Before the
DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, DC 20230

In the Matter of	)	
	)	
Public Wireless Supply Chain Innovation Fund	)	Docket No. 221202-0260
Implementation	)	RIN 0693-XC05

COMMENTS OF NOKIA

Nokia submits these Comments to the National Telecommunications and Information Administration ("NTIA") in response to the above-captioned request for comments on the implementation of the Public Wireless Supply Chain Innovation Fund, as directed by the *CHIPS and Science Act of 2022,* and in particular on the grant program to support the promotion and deployment of open, interoperable, and standards-based radio access networks (RAN).

I. INTRODUCTION AND SUMMARY

At Nokia, we create technology that helps the world act together. As a trusted partner for critical networks, we are committed to innovation and technology leadership across mobile, fixed, and cloud networks. Nokia has been a major part of the U.S. communications ecosystem from the beginning, providing networks and devices through multiple generations and evolutions. Our network solutions securely connect over 90 percent of the U.S. population. Nokia currently employs roughly 7,300 individuals in the U.S. and through our procurement from U.S. companies, we support an additional 40,000 indirect jobs. With five U.S. R&D Centers and the world-renowned Nokia Bell Labs, we are deploying 5G networks and cloud-

native software with all major U.S. communications service providers and providing mission-critical private networks for U.S. enterprises and public sector agencies.

Nokia's R&D efforts toward cutting edge advancements, including in 5G, 6G and Open RAN, are led by the storied Bell Labs, headquartered in Murray Hill, New Jersey. We have led numerous industry efforts to progress Open RAN to its current state, and we continue to work to advance Open RAN. For years, we have driven the policy frameworks and technical specifications of Open RAN through our participation in the O-RAN ALLIANCE, the Linux Foundation's ONAP initiative, ETSI's Multi-access Edge Computing (MEC) initiative, the Telecom Infra Project, the Open RAN Policy Coalition, and more. We are also active participants in multiple real-world deployments involving early-stage open interfaces, giving Nokia hands-on experience deploying this network architecture.

Our longstanding leadership in the area of open and collaborative architectures led to the opening in 2021 of our Open RAN Collaboration and Testing Center in Dallas, Texas. The Center is designed to support the development of partnerships among Open RAN vendors that will help with the verification, introduction, and launch of Open RAN compliant solutions to market. The project is the latest in Nokia's continued commitment to Open RAN, vRAN, and Edge Cloud innovation.

Nokia has a clear market incentive to embrace Open RAN architectures. While the current environment and state of technology continues to favor single-vendor solutions, Nokia and our customers have long understood and supported the march toward open architectures. In collaboration with other vendors and developers in our industry, we expect to partner with our customers and provide the equipment that they demand to build the innovative networks that serve their customers. Nokia also believes that Open RAN architectures are

critical for any company, including Nokia, wanting to gain global share of the RAN market. Nokia continues to offer best of breed RAN equipment and services and we are confident that easier swaps of equipment through Open RAN interfaces will allow Nokia technology to shine and continue to be a key choice for new potential carrier, enterprise, and government customers.

Below we respond to the specific lines of inquiry posed in this proceeding. We first describe the inherent openness of the 3GPP standards process that is critical to the evolution of telecommunications networks. We then provide Nokia's perspective on the challenges facing Open RAN and where funding could accelerate the ecosystem, including complexities of integration, need for improved product features/capabilities, greater energy efficiency, and others. Next, these Comments address Open RAN workforce constraints -- and technical areas of the greatest need -- followed by a discussion of standards and specification development and how greater resources could accelerate Open RAN. We then address the importance of Open RAN certification to gain customer confidence.

In these Comments, Nokia is pleased to present 11 specific examples of research, development, demonstrations, and testbeds that could be particularly fruitful in accelerating Open RAN and would be excellent candidates for funding. We close the Comments with a discussion of security and the importance of leveraging a global ecosystem for Open RAN advancement.

II. OPENNESS OF THE 3GPP 5G STANDARDS PROCESS

In the context of Open RAN, there is an understandable focus on the critical work of the O-RAN ALLIANCE to develop specifications for Open RAN interfaces, but it is also important to recognize the continued importance of 3GPP standards. A major part of the global

success of the 3GPP ecosystem is due to the open standardization process that has created an open architecture for wireless cellular communications that has been adopted worldwide. In short, the standardization process for 5G technologies is already open; as such, the development of 5G at 3GPP today already yields the commercial and security benefits promised from an open, consensus-based, and voluntary process. Further development in Open RAN within 3GPP and other standards and specifications bodies continues that promise.

