White Paper

Communications Service Providers
Radio Access Network

Parallel Wireless Creates OpenRAN "ALL G" Radio Access Network Architecture

Parallel Wireless's OpenRAN solution combines an OpenRAN controller with edge core, analytics, and hardware products for open standard virtual RAN. The virtualized solution utilizes Intel® architecture-based servers for performance.

Mobile network operators have built their wireless radio access network (RAN) using proprietary equipment that is not interoperable nor upgradable, and this has made expanding the network or moving to a new wireless generation costly and difficult. Now, as MNOs move to 5G, OpenRAN is an emerging option that promises an open network that supports all wireless generations ("ALL G") and is upgradable as new wireless technologies emerge.

The High Cost of Proprietary Wireless Networks

2G networks started the mobile data revolution in the late 1980s with SMS and data speeds up to 64 kbps. That was followed by 3G networks in 2000, which introduced speeds of 2 Mbps and ushered the world into the smartphone era. Now, much of the world has 4G services with multimegabit services and is anticipating the promise of 5G with tens or hundreds of gigabits of throughput.

One thing all these network generations have in common is that the transitions or expansions are difficult and expensive because of proprietary vendor designs that lock MNOs into a particular architecture and make interoperability of advanced features very difficult. This is especially true in the RAN part of the network as is evidenced by radio towers filled with antennas and RAN equipment from different vendors and different generations.

Radio signal processing is compute intensive and complex, and it must be done in real-time, which has required dedicated servers with specialized ASICs and optimized software. Because of these requirements, RAN consumes most of the capital expense that goes into a wireless network.

This high cost of proprietary RAN impacts MNOs in different ways:

- In low average revenue per user (ARPU) markets, MNOs face challenges to grow revenues. The high cost of network upgrades makes it very costly to add capacity to grow the user base or to add new data services.
- Some tier 2 and tier 3 MNOs in high ARPU markets need to expand, but the vendor lock in makes it hard to price services in order to get a return on investment. These carriers, mostly rural, have smaller customer bases on which to amortize their network investments, but still face service pricing pressure from larger carriers as they are their roaming partners and are expected to provide the same type of quality of service.
- All carriers are facing a competitive pricing model and a demand for new services to support IoT and other 5G use cases like eMBB and URLLC. In these situations, both the cost of proprietary network architectures as well as the long timelines for upgrades cause significant issues.

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Now, as MNOs consider the upgrades needed to deliver 5G services, open RAN architectures that can support multiple network generations offer an alternative to the "rip and replace" cycle of previous network updates.

There are two main organizations driving open RAN:

- Telecom Infra Group (TIP),[1] whose main objective is the deployment of fully programmable RAN solutions based on GPPP/COTS and disaggregated software. There are two groups within TIP looking at Open RAN. The OpenRAN project group focuses on defining and building 2G, 3G, and 4G RAN solutions, while the OpenRAN 5G NR group is focusing on defining a white box platform for a 5G NR access point that is easy to configure and deploy.
- The O-RAN Alliance[2] is the other main driver of the OpenRAN concept, focused on efforts to standardize interfaces. The alliance was founded in 2018 by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO, and Orange.

OpenRAN-based networks are built using network elements with open interfaces, white-box Intel® architecture industry-standard servers, and standardized interfaces that deliver intelligence and openness. This architecture allows an MNO to combine baseband units, radio units, and remote radio heads from any vendor into a single network, replacing the end-to-end vendor lock in that occurs with today's proprietary and vertically integrated networks.

Parallel Wireless, an Intel® Network Builders ecosystem member, has developed a complete OpenRAN solution to help MNOs manage the expansion of their 2G, 3G, and 4G networks, modernize legacy networks with OpenRAN, and enable the migration to 5G services with a simple software upgrade. Parallel Wireless has adopted the Intel FlexRAN Reference Software architecture as its path forward to 5G and virtual Open RAN. The two companies are working together to have an available, 5G OpenRAN product within 2020.

Complete OpenRAN Solution

Fundamentally, the open RAN concept is about building networks using a fully programmable software-defined mobile network solution based on open interfaces—radios, base stations, etc.—that runs on commercial off-the-shelf hardware (COTS) with open interfaces. Traditionally, mobile networks have been built with closed, proprietary software and purpose-built hardware. But today, mobile networks can be disaggregated and based on the open RAN concept (as defined by O-RAN Alliance).[3]

In this context, disaggregation means separating the hardware from the software. The 3GPP introduced this concept in Release 14 of its specifications with the control and user plane separation (CUPS) of evolved packet core (EPC) nodes, and the O-RAN Alliance produced the open RAN specifications. With 5G New Radio (NR) in 3GPP Release 15 and beyond, this split is continued with the service based architecture (SBA). 5G NR further abets disaggregation by continuing the split between control and user plane all the way down into the 5G base stations and radios with the central unit (CU) and distributed unit (DU).

The Parallel Wireless Open RAN solution (see Figure 1) includes a controller, edge core software, analytics, and an ecosystem of hardware radios and servers supporting the majority of 3GPP-compliant DU/CU splits.

