Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Promoting the Deployment of 5G Open Radio Access Networks	)	GN Docket No. 21-63
	)	

REPLY COMMENTS OF VERIZON

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INTRODUCTION AND SUMMARY

Verizon[1] welcomes the opportunity to provide comments on the FCC's Notice of Inquiry[2] on Open Radio Access Networks ("Open RAN"). Open RAN offers the promise of a wide range of benefits that could introduce new competition and innovation into the RAN vendor ecosystem, and Verizon is fully supportive. But this transition will be complex, and network operators will need significant flexibility to make the transition in a way that protects the customer experience and the quality and security of their networks.

Verizon is working toward the incorporation of Open RAN solutions into its network and is a leader in both the O-RAN Alliance, which is developing specifications for Open RAN, and the Open RAN Policy Coalition.[3]

As the *NOI* describes, Open RAN holds the promise of increasing supplier diversity and competition in the RAN solutions market through the establishment of open and interoperable interfaces between different hardware and software components within the RAN itself. The transition to Open RAN has the potential to bring many benefits in terms of deployment flexibility and greater supplier choice by increasing the opportunity for new entrants to provide competitive and innovative RAN solutions. Ultimately, Open RAN will benefit consumers through successful implementation that increases supplier diversity, competition and flexibility in deploying new solutions.

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[1] The Verizon companies participating in this filing are the regulated, wholly owned subsidiaries of Verizon Communications Inc.

[2] *Promoting the Deployment of 5G Open Radio Access Networks*, Notice of Inquiry, GN Docket No. 21-63, FCC 21-31 (Mar. 18, 2021) ("*NOI*").

[3] *See* About O-RAN Alliance, https://www.o-ran.org/about; Open RAN Policy Coalition, https://www.openranpolicy.org/about-us/board-and-executive-committee/.

While Open RAN promises many benefits, the evolution to Open RAN will be a complex technical journey, and there is yet much work to be done to ensure seamless interoperability while minimizing complexity for network operators, both of which are needed before Open RAN can be implemented at scale. It is important to recognize that wireless networks are not entirely software-based, and include a number of hardware elements such as antennas and hardware accelerators that must operate together. In order to support the development of the Open RAN supplier ecosystem, Verizon supports programs such as those established by the USA Telecom Act[4] that created the Public Wireless Supply Chain Innovation Fund to promote research and development of Open RAN.

Network operator decisions on deployment of new network technology using Open RAN are based on a number of complex technical and business factors unique to each operator. Much work remains to be done by the technical groups within the O-RAN Alliance and standards bodies such as the Third Generation Partnership Project ("3GPP") to develop Open RAN's capabilities to deliver advanced functionality demanded by 5G networks. Establishing open and interoperable interfaces are just the initial steps in the evolution of this emerging technology. There are numerous examples of Open RAN being deployed around the world, and though they may differ from each other in terms of scale, performance, functionality, and interoperability, these are all important examples of Open RAN's ongoing development. There are also important distinctions between networks that are being deployed as greenfield and those where Open RAN is being adapted to existing networks.

[4] Utilizing Strategic Allied Telecommunications Act of 2020, H.R. 6624, 116th Cong. (2020) ("USA Telecom Act").

While Verizon supports efforts to raise awareness around Open RAN and to accelerate the maturation of the ecosystem through funding of R&D, Verizon does not believe the FCC, or governments generally, should either require network operators or suppliers to deploy Open RAN or create incentives that skew decisions in favor of Open RAN in a way that distorts the competitive market between operators and between suppliers. Disruption in the marketplace is most effective and sustainable if it is based on the technical merit and track record of the competing technological alternatives rather than from regulatory intervention.

The O-RAN Alliance – which was created by network operators and counts the world's leading operators among its members – is testimony to the strong interest by operators globally in the development of Open RAN. Given the complex technical, network planning, and business factors each operator weighs when making network decisions, a government requirement to implement Open RAN would undermine its success and be counterproductive to the more rapid deployment of advanced wireless services. Government support for the development of Open RAN ecosystem will be the most effective and appropriate use of public resources to meet the public policy interests of increasing supplier diversity.