The openness of 3GPP provides broad and robust ecosystem of devices and vendor equipment supported by Billions of dollars of R&D investment that can be directly leveraged for carrier, enterprise, and government deployments. All of the key interfaces between RAN and User Equipment (UE), RAN and 5G Core, within the 5G Core Service Based Architecture (SBA), and from the 5G Core to data networks are all open and standard in the current 3GPP architecture. It is very common for vendors to interoperate across these interfaces, and global MNOs build multi-vendor networks that interoperate with very good performance and scale across these interfaces. By standardizing these interfaces 3GPP networks support a highly diverse ecosystem that supports thousands of devices built on low cost silicon and broadly interoperable RAN, core, cloud, and BSS/OSS systems.

Open RAN and related initiatives focus specifically on the RAN components within a 5G network with a goal of disaggregating the sub-components of the RAN and defining open and standard interfaces to enable interoperability between RAN sub-components. This promises to enable additional interoperability, but faces a number of challenges (several of which are described below). We are confident these challenges can be overcome with continued industry efforts, and can be accelerated through the government funding that is the subject of this Request for Comment.

III. RESPONSE TO SPECIFIC INQUIRIES IN THE REQUEST FOR COMMENT

A. Challenges Facing Open RAN Adoption (Questions 1, 2 & 4)

Nokia is at the leading edge, along with a number of other vendors, working to fulfill the promise of Open RAN. Investment by our industry in R&D, standards development, and product and services development are substantial, but could be accelerated through the Innovation Fund. Such U.S. government investment could help alleviate many challenges to the adoption and deployment of open and interoperable, standards-based RAN. Nokia highlights the following factors that are limiting Open RAN adoption in current networks, and which are examples of broad areas that could benefit from NTIA funding:

The marketplace of Open RAN components is still developing, and current deployments require intensive integration efforts: Disaggregating the RAN into components and then reaggregating those components into a functional RAN takes a great deal of effort. There are several concerns that should be addressed related to the multivendor environment. In fact, early Open RAN deployments have largely involved vendors implementing bespoke integrations that address specific deployment, commissioning, and integration scenarios and require alignment on configuration parameters between the vendors' equipment. These deployments are foundational to the future of Open RAN. However, because these deployments require a high amount of hands-on vendor-to-vendor collaboration and calibration, the customer cannot easily swap one of the original RAN vendors for a new one that was not part of the original deployment.

Through the O-RAN ALLIANCE, the industry is working to develop and mature specifications and profiles needed for specific radio types and use cases to facilitate an ecosystem of Open RAN components. NTIA funding could accelerate an Open RAN ecosystem where a customer has numerous choices for all Open RAN components, can install those

components with less intensive vendor-to-vendor one-off integration work, and can later swap components to take advantage of new innovations or market conditions. Several examples of possible accelerators are provided in the sections that follow. Some related perceived "gaps" facing vendors and their customers in Open-RAN's multi-vendor environment are:

- *System integration and its cost*: Someone must be responsible for baseline network integration. Service providers may choose to do this in-house, but many will not have the expertise or personnel resources to devote to integration and will contract with a third party to integrate RAN components. As such, it is crucial that Open RAN technology is advancing and that Open RAN services capabilities are developed that will drive down integration cost and complexity at the time of purchase.
- *Interfaces and their profiles*: As noted above, there is no "off-the-shelf" Open RAN solution today that works without significant integration work involving individual customer profiles. In the case of open fronthaul, there are numerous different profiles with hundreds of technical parameters to be reconciled. It is likely that the Open RAN market will need to settle on a smaller number of profiles to ease multi-vendor integration.
- *Risk associated with no single accountability*: Customers appreciate choosing a single vendor that they can call on to hold accountable for any number of potential network issues, such as faults, stability, security, and performance metrics. Adding more vendors (dispersing accountability) is not desirable to some service providers, particularly small and medium-sized carriers. Accelerating Open RAN technology development and environments for potential customers to test and work with Open RAN components is critical to de-risking Open RAN to spur greater adoption.

- *Security Risks*: Network security is only as strong as the weakest link in the chain. While security concerns can be overcome, in the short term, adding multiple vendors with common interfaces introduces new security issues that must be worked through.