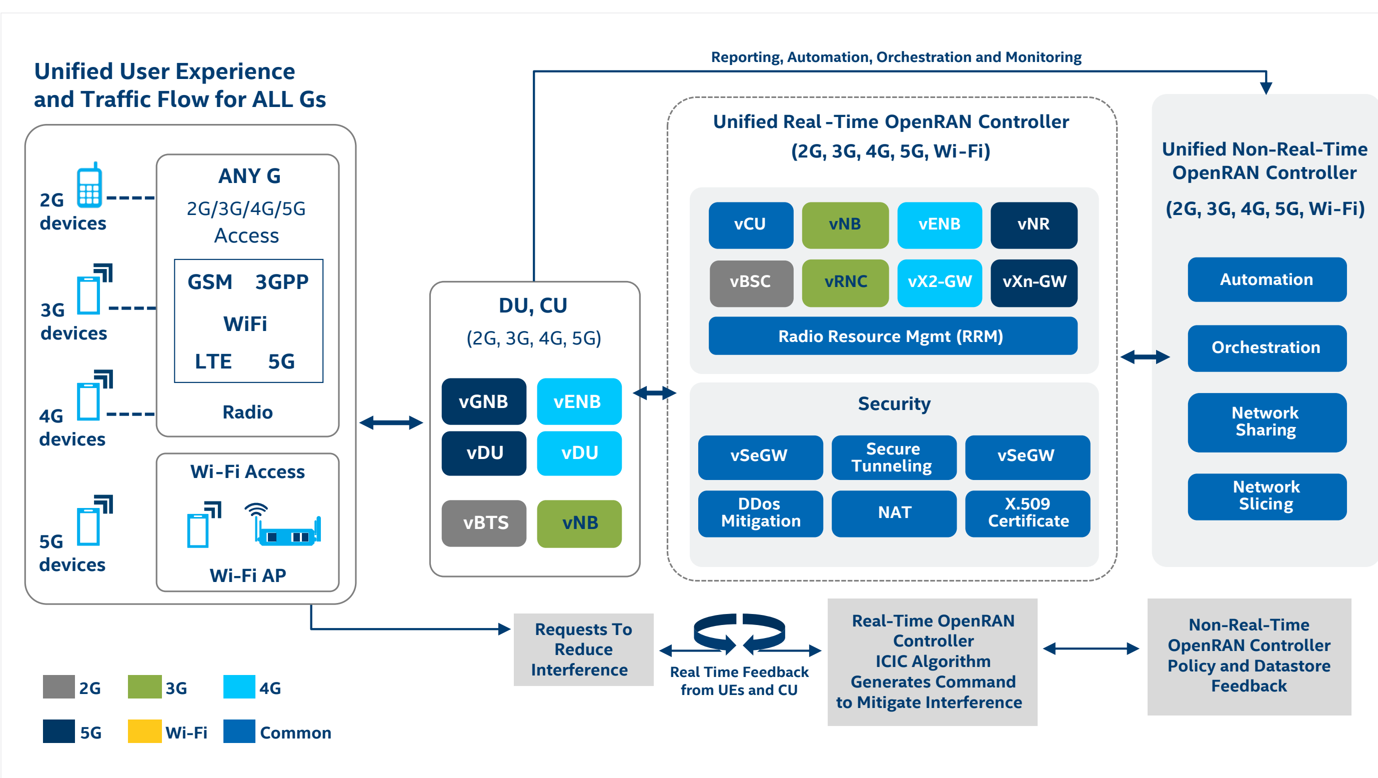

Figure 1. Parallel Wireless's complete OpenRAN software suite.

OpenRAN Controller and Network Software Suite

The unified solution for ALL G delivers high capacity, high availability, and high performance. Key features include the following:

- OpenRAN Controller: An O-RAN -compliant OpenRAN Controller provides both near real-time and non-real-time controller functionalities. Built on 5G-native architecture, the controller provides ease of deployment and fast time to market. It is standards based and interoperable with different hardware and software vendors for RAN/Central Unit (CU).
- Edge Core: A virtualized, modular and distributed core solution for both 4G and 5G networks. 4G functionality includes mobility management entity (MME), serving gateway (SGW) and packet gateway (PGW) and Wi-Fi gateway. For 5G networks, the Edge Core provides access and mobility management function (AMF), session management function (SMF), user plane function (UPF), and non-3GPP interworking function (N3IWF). The Parallel Wireless Edge Core is a fully distributed, cloud native solution. It enables deployment flexibility and allows operators to provide seamless user experience across multiple technologies.
- Network Intelligence: Network Intelligence software is an overlay framework that provides intelligence across the entire software suite by enabling ALL G self-organizing networks (SON), network orchestration, and analytics. It allows network optimization and improved quality of experience (QoE) for end users. The SON capabilities are important because they mitigate interference from base station signal overlap or different radio frequency (RF) signals. This is an important capability for higher throughput 4G/5G networks where small cells will be needed to fill in coverage gaps. Parallel Wireless's SON has predictive management to react automatically to changes in the network to optimize the signal strength and network resource utilization.

The software platform supports the multi-operator radio access network (MORAN) and multi-operator core network (MOCN) open standards for RAN sharing. This provides flexibility in 5G networks to route traffic from different networks to the proper core for processing.

OpenRAN Controller

The Parallel Wireless OpenRAN software suite completely decouples RAN hardware and software functionality. The solution is anchored by the Parallel Wireless OpenRAN Controller that provides RAN services, optimizes the network using analytics, and provides centralized management and intelligence for every generation of wireless network (2G, 3G, 4G, 5G, and Wi-Fi) for seamless mobility.