I. OPEN RAN IS A JOURNEY IN PROGRESS

Verizon is an industry leader in Open RAN and is on the path to deploying Open RAN solutions. Verizon takes pride in the performance and reliability of its wireless networks. Transitioning to a new architecture and new suppliers requires meticulous planning, testing and integration to ensure reliability, functionality, and performance.

Verizon has launched commercial Virtual RAN (vRAN), including Virtual Distributed Unit (vDU) and Virtual Central Unit (vCU) functions deployed on common off-the-shelf

hardware.[5] Verizon's vRAN efforts parallel and overlap with its Open RAN efforts. Virtual RAN provides flexibility by disaggregating the baseband software from hardware, and supports both deploying at scale and management of the network, while Open RAN allows for equipment from different suppliers to be combined. Following the conclusion of the FCC's recent C-Band auction, Verizon also announced that its suppliers will be providing Open RAN compliant equipment to support its C-Band and millimeter wave 5G deployments by the end of 2021.[6] These efforts demonstrate Verizon's leadership and commitment toward further development of the Open RAN ecosystem.

While Verizon is laying the groundwork for a transition to Open RAN that should ultimately offer Verizon the best option for a given application, Verizon does not believe that the choice for operators in the future should only be Open RAN. There may be circumstances – even when open and interoperable interfaces are widely available in RAN components – that the best choice is a vertically integrated, proprietary system. Wireless providers will be best positioned to determine the right mix of vendors and technology to best serve their customers.

Open RAN is promising, but there remains work to be done to fully realize that promise. Bodies like the O-RAN Alliance and 3GPP are developing technical specifications and standards for Open RAN, but there will still be many unspecified and non-standardized functionalities that Open RAN will need to support for network operators who provide customers with advanced wireless capabilities at scale. Developing those functionalities will require time and significant,

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[5] *See NOI*, ¶ 27 & n.72; Verizon Press Release, "Verizon completes first successful end-to-end fully virtualized 5G data session in the world" (Aug. 25, 2020), https://www.verizon.com/about/news/verizon-fully-virtualized-5g-data-session.

[6] *See* Mike Dano, "Verizon to start deploying open RAN gear this year," LightReading (Mar. 11, 2021), https://www.lightreading.com/open-ran/verizon-to-start-deploying-open-ran-gear-this-year/d/d-id/768021.

continued R&D. With the USA Telecom Act, Congress recognized the importance of supporting the burgeoning Open RAN ecosystem and the benefit of providing federal funding through the NTIA to accelerate its development and maturation. Assuming that Congress will fund the programs created by the USA Telecom Act, this should provide meaningful support for the development of emerging Open RAN solutions. As suggested by the *NOI*, the FCC should consider ways to partner with NTIA and other bodies to help create future-looking testbeds and other trials to advance the development of Open RAN.[7]

Network operators like Verizon will also play a significant role in supporting the growth of Open RAN. For network operators who have large-scale networks built on vertically integrated RAN solutions, the journey to Open RAN begins with procuring equipment from existing suppliers that is Open RAN compliant, thereby enabling a transition to multi-vendor solutions. This transition will depend upon each operator's unique network planning and capital investments; each equipment vendor's technological performance and service capabilities; availability of spectrum and other scarce resources; and, the rate of technological advances. With respect to non-standalone, millimeter-wave 5G cellular networks that rely on legacy 4G LTE components, some backwards compatible functionality may not exist in new Open RAN equipment, making interoperability with those legacy systems impossible. Further impacting vendor decisions will be that some Open RAN suppliers may not offer all the new functionality conceived for 5G systems.

The vision for vRAN technology which complements Open RAN is to allow network operators to provision wireless networks in much the same way that cloud service providers provision servers in data centers: provide power, cooling, and transport connections by utilizing

[7] *See NOI* ¶ 77.

commercial off-the-shelf (COTS) hardware for the particular workloads. In the fullest realization of this vision, the architecture allows an operator to scale and/or share workloads depending on the need and through automation/orchestration of the network end-to-end. Almost all systems integration would be performed through software. Realization of this model at scale and with the functionality demanded by 5G will take time due to the technical and operational challenges related to implementing a RAN using COTS hardware.

