Tackling Network Densification Challenges for 5G

Reimagine Your Network

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Introduction

With the introduction of 5G networks, mobile operators are set to experience explosive growth in data usage. To address this data growth the concept of heterogeneous networks, and deploying smaller cells and densification, becomes an urgent task for mobile operators around the world. While the concept of heterogeneous networks is not new, implementation of them in a multitier deployment remains a challenge. Interference and mobility related issues prevent deployment of heterogeneous networks in large scale deployments. 5G envisions heterogenous and densified networks as an important part of its success and different approaches and mechanisms considered for its deployment. In this paper we address the different issues related to densification and discuss 5G approaches to address them.

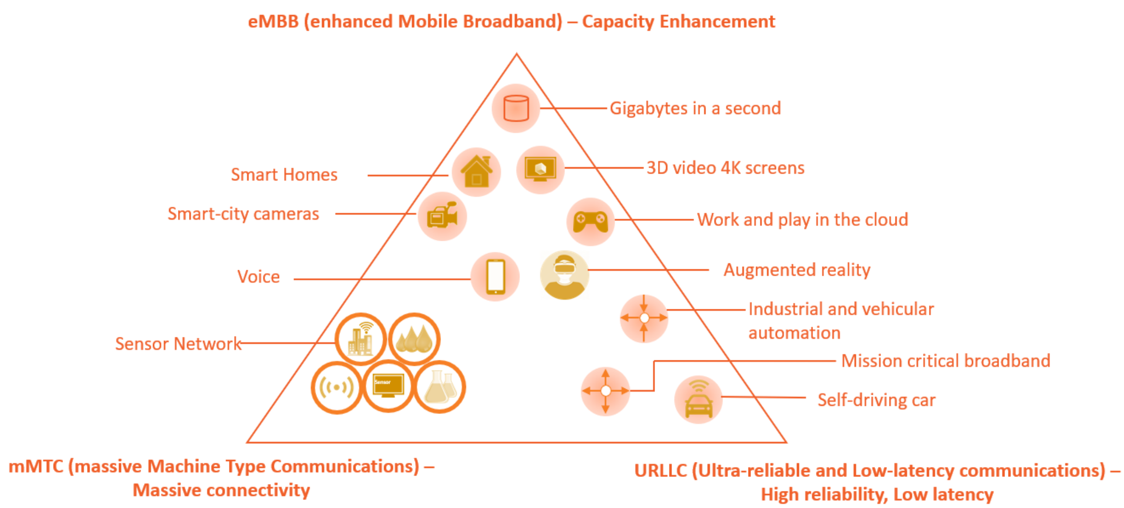

Figure 1: IMT-2020 Vision and Use Cases

The main 5G service types typically considered are as follows [1]:

- **Enhanced Mobile Broadband (eMBB)**; related to human-centric and enhanced access to multimedia content, services, and data with improved performance and increasingly seamless user experience. This service type can be considered an evolution of 4G network services.
- **Ultra-Reliable and Low-Latency Communications (URLLC)**; related to use cases with the most stringent requirements for capabilities such as latency, reliability, and availability. This includes wireless control of industrial manufacturing process, distributed automation in smart grids and transportation safety. It is expected URLLC services will provide the main platform for the 4th industrial revolution.
- **Massive Machine-Type Communications (mMTC)**; services for large numbers of connected devices with limited amount of data to transfer and low sensitivity for latency. However, the key challenge is the fact that devices are usually required to be low-cost and have a very long battery life. Key examples for this service type would be logistic applications.

Considering the diverse set of services supported by 5G, the single homogeneous deployment will not be an option for future 5G deployments. A multitier network, with a focus on densification for eMBB delivery, is a logical choice for 5G deployment. Although multitier cell deployment is not a new concept, the level of densification in 5G is a new concept. New methodologies and techniques are needed to make these deployments possible soon. The Parallel Wireless OpenRAN Software Suite is uniquely positioned to address this need.