The industry is still working to develop Open RAN products that are at least as robust as today's Classical RAN: Today's Open RAN components do not yet include the number of features/capabilities achieved by Classical RAN. This more limited functionality will continue to dissuade most service providers from deploying Open RAN -- especially at scale in large networks, which requires mature services capabilities -- until parity of features and capability with current RAN deployments is closer to reality.

An effective way to accelerate that parity of Open RAN features/capabilities is to advance Cloud RAN implementations (equipment, xApps, services), which are vital to Open RAN. The Cloud RAN environment is ideal to close the gaps in capabilities and robustness faced by Open RAN. Cloud RAN is maturing as a living, working environment for architecture, development, system verification and validation, ecosystem development and integration, new product and new service introduction, and field deployment, commissioning and integration. Specific examples of possible actions to accelerate maturity of the Cloud RAN environment are provided below.

While we must ensure that Open RAN is as robust as Classical RAN to spur greater adoption, the ultimate goal is for Open RAN to spur even greater RAN innovation through its more diverse ecosystem. Specifically, Open RAN's future promise lies with Open RAN vendors innovating to provide technology enhancements or other factors that would create an incentive for an operator to "upgrade" through a component swap. The hope is that a larger ecosystem for RAN components will lead to greater product differentiation to allow network

operators to achieve greater security, energy efficiency, throughput, or other enhancements over an installed RAN component. This innovation, of course, must still be standards-based so it can be easily integrated into networks. Nokia is not aware of its competitors achieving such innovation, and this is an area where government funding could accelerate the development of "a better mousetrap" promised by Open RAN.

Multiple parts of the equipment industry must be advanced to accelerate Open RAN: One critical dependency for the for the acceleration of Open RAN and new business cases is User Equipment (UE) Terminal support, including development of new UE chipsets. Development of UE is necessary to attract Open RAN deployment, especially in the enterprise and government space. Standard specifications define features and functionality to enable new opportunities for wireless services (*i.e.*, Verticals, Industrial IoT). Generally, these specifications have a UE Terminal implementation dependency. However, the UE Terminal business case for these new features, such as Ultra Low Latency Communications (URLLC) and Unlicensed Support, may not be strong due to the relatively smaller market size compared to enhanced mobile broadband (eMBB) features deployed by carriers. Not only must the Open RAN *network equipment ecosystem* advance for demand to accelerate, so must the *UE ecosystem*.

Open RAN architecture poses challenges for energy efficiency*:* Energy efficiency in mobile networks is important for a more sustainable future as well as for lowering operational costs. The portion of the mobile network responsible for the greatest amount of energy consumption is the RAN. Open RAN has the promise to help with the energy consumption challenge, but the complexity of the multi-vendor ecosystem makes it challenging for Open RAN to achieve the efficiencies of Classical RAN architectures. Each generation of

Nokia's products has provided our company yet another opportunity for fine tuning the energy efficiency of Nokia components working together. Such fine tuning becomes harder when the equipment must work in a multi-vendor environment with standardized interfaces. As such, it is critical that Open RAN components become at least as efficient as traditional RAN, and with the same technically robust capabilities.

B. Open RAN Workforce Constraints (Question 3)

In Nokia's experience, there is an acute need for greater expertise and training in all areas of RAN research, development, and related services, with perhaps the most acute deficiency in the area of Cloud Engineering, critical to Open RAN innovation. For the foreseeable future, the U.S. market will require a mix of increased domestic capacity as well as continued support globally to meet substantial near-term demand for Open RAN components. It is important to build U.S. domestic workforce capacity in Open RAN, but not be so restrictive as to impede near-term U.S. deployments. Nokia therefore encourages NTIA to consider funding projects, including advanced cloud infrastructure, cloud and RAN management, and automation knowledge and skills, which require (and can spur) an increased U.S. high-tech workforce as well as the global workforce that supports U.S. deployments. Such projects are necessary to drive the demand for increasing the capacity of the Open RAN workforce but should not be a condition of the government funding, which would risk stymying the development of Open RAN.

To meet the goal of increasing domestic R&D and high-tech manufacturing expertise, Nokia believes that the U.S. government should review its immigration procedures and policy to address near-term workforce challenges. Green cards and H-1B visas, which are typical instruments used by technology companies to fill their employment ranks, often are in

short supply. The U.S. government should consider how its immigration policies could better support the goal of maintaining global leadership in technology development and innovation, particularly in Open RAN development.