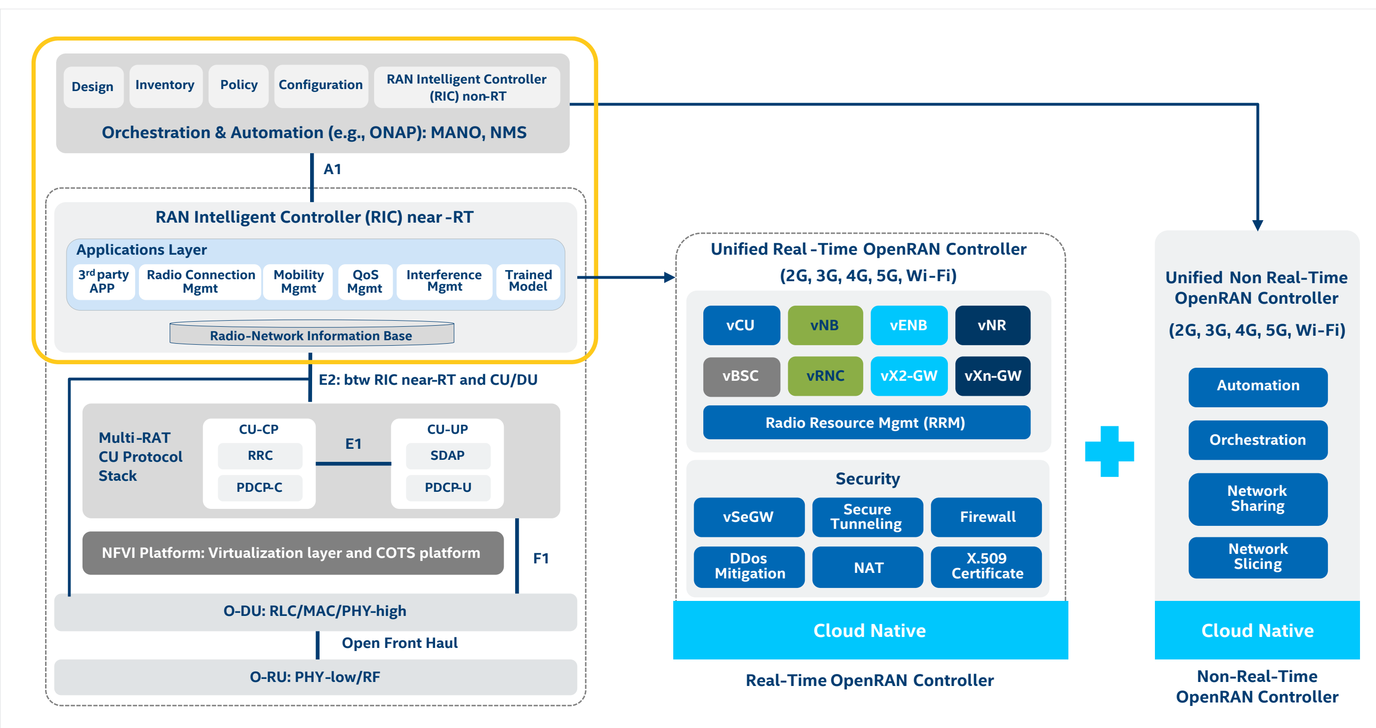

Figure 2. Parallel Wireless controller block diagram showing details on both the real-time and non-real-time controllers.

Core features include radio connection management, mobility management, quality of service (QoS) management, and interference management. The software's gateway management spans all networks, including support for vBSC/2G gateways, 3G gateways/vRNC, 4G gateways/X2 gateways, and Wi-Fi gateways. The controller functionality works in a multi-vendor RAN environment through a supported E2 interface.

For 5G networks, the 5G RAN controller functions can be deployed as either a non-standalone (NSA) or standalone (SA) controller for an easy migration from 4G to 5G.

The controller functionality consists of a real-time controller and a non-real-time controller.

Real-Time Controller: Provides OpenRAN-defined, near real-time RAN Intelligent Controller (RIC) functionality and extends it to real time. It provides complete RAN orchestration and real-time SON including self-configuration, self-optimization, and self-healing. All new radio units are self-configured by the software, reducing the need for manual intervention, which will be key for 5G deployments of massive multiple-input and multiple-output (MIMO) and small cells for densification. The self-optimization is responsible for necessary optimization-related tasks across different RANs, utilizing available RAN data from all RAN types (macros, massive MIMO, small cells) from the Parallel Wireless Analytics Module. The proactive approach utilized by the Parallel Wireless platform, in contrast to the legacy reactive optimization approach, improves user experience and increases network resource utilization, key for consistent experience on data-intensive 5G networks.

Non-Real-Time Controller: Provides OpenRAN-defined, non-real-time RIC functionality such as configuration management, device management, fault management, performance management, and lifecycle management for all network elements in the network. Network slicing, security, and role-based access control and RAN sharing are key aspects that are applicable to all the controller functions across the network.

This software suite also provides a layer of intelligence that can be realized across the network by using telemetry information gathered from across the network. By providing timely insights into the network operations, operators can use the non-real-time controller to further understand and optimize the network. This controller fully complements the suite of products that Parallel Wireless offers today to realize, deploy, manage, and optimize the entire network with a single pane of glass.

Parallel Wireless Converged Network Intelligence serves as non-real-time RIC in compliance with O-RAN alliance, powered by SON and analytics; helps deploy and manage OpenRAN software; and is radio access-neutral, supporting multiple radio access technologies across the network.

This successful platform has been deployed around the world (see Figure 3) by many leading mobile operators.[4] The software platform offers a flexible network architecture that integrates several network functions and enhanced services into a converged platform. This integration promotes seamless mobility through universal roaming, streamlines network management, enhances unified billing, and offers service uniformity as subscribers roam across different radio access technologies.