5G Architecture and Densification

Legacy mobile networks (2G and 3G) were designed and deployed with a single-tier network architecture in mind. They were based on the concept of the high-power macro base station with minimum overlap. Later, and during the explosive data usage growth, the concept of densification based on multitier heterogeneous networks (HetNets) got momentum in the industry. While macrocells span large areas and are mainly focused on providing ubiquitous coverage, smaller cells are deployed in hotspots at selected areas across macro-celled coverage to address the capacity challenge.

The frequency coordination between macrocells (overlay) and smaller cells (underlay) has been a challenge from the introduction of HetNet multitier densification. While allocating different frequency for different tiers (inter-frequency densification) is the easiest way to manage interference, it is not an ideal option for frequency resource utilization. Utilizing the same frequency resources across tiers is the most efficient way to utilize available frequency resources; however, it requires a very complex interference management scheme to enable the network to function at high efficiency.

5G networks will push the limits for small cell deployments. A combination of intra and inter-frequency for underlay and overlay cells will be a common practice in 5G networks. Channel sizes and operational frequencies have a wider diversity compared to 4G and add another dimension to network densification in 5G networks. Among new considerations, 3GPP considered the split concept (DU and CU) from the beginning for 5G to facilitate a simpler approach toward frequency coordination among different cells in a geographical area (figure 2). The gNB may consist of a Centralized Unit (CU) and one or more Distributed Units (DUs) connected to the CU via Fs-C and Fs-U interfaces for CP and UP respectively. This approach enables different DUs with the same or different operating frequency connected and coordinated through a single CU.

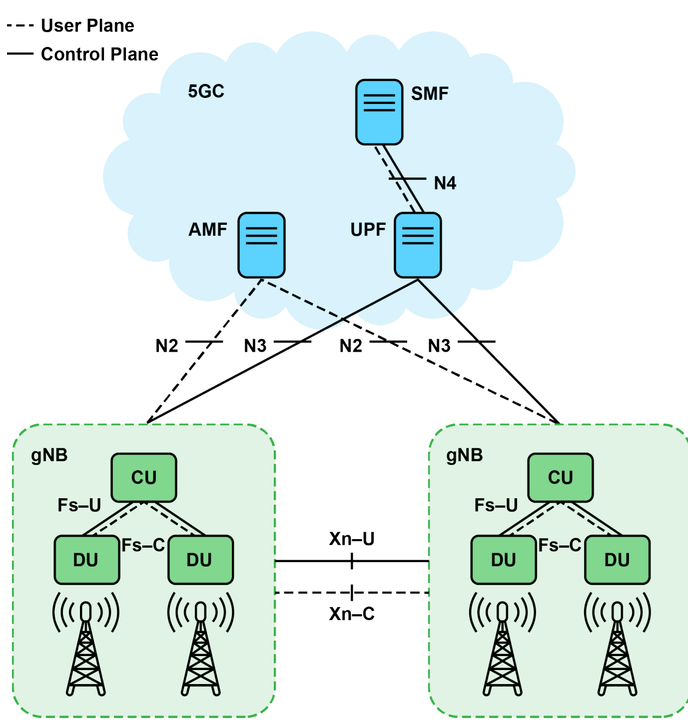

Figure 2: High-level Architecture of 5G RAN

Parallel Wireless believes the 3GPP approach to defining the CU concept as a centralized entity to manage numbers of DUs and remote radio heads (RRH) at different frequencies is the right approach. Parallel Wireless OpenRAN architecture will address all these requirements with a software-based approach in mind and full platform openness.

HetNets and 5G Deployments

Capacity increase for mobile networks has been the main challenge for technologies and network designers over the past 40 years. While governments across the world did their part to allocate more and more spectrum for mobile deployments, there is a limit for it. Since the early days of 2G networks, 3GPP and all involved industry partners have done their best at increasing spectral efficiency and pushing the envelope by introducing new technologies over time. However, there is a limit to spectral efficiency and how realistic it will be to push for higher level modulations and coding schemes. There was a huge amount of focus and efforts on these two pillars of "mobile network capacity" (figure 3). For 5G, Parallel Wireless believes densification will be the third pillar and the only way to increase the capacity substantially.