C. Questions on Standardization (Questions 7)

Nokia is a leading contributor to the O-RAN ALLIANCE, where the primary Open RAN specification work takes place. Specifications developed through the O-RAN ALLIANCE will drive the Open RAN marketplace, and greater participation by all stakeholders is needed to accelerate the process. We devote significant resources to supporting our delegates to the O-RAN ALLIANCE's specification activities, chairing or co-chairing several working groups and technical committees. Standardization of the Open RAN interfaces requires all stakeholders to arrive at consensus for complex technical questions. While the hard work of building voluntary consensus among the diverse contributors is a process that will always take substantial time and resources, Nokia submits that the work of the O-RAN ALLIANCE would greatly benefit from increased participation by all stakeholders, including the types of new market entrants that can help meet Open RAN's promise of vendor diversification. In contrast, the process is hampered when stakeholders are missing or unable to contribute.

The Innovation Fund can support this important activity by ensuring that additional stakeholders are in the room for the conversation. Financial support for the hiring of qualified technical experts, transportation to working group meetings, Standards Development Organizations (SDOs) for facilitating meetings, visa applications, and the other costs of standardization activities will ensure progress in standardization.

Support for research by individual and corporate contributors into particular areas of interest may also help to drive contributions to the standards of most pressing interest. From

Nokia's vantage point, there is significant interest from multiple global markets on Open RAN fronthaul support, service management orchestration, RAN automation generally, Acceleration Abstraction Layer, and security. However, all areas of Open RAN standardization must progress to achieve true interoperability.

D. Questions on Integration, Interoperability, and Certification (Question 9, 10, 11)

As discussed above in these Comments, integration of equipment in multi-vendor environments poses one of the biggest challenges to vendors, operators, and enterprises, stymying mainstream Open RAN adoption. While these challenges will abate with continued experience, the Innovation Fund can help to accelerate the timeframe for gaining that experience by supporting integration labs, testbeds, plugfests, and other scenarios that can help increase the industry's understanding of typical integration glitches and their solutions. While the sharing of information such as test results is critical to progressing the Open RAN ecosystem, conditions for funding should not weaken the participants' ability to safeguard the confidentiality of proprietary information and for participants to set appropriate guardrails for the distribution of testing information.

Certification of compliance and "Badging" of interoperability with O-RAN ALLIANCE-based specifications also can mitigate integration challenges and promote confidence in operators for commercial adoption of Open RAN equipment. While certification should not be mandatory, it can provide credibility for vendors and assurance to operators that the equipment has been built per the O-RAN ALLIANCE conformance standard. Badging can provide confidence on a pair of devices or multiple devices are interworking per O-RAN ALLIANCE interoperability and End to End standard.

As defined by the O-RAN ALLIANCE Testing and Integration Focus Group, the Certification and Badging testing can be performed in an Open RAN Testing and Integration Center (OTIC) and also outside of the OTIC. Currently, Nokia uses its own labs (outside of the OTIC) to perform the Certification and Badging testing according to the O-RAN Certification and Badging Process and Procedures document. The Nokia Open RAN Collaboration and Testing Center in Dallas, Texas is one of the labs.

Nokia proposes that the Innovation Fund be used to support labs accredited with ISO 17025 to carry out conformance and interoperability testing based on O-RAN ALLIANCE specifications. This approach would offer additional lab facilities beyond OTICs and, therefore, help in reducing the time-to-market of O-RAN ALLIANCE compliant products. It would also encourage the development of testing procedures by allowing mature and trustworthy labs to contribute to the still-growing ecosystem for testing and accreditation. Such ISO-accredited labs would offer assurances that procured Open RAN solutions comply with O-RAN ALLIANCE specifications, while reducing overhead associated with O-RAN ALLIANCE OTIC certification and badging from an OTIC lab.

E. Proposed Research and Demonstrations to Promote Open RAN for 5G and Future Generations of Wireless (Questions 13, 14, 15)

Nokia and others seeking to advance Open RAN have engaged in enormous efforts to develop, test, and deploy Open RAN solutions in the U.S. and the global marketplace. Already there are numerous live deployments based on Open RAN architecture but there is wide agreement that there is work to be done for Open RAN to meet the rigorous demands of large networks at scale and for there to be true diversity of interoperable Open RAN components. There is no quick fix or silver bullet; suppliers of Open RAN solutions must continue to work on all aspects of Open RAN equipment and services to move the ecosystem forward.