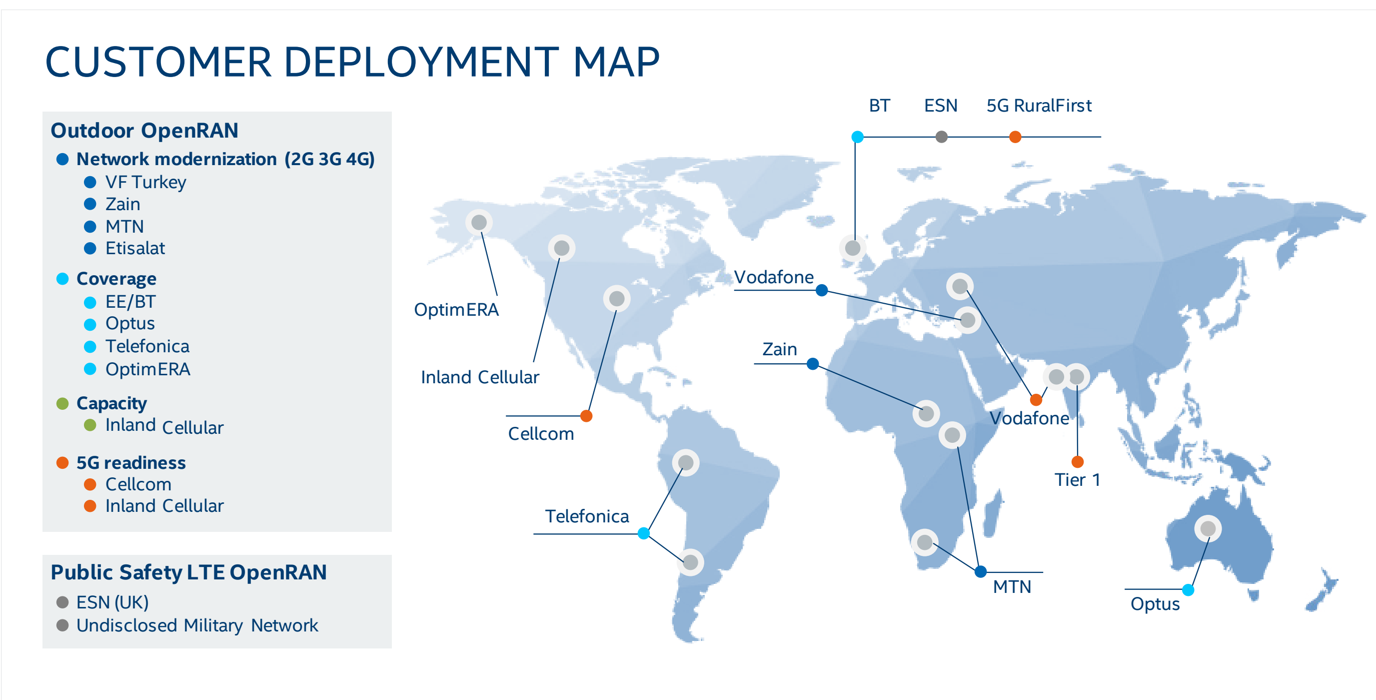

Figure 3. Chart of Parallel Wireless MNO customers organized by network need.

Network Intelligence Software Module
The Parallel Wireless Network Intelligence Software Module consists of real-time SON features as shown in Figure 1 as "resource management" functionality under real-time controller supporting ALL G networks. The features of the module simplify deployment and ongoing operations via automated maintenance, network orchestration for real-time optimization, and analytics. Combined, these features provide real-time insights into network health and automated service optimization. This software is built for cloud scale and is secure and scalable to meet the demands of large new service rollouts.

The Network Intelligence Software Module works with and complements all components of the Parallel Wireless solution—including RAN, Unified OpenRAN Controller, Unified Edge Core, and Security Gateway. It also supports network slices and RAN sharing across the network.

Analytics Capability: The Parallel Wireless Analytics Module consists of a comprehensive set of data analysis tools that provide rapid and actionable intelligence to help deploy, manage, and optimize network operations. The Analytics Module uses its analysis to provide understanding of data traffic patterns that help with automating service deployment, lifecycle management and reducing maintenance costs.

The Analytics Module (see Figure 4) can analyze a full range of data—including user reports, network conditions, network-connected mobile devices and IoT sensors, and external data such as weather, traffic, and events—to predict network conditions and issues. A unique feature for Parallel Wireless is analyzing data from container-based microservices and from network elements, including SON.

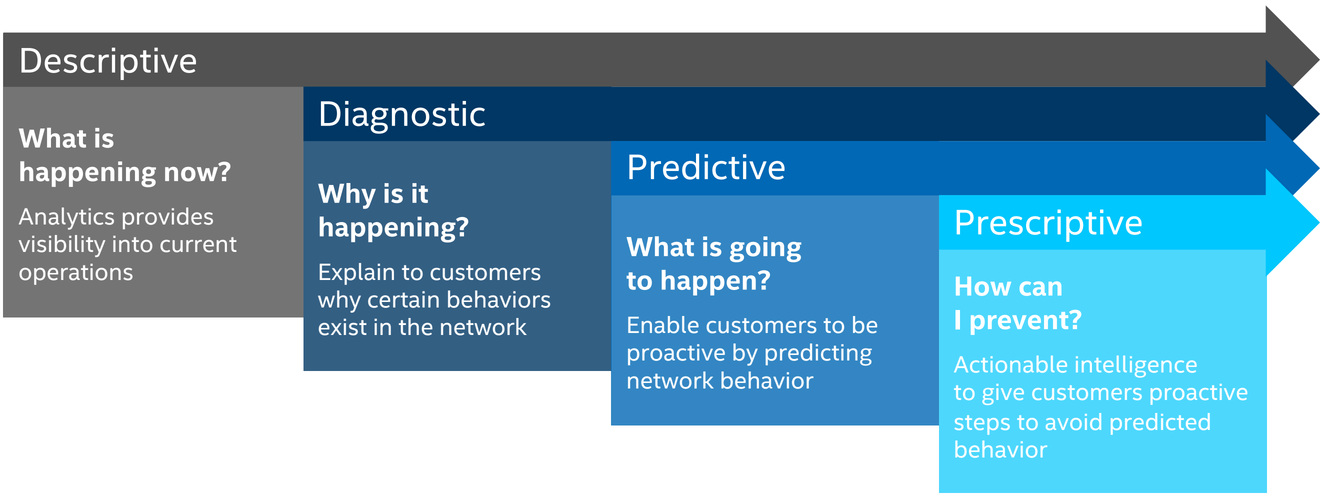

Figure 4. Parallel Wireless analytics module

The Analytics Module also provides northbound interfaces to makes its data available to other VNFs. One example is network-wide load balancing, where the analytics data ensures an appropriate workload distribution based on requirements for each of the network functions.

Some network functions, such as real-time interference management of the cells based on user equipment (UE) reports, may be deployed closer to the tower as virtualized functions. Other network functions that require more storage and computation, like trend analytics for network expansion planning workloads, can be deployed at the data center.

The Analytics Module also provides necessary data for training and inferencing of machine learning models essential for anomaly detection and prediction algorithms.

In one customer application, an in-vehicle cellular base station in a city bus communicates usage data to the Analytics Module. The OpenRAN controller analyzes this information and determines that one base station is crowded and anticipates an increased user load as the bus pulls into a crowded area. The platform is able to offload some of those users to a different base station with more capacity so users are not impacted.