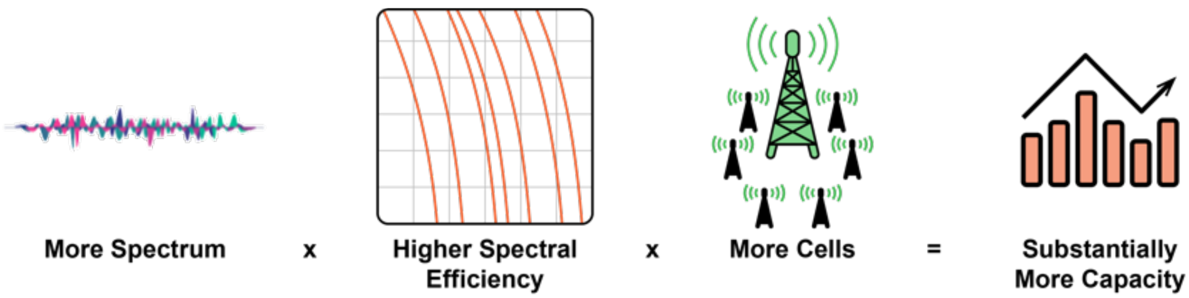

Figure 3: Capacity Growth Pillars

Going forward, we believe effort will continue to try and improve spectral efficiency even further in mobile networks, as well as allocation of more spectrum in different bands, particularly mmWave. However, the most improvement in future mobile networks will be the outcome of aggressive frequency reuse and intelligent offloading across cells with different frequency ranges. Parallel Wireless OpenRAN Software Suite is uniquely positioned in OpenRAN network architecture to address intra and inter-frequency cell coordination intelligently and improve overall system capacity.

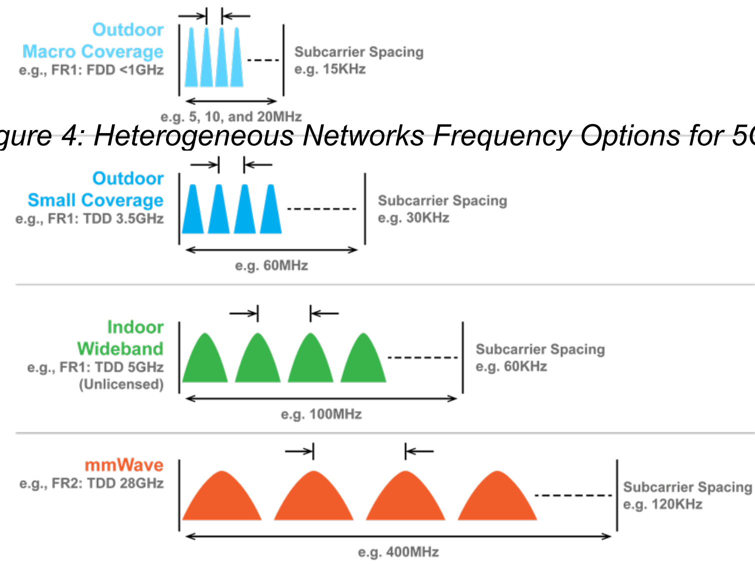

Figure 4: Heterogeneous Networks Frequency Options for 5G

Possible HetNet Deployment Varieties for 5G

As discussed before, 5G networks will utilize a variety of frequency bands simultaneously with very different characteristics. While lower frequency ranges will remain the main candidate for macro-cell deployments as an overlay, mid-band frequencies will be utilized for underlay capacity-limited deployments. This can be an urban or dense urban morphology that utilizes mainly TDD duplex for data-intensive usages. mmWave will be the main candidate for ultra-dense urban or indoor deployments, providing more capacity for hotspots. Figure 4 shows potential frequency band utilization in a fully heterogeneous 5G network deployment across multiple bands and different morphologies.

While spatial densification (utilizing the same frequency band for different layers) is a relatively old concept, vertical densification (utilizing different frequency bands for different layers) is quite new. Many different bands will be used for 5G deployments. Although vertical densification will reduce the interference issues dramatically, the wider range of spectrum across different bands need to be supported by the mobile phones will add complexity and increase the cost. As shown in figure 5, a high-power macro base station utilizing lower bands (< 3 GHz) can be a good candidate for an umbrella overlay while utilizing different higher frequency bands (> 3 GHz) for small and underlay cells to provide more capacity. This approach will fit nicely with future architectural plans to separate the control plane (CP) from the user plane (UP). While the lower band macro-cell with a good coverage radio carries CP, the UP will be carried by higher-band smaller cells to provide high capacity across the coverage area [2].

