The layered approach takes advantage of the fact that 5G is a standard that meets many different requirements, and lets operators tailor network operation to meet specific needs while keeping costs in check. A single operator might, for example, use 4T4R or 8T8R macro cells to service rural and suburban areas, while 32T32R mMIMO cells will serve semi-dense urban areas, 64T64R mMIMO cells will serve dense urban areas. The higher cost of mmWave can be saved for the areas with the highest densities, such as a crowded business district, an international shipping port, or an entertainment venue that hosts major sporting and cultural events.

But we are just at the beginning of the 5G super-cycle. The 5G networks already in place today mostly leverage legacy 4G networks, in what's called a Non-Standalone (NSA) network setup. The 5G capability is essentially anchored to 4G, so users can back off an LTE connection when a 5G connection is unavailable. Before 5G becomes widely available, mMIMO can be used to increase LTE speeds and improve latency, but the real benefit of mMIMO, and its positive effect on network density, will start to kick in once the infrastructure transitions to the Standalone (SA) setup, which is a pure 5G network for higher-frequency operation.

FLEXIBLE NETWORK COMPUTING

Edge computing is an important feature for both Wi-Fi and cellular scenarios, as local servers connected closer to the end-user can perform advanced tasks to reduce the amount of traffic that is transported to/from the cloud-infrastructure they are typically hosted on today. In a sports stadium, for example, instant-replay video, streamed from onsite cameras, can heighten the fan's experience of the game, while orders for food and beverages, placed and paid for from the spectator's seat, can reduce lines and wait times for service. Using local processing with Wi-Fi 6/6E or 5G small cell connectivity for these kinds of services reduces latency and offloads the operator macro 5G network – whilst improving customer experience through latency reduction and bandwidth increase. Edge computing can be provisioned at the end-user (for example: Machine Learning capabilities inside the mobile phone), at the Radio Network edge (compute near WiFi Access Points or 5G Small Cells), or at the site (a compute farm local to the stadium example we used here), all optimized the deployment use-case that makes most sense to the operator.

THE NXP PERSPECTIVE

At NXP we've expanded and diversified our technology toolbox dedicated to 5G, to develop a large array of solutions for all types of 5G deployment options. Our multi-faceted portfolio reflects the fact that 5G is not a one-size-fits-all proposition. From high-power transistors, Gallium Nitride multi-chip Modules and SiGe beamforming ICs to power-efficient Arm processors and customizable, DSP-driven baseband devices, our components make the 5G infrastructure more efficient, more effective, and more reliable. We even extend the options, with industry-leading solutions for Wi-Fi 6/6E, so network operators can support use cases that benefit from wireless co-existence.

To learn more about how we're enabling 5G densification, visit **www.nxp.com.**

Franck Nicholls

Franck Nicholls is the head of Commercial Marketing within the Radio Power Business Line at NXP. He is responsible for promoting NXP's RF Power solutions. Prior to this position, Franck held several marketing and business development responsibilities for NXP and previously Freescale in the US and in Europe. Franck received his M.Sc. degree from Telecom Paris in France.

NXP and the NXP logo are trademarks of NXP B.V. All other product or service names are the property of their respective owners. © 2021 NXP B.V.