Edge Core Software

Figure 5 illustrates Parallel Wireless's Edge Core, which is a virtualized evolved packet core solution consisting of MME, SGW, and PGW for 4G RAN. To support 5G networks, the Edge Core features AMF, SMF, UPF, and N3IWF, or any combination of these. Its scalable architecture allows flexible deployments, from small-footprint cost-efficient packet core from a few thousand, to millions of connected devices.

Parallel Wireless's Edge Core solution provides the ability to deploy distributed core with flexibility to distribute the different functions across the network as per the needs of the use cases. For edge deployments, the solution offers the following capabilities:

- Converged Edge solution for 4G/5G, Wi-Fi, fixed access
- Significant latency reduction for offloaded traffic (LBO), crucial for low-latency 5G traffic
- Value-added services, including Gi-LAN-enabled services offered at the network edge (NAT, tethering det, TCP opt, etc.)

This leads to following benefits:

- Provides a simplified converged distributed core solution
- Enables ultra low latency (ULL)-sensitive applications
- Allows the launch of value-added use cases and services to end users

Open RAN Hardware Ecosystem

The Parallel Wireless OpenRAN complete solution also features an ecosystem of virtualized functionality that replaces dedicated hardware appliances with VNFs running on Intel® Xeon® processor-based servers. The Intel Xeon processor family offers the performance for mission-critical and data-demanding workloads. With a range of price/performance levels, Intel Xeon processor-based servers allow MNOs the flexibility to cost-effectively deploy the software both in the network core and on the edge.

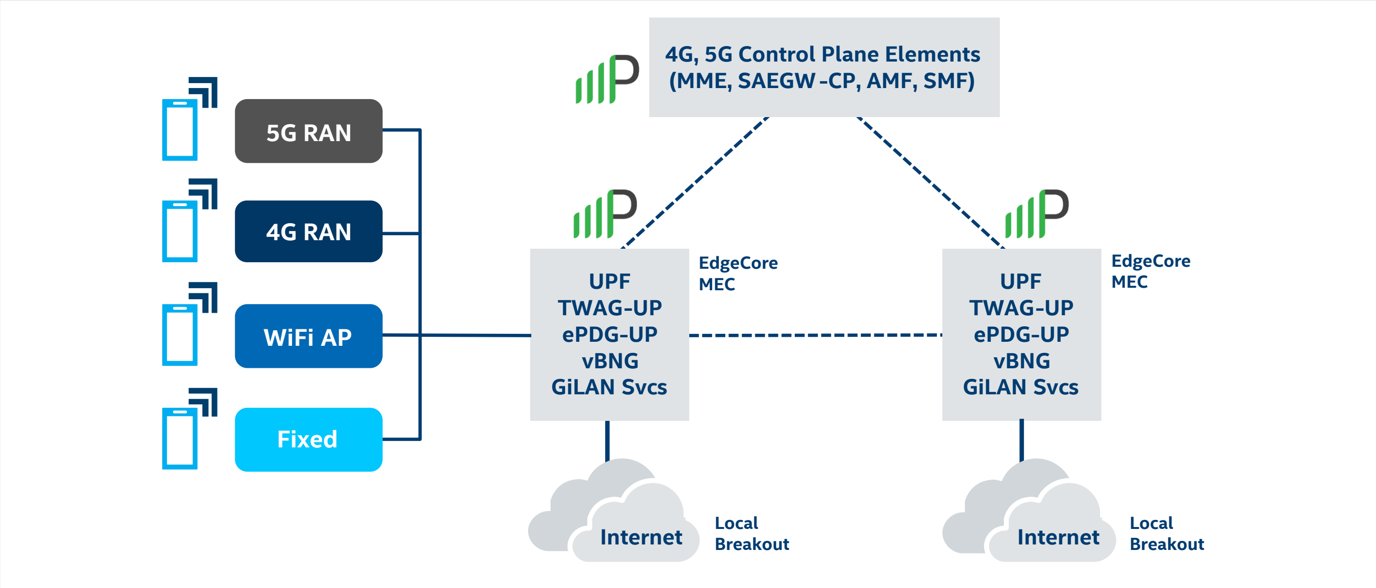

Figure 5. Software components of Parallel Wireless edge core solution.

Parallel Wireless OpenRAN support integrated (on Intel SoC) and split OpenRAN architectures (see Figure 6) based on Intel FlexRAN. All options can be deployed based on the customer use case: the integrated option is more applicable in rural areas with smaller user count and the need for an all-in-one approach where digital and RF processing happens inside the base station; the split architecture is applicable for capacity or coverage deployments in urban and suburban scenarios where digital processing is happening on the server, enabling more throughput and user counts for ALL G.

The hardware ecosystem solutions include the following:

- Virtualized Baseband Unit (vBBU) brings the future-ready architecture of a DU and a CU, deployed at the network's edge. The vBBU resources can be shared among multiple remote radio units (RRUs) on site in a multi-carrier 1-sector, 3-sector, or 6-sector configuration to achieve optimal resource pooling for low cost of operation. The BBU function is split between the CU and DU. This depends on which path the mobile operator is taking toward 5G, as there are many options that accommodate incumbent 2G, 3G, and 4G networks, as well as the level of integration between the current network and a new 5G network.
- Software-defined Remote Radio Head (vRRH) allows 2G, 3G, or 4G implementation, but as 5G grows in popularity, the radio hardware can be reconfigured to support ALL Gs, including 2G + 4G and 4G and 5G and, eventually, a pure 5G implementation—all without new hardware.