We believe Parallel Wireless OpenRAN Software suite is well-positioned to support all types of densifications in the future. While in a spatial densification deployment OpenRAN Software Suite can manage intra-cell interferences, for vertical densification deployment it will be able to coordinate all load-related handoffs and other functionalities to utilize different layers accordingly and improve overall system performance and frequency utilization. These issues will be discussed in detail in the following sections.

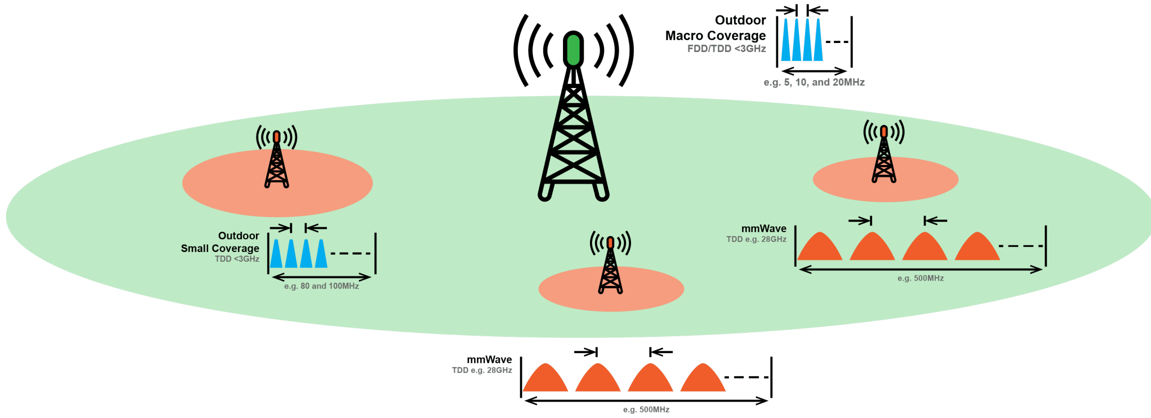

Figure 5: Vertical Densification

Interference Challenges and Solutions for 5G Network Densification

Cell splitting and network densification is a well-known concept and has been widely utilized for the past couple of decades. However, smaller cells in proximity will increase the inter-cell interference and can affect the overall system capacity gain. 3GPP Release 15 (5G NR) follows almost the same framework for downlink interference mitigation as of Release 14.

These include network-based resource portioning mechanism:

- Spatial-domain resource portioning: Massive MIMO and beamforming are different varieties for this kind of partitioning.
- Time-domain resource partitioning: This includes techniques such as enhanced inter-cell interference cancellation (eICIC) and enhanced coordinated multipoint (COMP and CoMP)
- Frequency-domain resource partitioning: this is the legacy approach toward HetNet deployments and may include hard and soft frequency partitioning across overlay and underlay cells.

Transmit power control is an inherent part of all interference mitigation techniques and will appear in different forms in many of the previously mentioned techniques. Also, as in Release 14, Almost Blank Sub-frame/Slot (ABS) remains one of the main interference mitigation tools in the future intra-frequency multi-layer deployments. Underlay small cells in coordination with macro overlay lay cells can plan their transmission and its power level at the subframe/slot level. In a dense deployment, it will allow the small-cell's effective range to be larger by playing with certain mobility and reselection parameters for the UE. Figure 6 shows the multitier network utilizing ABS [3].