As noted earlier, one key aspect of this are efforts such as Nokia's Open RAN Collaboration and Testing Center in Dallas, Texas. The center is designed to support the verification, introduction, and launch of Open RAN compliant solutions to market, and test for interoperability. Nokia has also found extremely effective the proliferation of demonstrations, plug fests, and similar opportunities to experience and further develop Open RAN. Several of these innovation and development beds bring together vendors in live, limited purpose networks to demonstrate interoperability, performance, security, and feature (capability) parity.

With respect to the Innovation Fund, the research, development, and testbed environments that Nokia recommends run the gamut. We expect that projects submitted to NTIA will be varied and that there will be no shortage of proposals with merit.

Here, we suggest several categories of projects that we believe NTIA should target for funding in its forthcoming Notice of Funding Opportunity.

Example 1: Field Validation Labs for Services Methods and Procedures. Nokia is actively engaged in the implementation of a U.S.-based secure Cloud RAN/Open RAN test facility and staging lab, where the goal is to develop highly scalable services methods and procedures, tools, and training for Cloud RAN engineers. The state of automation for Cloud is strong, however, automation of services methods and procedures for high volume Cloud RAN deployments critical to the acceleration of Open RAN is only in the earliest stages. Funding in this area of Cloud RAN Services Methods and Procedures Validation will encourage more effective Open RAN rollout by proving the reliability of scale deployment.

Example 2: Customer Labs Supporting Field Trials and Pilots. Nokia continues to find that individual customers want the best of all worlds - reliable, automated, streamlined deployments but with their own custom flavors for favored architectures. The

Innovation Fund could accelerate the discovery of where Open RAN compliant services methods and procedures supporting Open RAN compliant equipment and architecture will yield the most reliable and economical RAN deployments – and where they may not. Custom flavors enable operators to differentiate their networks and cater to the needs of their customers, but custom-only networks will leave us with deployments more similar to Classical RAN and increase costs. Funding in this area of Field Trials and Pilots will encourage more effective Open RAN rollout.

Example 3: The RIC and xAPP Development and Proofs of Concept for Numerous Use Cases. The RAN Intelligent Controller (RIC) is a major enabler of RAN innovation and a natural place for innovation and collaboration through third party xApps. xApps can be used for RAN optimization, implementing open Application Programming Interfaces (APIs) to enable advanced RAN functionality. As an example, Nokia developed an API as an xApp to facilitate the Dynamic Spectrum Sharing capabilities implemented in the Department of Defense-sponsored testbed at Hill Air Force base. A principal function of xApps running on the RIC can be to enhance energy efficiency, which we discuss in greater detail in Example 4, below.

The possibilities are endless for xApps – basically any application that benefits from having access to a low latency, direct connection to the RAN. As just a few examples, xApps can be used to introduce and enforce network policies, load management, or implement network slicing (a major enhancement for logically partitioning network resources in leading edge networks, allowing unprecedented flexibility using a single physical network). xApps present perhaps the greatest opportunity for market entry into the RAN ecosystem and are critical to the success of Open RAN now and into the future. No aspect of Open RAN is more

collaborative than xApps, where third-party developers are encouraged to introduce new use cases and services onto communications networks through the RIC.

Example 4: RIC Development to Optimize Energy Efficiency. The RIC provides functions and interfaces to support more efficient optimization of the RAN through policy-driven closed-loop automation and faster, more flexible service deployments using AI/ML-based programmability. Closed loop automation continuously monitors, measures, and assesses network traffic and service performance, allowing xApps to optimize services with near-real-time feedback.

Studies indicate that as much as 70 percent of the network resources on average are on idle, so there is significant opportunity to reduce the consumed energy by powering down resources when not needed. Optimization of radio units' energy consumption requires determining which radio units or their resources (carriers, cells, MIMO transmit paths, etc.) can be switched off at a particular point of time without negatively affecting end user services. This risk of a negative impact is a major concern for the operators and one of the key obstacles for deploying energy saving features. The RIC can greatly improve the ability to manage these resources while maintaining service quality by use of enhanced AI/ML capabilities. Since the RIC also optimizes the use of the radio resources for improving spectral efficiency and overall performance, it means less radio resources are needed. This reduces the need to deploy additional radio resources, which further contributes to sustainability.