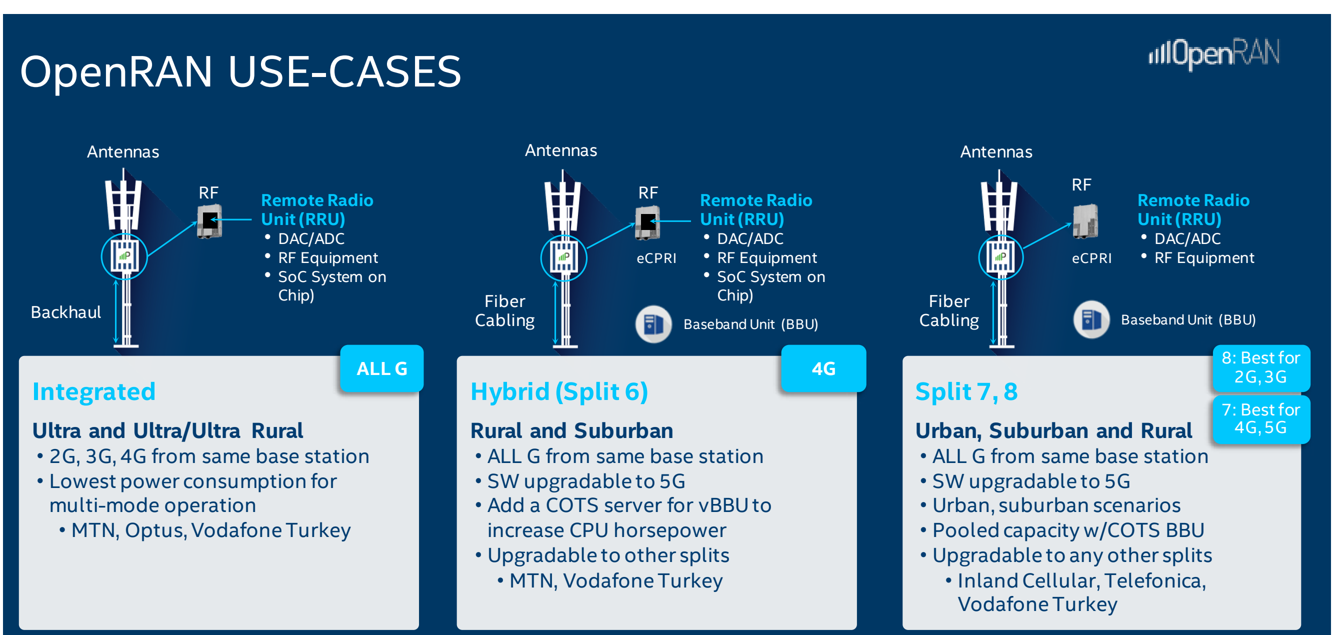

Figure 6. Supported types of OpenRAN use cases.

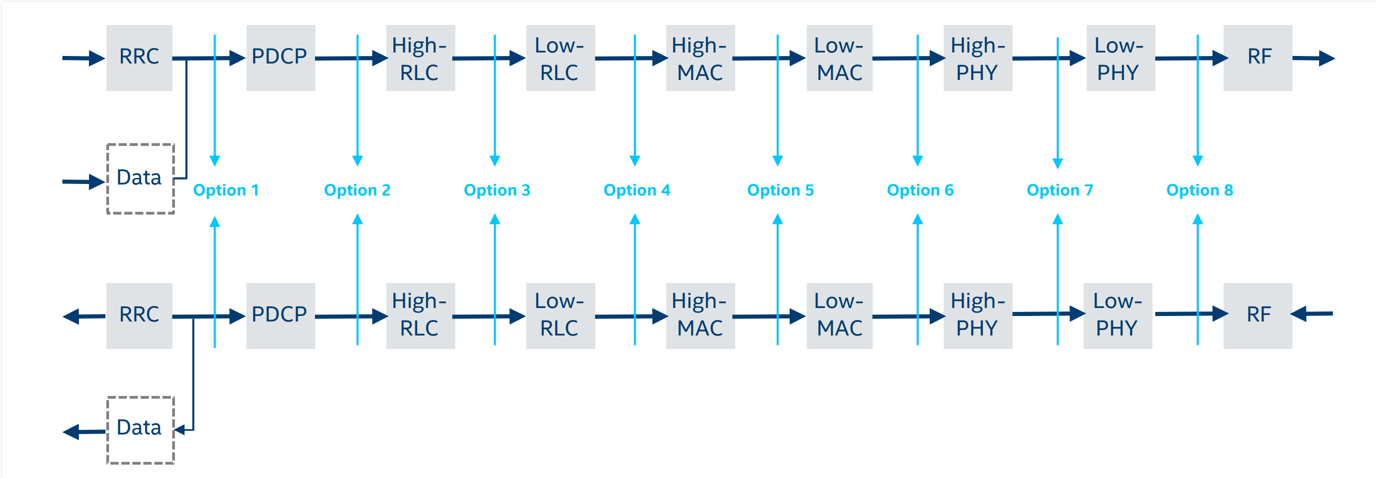

Figure 7. The eight 3GPP DU/CU split options available for different networks.

3GPP-Compliant RAN splits

Parallel Wireless 5G RAN virtualization will address all these requirements through its OpenRAN Software Suite as an anchoring point and aggregator.

Parallel Wireless OpenRAN can support all 3GPP compliant RAN splits). 3GPP considered the split concept (DU and CU) from the beginning for 5G. The gNB may consist of a CU and one or more DUs connected to the CU via Fs-C and Fs-U interfaces for CP and UP respectively. The split architecture will enable the 5G network to utilize different distribution of protocol stacks between CU and DUs depending on fronthaul availability and network design criteria.

The centralized baseband deployment is initially proposed to allow load-balancing between different base stations. Therefore, in most cases DU will be co-located with RRH to conduct all computationally intense processing tasks such as fast Fourier transform/inverse fast Fourier transform (FFT/IFFT) which are not load dependent and exhibit no sharing gains. CU can be separate or co-located with the aggregator depending on fronthaul availability.