II. INDUSTRY STANDARDS AND IPR PREDICTABILITY

The development of mature technical standards for Open RAN, together with appropriately calibrated intellectual property protections, will be central to its success and deployment. Operators are already leading the way in the development of the specifications and standards around Open RAN. The O-RAN Alliance and other global standards bodies such as the European Telecommunications Standards Institute and 3GPP are working toward these ends. We do not see a benefit for governments in directing or influencing the development of these standards. Until Open RAN specifications and solutions are mature, heightened intellectual property rights (IPR) infringement concerns may introduce uncertainty in the marketplace. Standards define interoperable and globally scalable solutions, but standards bodies will need also to promote cross licensing of fundamental Standard Essential Patents (SEPs) and other intellectual property rights through enforcement of IPR Policy.

3GPP has already adopted 5G standards in which network functions may be virtualized and performed using COTS hardware. But the 3GPP standards do not provide detailed instructions for specific implementations of an actual virtual RAN deployment. Efforts are underway within groups including the O-RAN Alliance, Open Networking and Automation

Platform, and Open Compute Project, among others, to further specify standards for implementation of vRAN, and in some cases provide open source software implementations.

Generally speaking, there are both economic/commercial and technical challenges inherent in the standards process around Open RAN. Economic/commercial challenges include overcoming incumbent supplier objections to new technologies that may eventually replace existing products. Technical challenges generally relate to 5G wireless network-specific constraints that do not exist for traditional virtualized software deployments, such as extremely low latency requirements (potentially requiring workload-specific hardware accelerators), support for 5G-specific communication protocols rather than HTTP, energy efficiency, and security. It is important to note that Open RAN is not intrinsically more or less secure than vertically integrated RAN. In both models, security is dependent on how they are implemented.

The need for open standards in building and maintaining networks has been demonstrated in the development of 4G LTE and earlier generations of network technology. The option to implement open source software is new to 5G technology, and results from software virtualization of network functions traditionally performed by dedicated hardware starting within the core network and reaching (potentially) all the way out to the analog-to-digital and digital-to-analog converters attached to antennas in radios embedded in, or in close proximity to, user equipment. An open source implementation may create a new degree of transparency and visibility into software functionality.

Virtualized software development has been driven by large-scale multilateral collaboration across industry and other stakeholders. The United States government should support full Open RAN development by encouraging grants to academic and non-profit software research labs for open source implementations of 5G RANs and other related 5G (and beyond)

network functions. Without public funding for a public reference, open source implementation, it is doubtful that any private company will invest the resources necessary to explore this aspect of Open RAN benefits.

Access to Standards Essential Patents on Fair, Reasonable and Non-Discriminatory (FRAND) terms is another important factor as it will limit the uncertainty around intellectual property right infringement challenges that delay the development of new technologies such as Open RAN. This would lead to greater cross-licensing and less disruptive patent litigation.

III. HOW THE FCC CAN SUPPORT OPEN RAN

The FCC can support the development of Open RAN through a variety of ways. The FCC will provide a valuable perspective in engaging with NTIA and other government agencies in identifying, reviewing and approving R&D projects for the Public Wireless Supply Chain Innovation Fund and other programs. It can also work with agencies such as the Commerce Department and the Department of State to engage with policymakers internationally on the expected benefits of Open RAN. Facilitating interoperability and integration by sponsoring plugfests for different Open RAN solutions providers would also help support growth of the Open RAN ecosystem.

As the *NOI* highlights, there is growing global momentum and interest around Open RAN development with many different examples of companies working with new entrants in the marketplace for RAN equipment. Indeed Verizon is working with both existing and new suppliers to work toward an Open RAN-based network. We are also unaware of any FCC regulatory position that favors one network architecture over another, and we are unaware of any constraints on Open RAN posed by any existing FCC rules. In fact, we support the FCC's

longstanding principle of technology neutrality, which we think should continue to guide its approach to Open RAN. As stated earlier in our comments, we do not support any regulatory mandates that would force procurement or deployment of Open RAN solutions, as such mandates would be counterproductive to the ongoing deployment of advanced wireless networks and could undermine the future of Open RAN if operators are forced to deploy it prematurely.