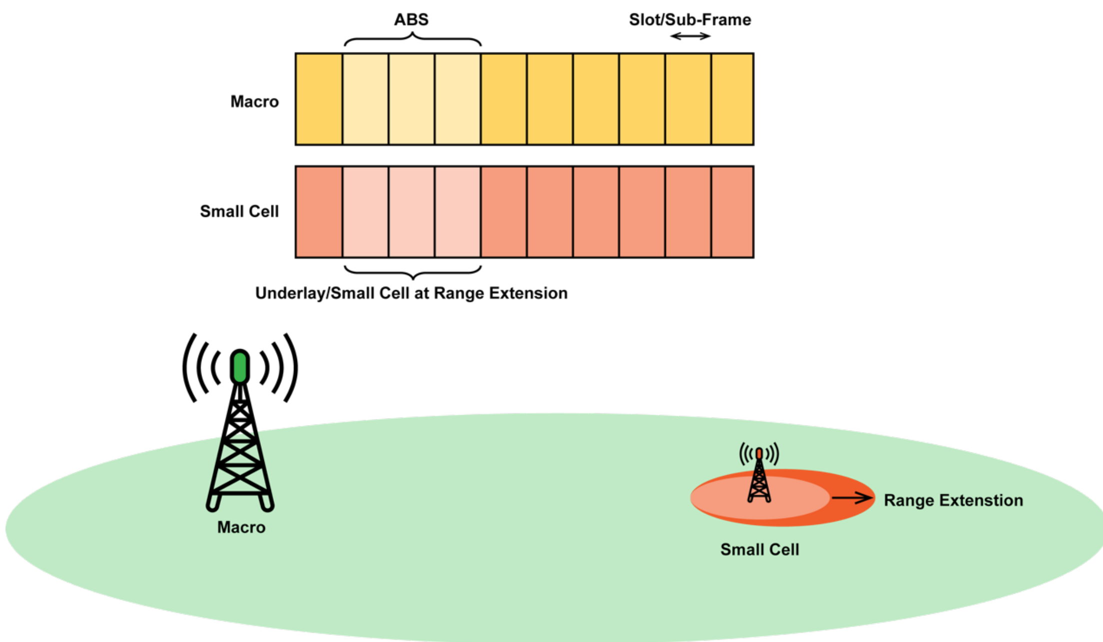

Figure 6: ABS and inter-cell interference coordination

Different Coordinated Multipoint (CoMP) transmission and reception techniques have been proposed by 3GPP in Release 11to enable users connecting to multiple radios at the same time and address the cell edge interference issues. Considering 5G network densification, this can be an important issue needs to be addressed by CoMP. While not all mobile phones can support CoMP initially, there is a trend toward more and more enabled phones in the future. Figure 7 shows the different flavors of CoMP proposed in Release 14.

As shown in figure 7, different downlink CoMP flavors are as follows [3]:

- Coordinated scheduling/beamforming: Each UE receives data through one RRH at any given time. This approach will improve the overall received signal quality.
- Dynamic point selection: UE will receive data through multiple RRH; however, single RRH transmit at a time. The scheduling graduality is at the slot level.
- Joint transmission: Data through multiple RRH at the same time. This scheme can provide the highest gain.

All the interference mitigation techniques so far require tight coordination among different RRHs. Parallel Wireless architecture is well-positioned to provide these functionalities across the multitier network. While it can coordinate with RRUs directly connected, it will provide all required signaling to macro cells and reduce the overall system control signaling.