Dynamic functional splits between a CU and DUs are an ideal approach for 5G systems and beyond. While CUs will maintain BBU-like functionalities, DUs will complement RRHs by providing extra processing capabilities, thereby increasing the capacity while reducing the fronthaul/midhaul bandwidth requirements.[3] In cases of more delay-sensitive service in 5G (including but not limited to beamforming and configuration), based on appropriate fronthaul availability, the MAC-PHY split will be the preferred solution. Parallel Wireless has developed its products to accommodate not just one specific split but with options that build in flexibility and the ability to create different splits based on different morphologies and deployment scenarios. Parallel Wireless's 5G RAN virtualization will address all these requirements through its OpenRAN software suite as an anchoring point.

Lower level splits, 7.x, are optimized for deploying future mobile networks in different environments and morphologies. While its requirements for fronthaul are not as demanding as split 8, by utilizing the vBBU our solution can support traffic in a dense urban area while maintaining a less-than-ideal backhaul to connect this local vBBU to the OpenRAN software suite.

Parallel Wireless recommends option 7.2 split of 3GPP for the case when high throughput and low latency fronthaul is available between vBBU and the RRH. This is a very efficient and practical PHY split, considering IFFT/FFT are not load dependent and add no sharing gain by accommodating it in the CU. RRH, vBBU and OpenRAN software suite products are naturally equipped to support Split 7.2.

Also, for rural areas where there is no reliable and high capacity fronthaul availability, the local vBBU connection to RRH will utilize a close-to-ideal fronthaul since they are in proximity and utilize less-than-ideal backhauls (for example, satellite links) to connect the vBBU (virtualized BBU/vBBU) to the OpenRAN Software Suite that acts as a vCU, orchestrator, and aggregator.

Open RAN is the key to next-generation mobile network infrastructure. The ALL G OpenRAN architecture, designed with cloud-native virtualization techniques, enables the hardware ecosystem and the ALL G RAN itself to adapt and scale in real time based on usage and need for coverage or capacity. This flexibility provides edge network location choices for the baseband processing fitting the existing networks' backhaul infrastructure, and it is future ready for any future backhaul architecture. In addition, it offers:

1. Ability to use non-ideal fronthaul (that is, Ethernet), overcoming the traditional constraints of CPRI over fiber: Legacy RAN platforms have been based on proprietary hardware and rely on long and costly life-cycles in development, deployment, and operation. This created vendor lock-in and the inability to keep pace with technology and demographic changes. With each generation of radio interface change, these radios are typically replaced with newer versions at a significant investment and inconvenience to the mobile operators, perpetuating the vendor lock-in.

2. Ability to select any COTS BBU and pool them as necessary for ALL G deployments: a strategic software differentiation by enabling the OpenRAN based Remote Radio Units (RRUs) to interwork with the COTS-based Virtualized Baseband Unit (vBBU), preventing vendor lock-in.

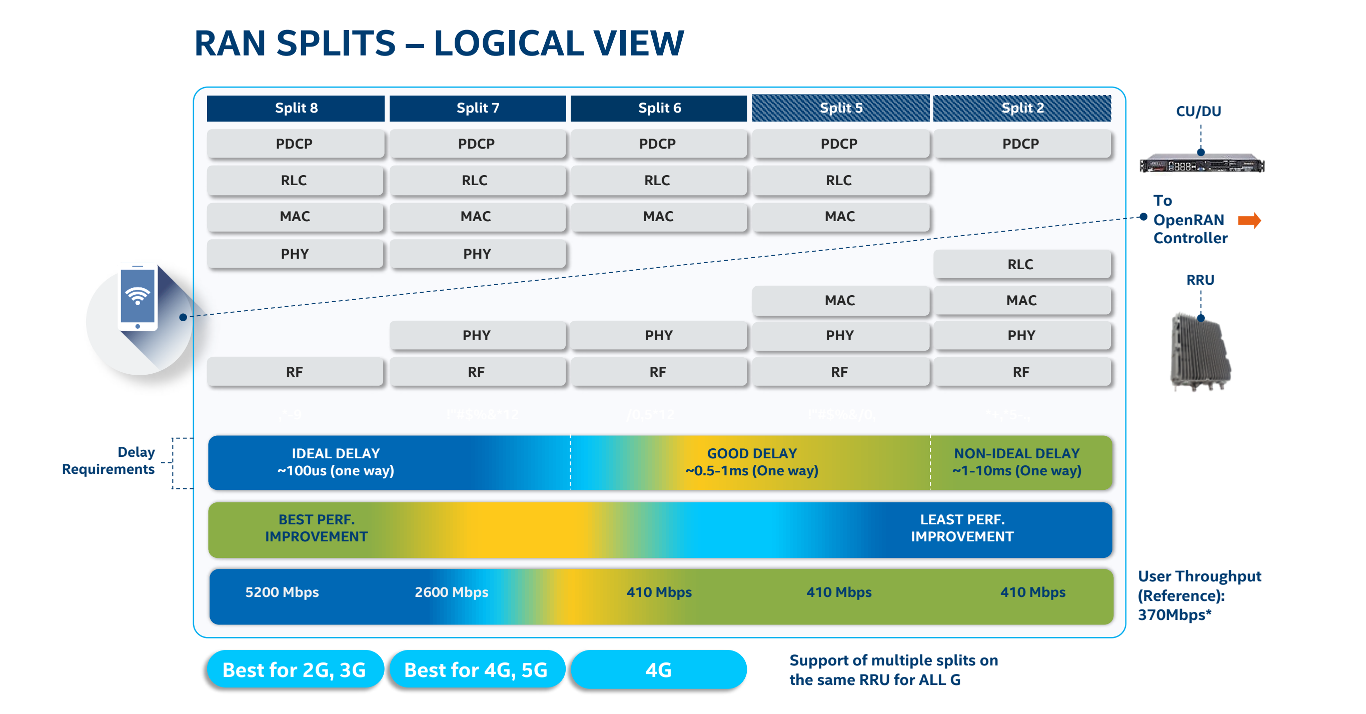

Figure 8. RAN splits options overview.