Example 5: RIC Platform and Tools Development. At the same time as xApp development promises to accelerate Open RAN adoption, it is imperative that the RIC Platform continues to evolve to meet the demands of leading edge xApps. One can analogize this to the race for personal computers and gaming systems to keep up with the ever more demanding

software developed to run on them. The RIC is defined in the O-RAN ALLIANCE specifications and open source RIC platform components are created in the O-RAN Software Community (OSC). Evolving the xAPP use cases and capabilities will in turn require further development of RIC platform capabilities, much of which will be contributed to the OSC open source.

In addition to RIC platform development, various tools, such as network simulators are needed to support the use case development. The RIC simulator will allow vendors and operators to analyze the behavior of a particular xApp and the gains and benefits obtained are analyzed in a simulated environment before deployment in an actual operator environment.

Example 6: 6G System Simulator. A theme throughout the Request for Comment, Open RAN must be more than just a technology to be implemented in today's networks. As the decade progresses and our communications networks evolve to 5G-Advanced, 6G and beyond, Open RAN must be future-proofed to meet those generational advancements. A 6G System Simulator will be a major tool for this advancement. The Innovation Fund could be used to establish an open source framework for a 6G system-level simulator that could be leveraged throughout the 6G vendor ecosystem to prepare for 6G deployments.

Certain technical aspects that could be developed and tested in the simulator environment include basic execution framework, user/cell context management, interfaces between layers, traffic generator, channel models, parameter configuration, logging/tracing, visualization, and others. Through the 6G Simulator, the Innovation Fund could facilitate Open RAN keeping pace with network evolution to 6G as well as early vendor collaboration with

operators to achieve trust and confidence for increased adoption of Open RAN in the next generation of wireless.

Example 7: Advanced mMIMO Experimentation Testbed. The 3GPP 5G specifications incorporate advanced functionality to support massive Multiple Input, Multiple Output (mMIMO) functionality with large antenna panels with up to 64 transmit and 64 receive antenna arrays. In a Mobile Network Operator (MNO) 5G network these mMIMO arrays are used to increase capacity through spatial multiplexing and improve coverage using beam forming patterns. An ORAN RIC-enabled testbed could make these capabilities available to government researchers, partners, and developers to experiment and develop capabilities specific to government missions. For example, beam forming could be used to focus the signal from the mMIMO array on a specific user or group of users avoiding detection while improving performance. The specificity of the beams can enable multiple use cases for secure communications needed by the commercial and government sectors.

Example 8: Wireless Future Technology Testbed. Nokia recommends that the Innovation Fund be used to create an environment for Open RAN innovation to achieve as realistic an over-the-air test environment as possible for future mobile network deployments. This testbed should support multiple technologies at once (FDD, TDD, mmWave, etc.).

This is an ambitious proposal and unlikely to be privately funded by a single entity because it ideally would require construction of buildings, landscaping, streets, and other aspects of real deployment environments but in a remote location to guard against interfering with commercial networks that are actually in service. Nokia recommends that the test bed environment should include fully automated testing, log collection, and analysis using robot, self-driving vehicles, and drone technologies with GPS location capabilities.

It is critical to be able to test new technologies outside the confines of commercial networks or supplier labs. This allows maximum flexibility to test these technologies without harming commercial subscribers or to succumb to the limitation of what labs can provide for simulating a real field environment. Full automation provides order of magnitude lower cost and efficiencies to accelerate technology development.

Example 9: Advanced Open RAN Radio Development. NTIA should also consider funding R&D into the Open RAN Radio Unit (O-RU), which translates the radio signals between the antenna and the baseband unit. The network relies on having an efficiently designed O-RU to maximize capacity and minimize power consumption. However, the product variants for O-RU are proliferating significantly due to form factor (mMIMO/macro), different frequency bands, and indoor versus outdoor usage. Covering this roadmap will be challenging for any one vendor, even those few vendors with experience deploying networks at scale, to develop the O-RU products required for these deployments. Nokia therefore urges that funding be allocated to O-RU product development to help fill in the portfolio needed for successful wide range of Open RAN deployments, for various Indoor/Outdoor scenarios (Power Consumption/Size optimized).