Similarly, the FCC should not tie spectrum licenses or other authorization to requirements to deploy Open RAN. The FCC's licensed, flexible use approach to spectrum is globally recognized as having spurred great investment and innovation in wireless services. It is important to emphasize that expensive network deployment decisions are based on a number of factors, including the regulatory environment.

IV. THE INTEGRATION CHALLENGE

As Open RAN matures, it will offer opportunities for new entrants into the RAN marketplace by offering micro services and disaggregated solutions. There will be increasing complexity and integration costs associated with integrating different components at scale and ensuring interoperability at the level of reliability that network operators' demand. Indeed, one of the bigger challenges in a virtualization environment is integration, where more focus and responsibility is on the operator to ensure systems integration across multiple partners to meet its requirements and performance expectations. Extensive testing is a must as is the tight collaboration between operators and vendors to integrate functions. Right now Verizon is playing a larger role with respect to Open RAN integration than it typically would in a vertically integrated RAN model.

The more suppliers that are introduced in the RAN environment, the higher the interoperability testing complexity. At this point it is difficult to determine where the burden will ultimately fall – supplier or operator – in a more mature Open RAN environment. Should the FCC seek to assist in this area, it might consider ways in which it could support plugfests to enable different vendors to test and demonstrate interoperability between their different product offerings, such as radio integration with virtual baseband functions and/or multivendor baseband environments where interoperability support is a requirement. Support for test beds and R&D would also be helpful.

Performance in a multivendor environment can be more difficult to optimize. For example a multivendor environment can require greater coordination around applying software patches, which requires a complex validation matrix. System architecture and scale of the deployment also are factors in optimizing performance in a multivendor environment. Other challenges to implementation of Open RAN include the need for more precise timing and synchronization than standard virtualization software; workload-specific acceleration; low-latency load balancing and inter-process communication; improved energy efficiency; and fully-integrated security.

Interoperability of components within the RAN are key to achieving the full benefits of Open RAN. In 5G RAN architecture, the baseband unit (BBU) functionality that before had been combined into a single BBU has been disaggregated into two functional units: a distributed unit (DU) and a centralized unit (CU). To realize the full benefits of Open RAN, interoperability of virtualized CUs and DUs with radio units from different vendors is required. Even when vendors agree on standards that allow for CUs and DUs to be virtualized, if there is no common interface for communication between them (and between them and other parts of the network,

including Network Management Systems), operators will be locked into working with a single vendor to provide all of the equipment needed for a virtualized RAN. The O-RAN Alliance is working on specifications for some of these interfaces, which will require testing and integration when deployed.

One of the challenges to accelerating Open RAN is the lack of incentive of any for-profit entity (whether incumbent or new entrant) to publish or open source a complete Open RAN implementation. Incumbent equipment vendors can build proprietary vRAN solutions that lack interoperability. New entrants can develop complete "Open" RAN alternatives based on open source software with a proprietary integration and orchestration layer. Both are likely to keep as much of their work private as possible to keep or gain market share. Grants to academic and non-profit labs specifically aimed at development and publication of a complete, public Open RAN implementation could help overcome this challenge and accelerate commercialization of Open RAN technology.

V. INCREASING SUPPLIER DIVERSITY

Open RAN is an evolution in network architecture that should enable greater modularity, and, as a result, greater opportunity for new entrants to compete in the RAN equipment space. Ideally, the success of Open RAN will help overcome the challenge of vendor lock-in experienced with the vertically integrated model, and the result should be more competition, more innovation, and increased vendor diversity.

Open RAN will be built on virtualized network infrastructure, so the availability of a robust supply chain with high performance hardware components will be an important aspect of improving supplier diversity. Compute and storage capability of COTS hardware will still need

optimization to support the dense footprint, energy efficiency, and cooling requirements that the software will utilize. This may create tiers of performance within the COTS supply chain. The interoperability of virtualized RAN devices is crucial to achieving the full economic benefit of Open RAN. If the RAN is virtualized, but can only interoperate with radios or baseband units from the same manufacturer, some characteristics of the system (including performance and power consumption) may actually be worse without the offsetting benefit of vendor diversity and competition within the RAN. This is because without a truly open implementation, the resilience and performance of the overall system may be optimized to achieve specific goals of a particular vendor rather than a global optimum beneficial to the customer.