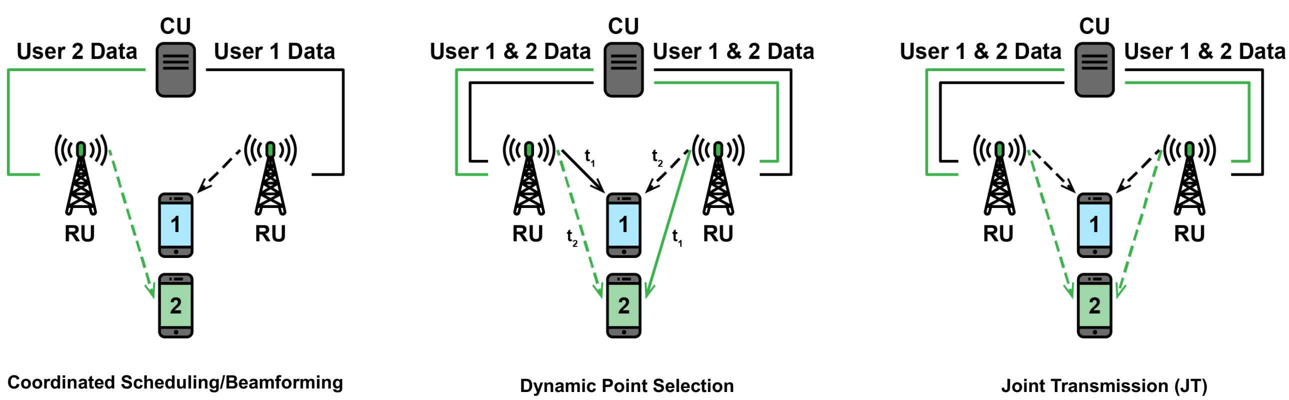

Figure 7: CoMP different flavors

HetNet Densification and Mobility Optimization

Besides interference issues, the densification of cellular networks can impact user experience due to increases in handoffs and related signaling loads. While in a macro cell deployment, cell overlaps are less frequent due to large areas of cell coverage and the limited number of handoffs a user can experience during a call. In a HetNet deployment, a UE can cross the boundaries of many small cells during a short period of time (figure 8). The increase of handoffs in a mobile system can directly impact the volume of signaling in the system and have a negative impact on overall user experience and system capacity.

New methods including mobility state estimations and time-to-trigger (TTT) scaling have been proposed and utilized in recent deployments to address this issue. The network will estimate UEs' mobility based on their history and adjust TTT dynamically for different UEs and facilitate a faster handoff execution. This will improve the overall quality of service for users and reduce the number of call failures.

Parallel Wireless Open RAN Software Suite can utilize its ability to see the network end-to-end and dynamically execute parameter changes to optimize the user experience based on their mobility.

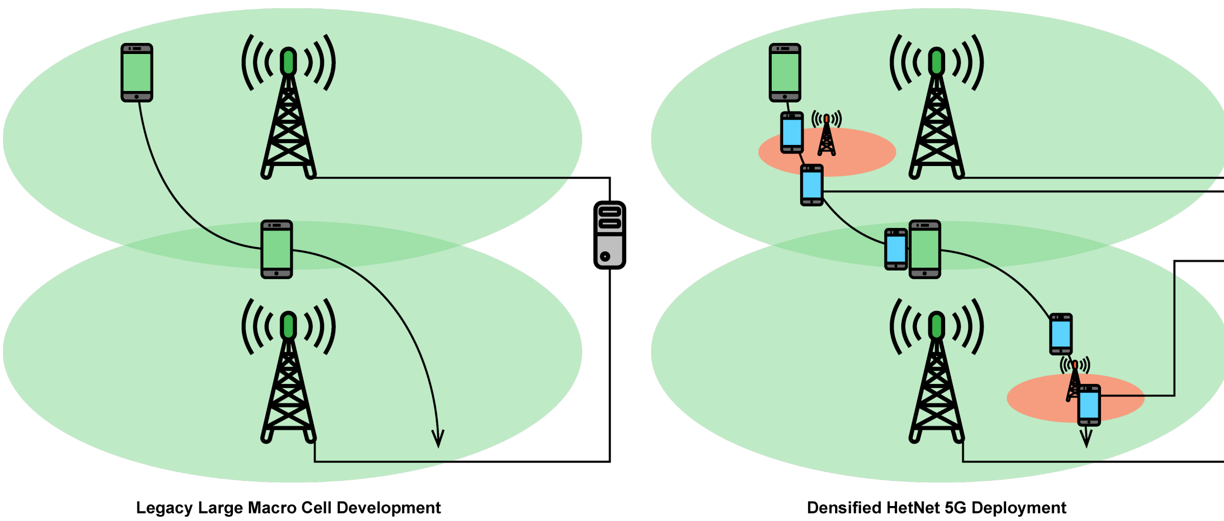

Figure 8: Mobility Related Issues in Densified Networks

Parallel Wireless Open RAN Software Platform

By supporting all RAN networks under the same software umbrella via our OpenRAN Controller, Parallel Wireless delivers on the promise of real-time orchestration and network automation. Future proofing for network upgrades is made possible by the white box and Open Compute movement, resulting in a unified multi-RAN and a radically lower cost structure that enables service providers profitability and makes their networks ready for evolving subscriber needs.