Parallel Wireless's innovative OpenRAN solution (vBBU and RRU) is truly open, and it is architected to address the requirements of 2G, 3G, 4G, and 5G networks with design and programming capabilities that enable software upgrades to 5G—providing investment protection and deployment flexibility in comparison to the legacy traditional radio infrastructure expansion that requires costly physical replacement in evolution race to 5G.

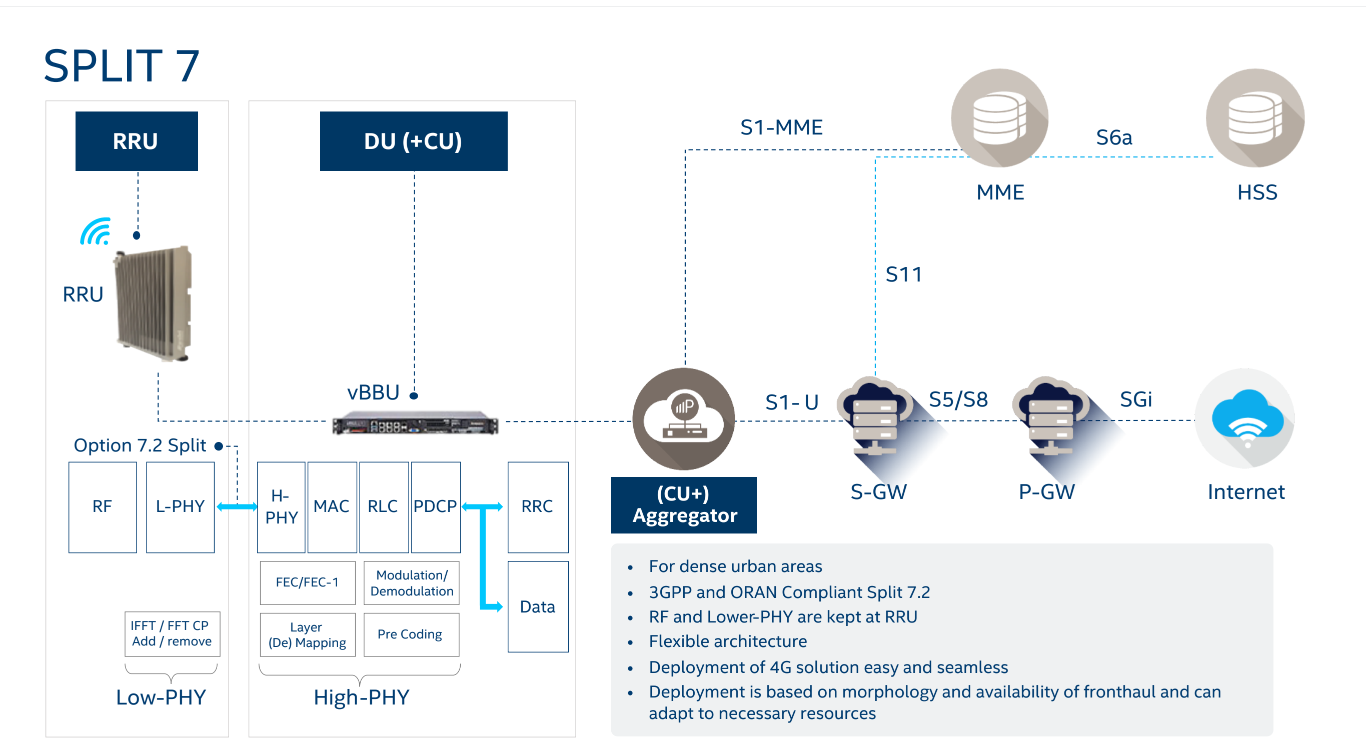

Figure 9. Parallel Wireless split architecture

Deployment Scenarios

The overall solution is compliant with ETSI's NFVI architecture, agnostic to the underlying data center infrastructure, so can use any Intel architecture-based server. The solution has been certified and deployed with all major market-leading hypervisors. It can be managed via any standards-compliant VNF Manager (VNFM) and NFV Orchestrator (NFVO). Parallel Wireless has a strong partnership ecosystem in place with all leading vendors in the virtualization space.

Examples of deployment scenarios:

- Coverage: providing new RAN coverage to areas without mobile service
- Capacity/Densification: adding capacity to existing 2G/3G/4G networks
- Network modernization: replacing outdated legacy technologies (that is, 2G and 3G) with newly virtualized functions, along with newer technologies like 4G and 5G, all with the same architecture
- Network expansion: deploying Parallel Wireless Open RAN solution to extend and expand coverage as an addition to an existing network

Conclusion

Parallel Wireless's OpenRAN solution combines open standards with a full range of functionality to enable a complete vRAN to support the move to 5G or the expansion of any "G" networks. The solution is able to replace the most compute-sensitive part of a wireless network with software running on general purpose servers powered by Intel architecture CPUs for network scalability, agility, and low capital expense costs.

About Parallel Wireless

Parallel Wireless offers a unified 2G/3G/4G/5G software-enabled solution based on OpenRAN. This cloud-native network architecture redefines network economics for global MNOs in coverage and capacity deployments while paving the way to 5G efficiently and cost effectively. The company is engaged with many leading operators worldwide and has been named as a best performing Open RAN vendor by Telefonica and Vodafone. Parallel Wireless's innovation and excellence in multi-technology Open virtualized RAN solutions has been recognized with 75+ industry awards. More information on Parallel Wireless is at https://www.parallelwireless.com.

About Intel Network Builders

Intel® Network Builders is an ecosystem of infrastructure, software, and technology vendors coming together with communications service providers and end users to accelerate the adoption of solutions based on network functions virtualization (NFV) and software defined networking (SDN) in telecommunications and data center networks. The program offers technical support, matchmaking, and co-marketing opportunities to help facilitate joint collaboration through to the trial and deployment of NFV and SDN solutions. Learn more at http://networkbuilders.intel.com.

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[1] https://telecominfraproject.com/openran/

[2] https://www.o-ran.org/

[3] https://www.o-ran.org/specifications

[4] https://www.parallelwireless.com/case-studies/

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