Certain hardware components cannot be virtualized, including the antennas and mixed signal semiconductors needed to transmit and receive signals over 5G networks. Mixed signal semiconductors necessary to handle the low latency, high-bandwidth requirements will still need to be sourced. Similarly, even if Open RAN is fully implemented, workload-specific hardware accelerators may still be desirable. Hardware accelerators include Application Specific Integrated Circuits (ASICs) or Field Programmable Gated Arrays (FPGAs) designed to implement Central Processing Units (CPUs) or Graphics Processing Units (GPUs) designed for specific types of computations, such as machine learning or computer vision. Development of newer instruction set architectures like ARM and RISC-V to compete with existing x86 architectures will also be important in this process. Overall health of the semiconductor supply chain, including having diverse, robust, and scalable sources for design and fabrication are also important to 5G.

Tight integration of workload-specific accelerators (such as ASICs or FPGAs) and improved energy efficiency may be key differentiators for new entrants in the RAN vendor

market. Incumbent equipment vendors have been able to achieve these goals through custom hardware and software integrations. By moving from custom to COTS hardware, operators gain vendor diversity but may lose some of the speed and power efficiency of custom solutions. New entrants may be able to compete by focusing narrowly on offering customizations to the COTS hardware for specific RAN components that can be sold to any operator and mixed and matched with other vendor equipment.

Cost benefits to operators from Open RAN deployment will likely vary by operator depending on the pace of deployment and whether the deployment is brownfield (on top of traditional RAN architecture) or a brand new greenfield deployment. To achieve the widest possible benefit, government efforts to promote Open RAN should focus on R&D.

It is important to recognize that there are a number of factors that have contributed to the current constrained supplier landscape, many that have been well documented.[8] While Open RAN is part of the solution toward creating a more diverse supplier base, we think that it would be unrealistic to believe that its successful deployment alone will address the larger global policy challenges that have led to the current supplier diversity concern. The potential solutions to those challenges and pressures depend on factors that lie beyond just the success of Open RAN architecture.

[8] *See Accelerating 5G in the United States*, Center for Strategic and International Studies (CSIS) (Mar. 1, 2021), https://www.csis.org/analysis/accelerating-5g-united-states (follow "Download the Report"); *see also* James A. Lewis, *How 5G Will Shape Innovation and Security*, CSIS (Dec. 6, 2018), https://www.csis.org/analysis/how-5g-will-shape-innovation-and-security.

VI. SECURING OPEN RAN

Verizon is a leader in the U.S. and globally in deploying secure and reliable wireless network infrastructure. Security is built into 5G standards, which will also be expected in relevant Open RAN components.[9] Security is also a function of a number of factors, including the hardware and software components. Verizon views the vertically integrated model and the modular Open RAN as each having their own unique security attributes that are dependent on successful implementation when deploying and operating the network. Many of the security concerns expressed about Open RAN were similarly expressed with cloud-based data architecture – in fact the more distributed nature of the cloud parallels that of a more distributed RAN software architecture. And one of the benefits of virtualization of functionality traditionally performed by dedicated hardware is that COTS hardware and virtualized software can be more easily swapped out without interruption of service.

While virtualization through hypervisors (software that runs virtual machines) or containers does abstract details away from the hardware on which an application runs (on the hypervisor or in the container), compromised hardware can still allow for backdoors into the operating system on a given device, and therefore compromise of any software running on the device. This is especially a concern for custom hardware accelerators (ASICs or FPGAs) used to translate communication protocols (hence having direct access to packet content).

Verizon takes a zero trust approach to security, building in protections that assume the operating environment is not without potential vulnerabilities. In a multi-vendor RAN environment new paradigms will need to be established by network operators and vendors to

[9] *See The Security of Verizon's 5G Network: Network Security Planning 1.0* (Aug. 2020), https://www.verizon.com/about/sites/default/files/2020-09/200574_Schulz_07242020.pdf.

quickly identify points of failure and remediate issues that arise in an Open RAN framework. These arrangements will likely build on the current contractual framework that govern supplier obligations around security to network operators.