Parallel Wireless's 2G/3G/4G/5G unified OpenRAN software platform enables OpenRAN through the complete decoupling of hardware and software functionality. This functional separation enables the Unified Software Platform to support all the different protocol splits between DUs and CUs based on available backhaul, midhaul, and fronthaul options. Different RAN element functionalities consolidate on the platform, reducing complexity and making overall network maintenance simpler and less resource intensive.

The Parallel Wireless Unified Software Platform also provides complete RAN orchestration including self-configuration and self-optimization. All new radio units are self-configured by the software, reducing the need for manual intervention. The self-optimization module is responsible for necessary optimization-related tasks across different RANs, utilizing available RAN data from the Analytics module. The predictive approach utilized by the Parallel Wireless platform, in contrast to the legacy reactive optimization approach, improves user experience and increases network resource utilization.

Being a 5G native platform, it will provide a smooth migration path to 5G utilizing any migration option.

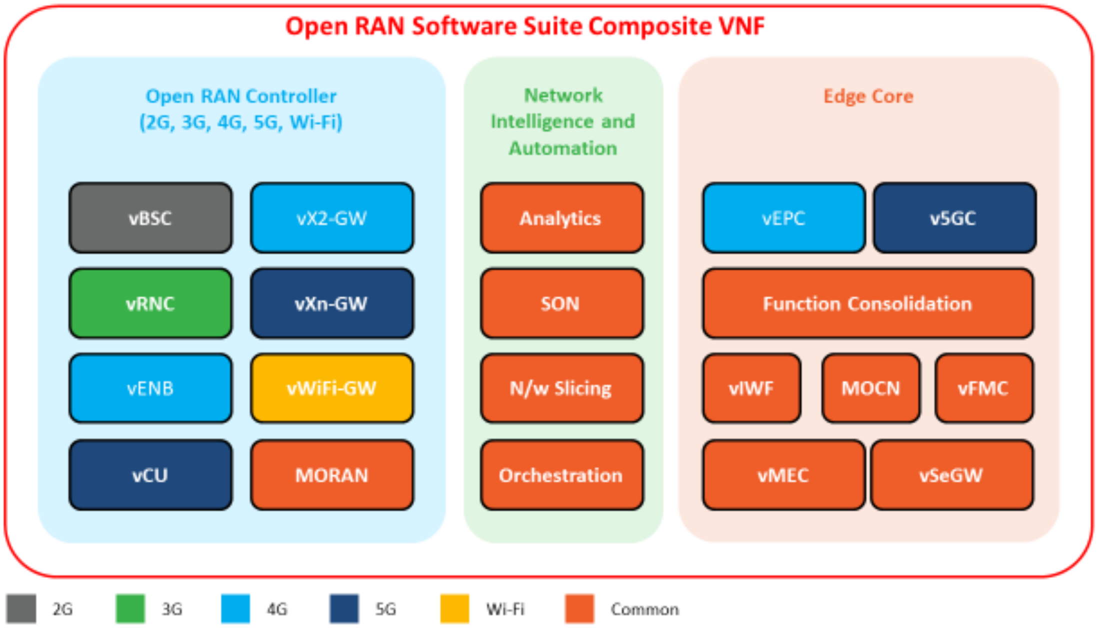

Figure 9: Parallel Wireless OpenRAN Software Suite

Summary

By putting software at the heart of the network, operators can unify all generations of connectivity under the same umbrella and eliminate the need to spend millions of dollars on new equipment and infrastructure upgrades. This approach can help MNOs unify their cellular network infrastructure to deliver quality end-user experiences for all coverage or capacity use cases: low density/high density, indoors or public safety. This is made possible by utilizing Parallel Wireless OpenRAN Controller as the network orchestrator optimizing among other things, interference and mobility across its RRHs and towards any 3rd-party RAN elements. This abstraction will reduce overall signaling across the network and improve network performance.

References

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