While Open RAN can provide comparable security to vertically integrated systems, whether it provides enhanced security will depend on whether it relies on open source software for implementation of key functionality. A virtualized RAN that complies with Open RAN standards, but relies on proprietary software to implement those standards, has no systemic advantage to any other proprietary software system. Open Source software has advantages over proprietary software from a security perspective because it allows for more eyes to be on the code, allowing bugs to be spotted and patched quicker. Open RAN standards may also incorporate requirements for reporting of open source software dependencies to facilitate more rapid identification and patching of vulnerabilities.

Open source software has its advantages and disadvantages. An Open RAN solution using open source software would have some security advantages because, in addition to allowing for remote software updates, more of the code base running on individual components would be exposed to scrutiny by engineers and scientists interested in security.

The main disadvantage to open source software is that attackers can review the version history of a given open source project and identify open source software dependencies that may have had known vulnerabilities reported. Operators need to move quickly to patch vulnerabilities through remote updates as quickly as they are identified. Operators would need to keep pace with the identification of known vulnerabilities. This could foster a culture in which remote software updates happen routinely, both to implement improvements to network features and functionality and to patch vulnerabilities. Any virtualized RAN cannot be treated as a static

fixture; it needs to be maintained as a dynamic complex system. Another disadvantage may result from use of open source subject to license conditions that require any modifications or derivative works be made available, such as the GNU General Public Licenses (GPL).[10] If the modifications or derivative works represent source code that performs sensitive security functions, a demand for compliance with the GPL license obligations could result in a security compromise. But these kinds of risks can be mitigated through careful open source license compliance practices.

We don't see any particular advantages or disadvantages from Open RAN to public safety. Once mature and deployed at scale it can be expected to deliver the same, or exceed, the reliability that is present in existing RAN architecture.

VII. BENEFITS OF MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

Machine Learning (ML) and Artificial Intelligence (AI)-based RAN optimization is already available to a limited extent in a vertically integrated RAN system.[11] Open RAN may benefit from ML and AI innovation using a variety of data that can be made available to RAN Intelligent Controllers operating at different time scales. Such innovation may lead to better network operation efficiencies, improved performance, and enhanced user experiences. Also, it may allow over-the-top innovation and app development for RAN by non-RAN vendors. There are still challenges to be overcome, however, including standardization of relevant APIs, compatibility/interoperability with other Open RAN components, etc. While AI/ML-based Open

[10] GNU Operating System, https://www.gnu.org/licenses/licenses.html.
[11] For example, Remote Electrical Tilt of the antenna is already available in vertically integrated RAN.

RAN Intelligent Controller focused development is promising, it is expected to pass through its own technical journey before being able to provide its full benefits to network operators.

VIII. BENEFITS TO VERTICALS

Network slicing and 5G architecture already bring benefits to vertical applications such as smart cities, automotive, and telehealth. There are emerging testbeds/pilot projects examining whether there are new benefits that Open RAN could provide, though it is still too early to know the results of these efforts. For example, MITRE Engenuity's Open Generation Consortium is bringing together different technology leaders to develop innovations to take advantage of the capabilities enabled by 5G.[12] Northeastern University's Colosseum project is another example of efforts to explore and test IoT solutions through open interface wireless architecture.[13] Projects such as these are building an understanding of the potential added benefits of Open RAN for specific applications.

[12] *See* Mitre Engenuity, "Open Generation Consortium: Radical Collaboration to Drive Breakthrough Innovation" (Nov. 10, 2020), https://mitre-engenuity.org/5g/opengeneration/.
[13] *See* Northeastern University, "Colosseum: The World's Most Powerful Wireless Network Emulator, https://www.northeastern.edu/colosseum/ and https://www.northeastern.edu/colosseum/wp-content/uploads/2020/01/colosseum_brochure.pdf

IX. CONCLUSION

Verizon appreciates the FCC's interest and support for Open RAN and supports U.S. government R&D grants to help the ecosystem mature. We look forward to future opportunities to provide our views on this important technological evolution in the RAN.

Respectfully submitted,

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