Example 10: Multi-Vendor Integration Use Case Exercises. Below, we describe a number of integration scenarios, or use cases, for open and interoperable networks that should be accounted for in Open RAN networks. Providers of multi-vendor services and managed services operations must successfully handle these (and similar) cases as these scenarios are likely to occur in an Open RAN architecture. Understanding these cases in a formal, systematic way will alleviate the "last mile" problems with adoption of Open RAN. Key use cases include:

- Integration of Cloud Software from one vendor (e.g., Red Hat, VMware, AWS EKS, etc.) with commercial off-the-shelf (COTS) hardware from another (e.g., HPE, Dell);
- Integration of hardware accelerators from RAN vendors with COTS hardware suppliers and Cloud Software suppliers;
- Implementation of multi-vendor CI/CD pipelines for synchronous delivery of hardware firmware, Cloud software, and application software;
- Integration of multivendor network infrastructure with independent service management and orchestration (SMO) layer; and
- Deployment of third-party xApps on a Near Real-Time RIC platform from an incumbent RAN vendor, and development of xApp ecosystem.

Example 11: Cloud RAN Trials with Carriers, Enterprises, and Government Users. Carriers, enterprises and government segments have different operational drivers and mindsets with respect to the selection and costs of equipment and services as well as the management and automation of operations. These choices can significantly impact end-to-end performance, especially as more near-real-time capabilities are required by all users in these segments. Engaging in near-term Cloud RAN trials with carrier, enterprise, and government customers can drive thorough end-to-end experience and testing of orchestration and automation, operational scaling, and performance. While the performance focus is on the customer and user experience, well-defined trials can effectively exercise the interoperability of server partner and web scaler partner offerings and solutions. The near-term exercise of such customer segment trials will accelerate the adoption of Open RAN compliant network implementations (equipment and services). Feasibility studies relating to systems integration ownership of multi-vendor,

multi-partner solutions should be conducted to determine end-to-end performance ownership/responsibilities and triage handling for multivendor solutions.

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In summary, we expect the above trials, pilots, and proofs of concept to result in many major beneficial outcomes, including the following:

- Determine how to optimally perform end-to-end design and systems integration of multivendor solutions;
- Determine end-to-end performance of the key performance indicators (KPIs) for multivendor solutions (i.e., Cloud hardware, Cloud software, and RAN applications sourced from different vendors and integrated into a cohesive solution), their comparison to current single-vendor solutions, and analyze how to achieve performance parity with current solutions.
- Identify the operability challenges for managing multivendor solutions in a production environment (e.g., triage of solutions comprising different vendors, and associated technical support); challenges to be considered include technical, capability, and business process re-engineering.
- Identify training requirements to upskill the technical resources on new technologies that are based on software-centric API driven multivendor solutions as opposed to monolithic appliances.

F. Questions on Security (Questions 17-20)

Nokia is leading the development of new network technologies with built-in security and privacy. We not only engage in a rigorous program to ensure our own product security, we also work to improve the security of our entire ICT ecosystem by sharing our

security expertise and practical experience in numerous industry standards groups and by investing heavily in security testing and technical collaboration.

Beyond thought leadership as an advisor to government and industry, Nokia has made major commitments to security testing and R&D centers. In 2021 and 2022 alone, we launched several major 5G security initatives, including our ASTaR (Advanced Security Testing and Research) lab in Dallas, Texas and serve as a lead technology provider and collaborator for the National Institute for Standards and Technology's (NIST's) National Cybersecurity Center of Excellence (NCCoE) 5G Cybersecurity Project. The ASTaR lab is the first end-to-end 5G testing lab in the U.S. focused solely on cybersecurity. ASTaR uses and develops cutting-edge tools and techniques to assess the security resilience of 5G networks, as well as their associated software, hardware, and applications. ASTaR will use these assessments to address emerging security threats, and lab researchers will engage with the cybersecurity community to identify emerging threat vectors and potential vulnerabilities.

Nokia's products and services support a zero-trust approach to network security -- the premise that trust cannot be assumed and must continually be validated. Zero trust is especially important as modern networks, including Open RAN networks, can be local, in the cloud, or a combination, and as network products and services can reside anywhere and employees and contractors can obtain network access from any location. Zero trust is critical to securing government, corporate, and personal information and physical assets.

While zero trust architectures can help guard against security lapses (a weak link) or even against a malevolent actor, Nokia urges that reputation and competence still matters across the supply chain. Governments, carriers, and enterprises deploying network infrastructure, including Open RAN networks, should seek a combination of technical security expertise based

on a zero-trust architecture combined with a review of other factors to ensure they work with trusted partners with a strong business, technology, and ethical track-record. NTIA should similarly consider not only technical security but also a company's heritage of trustworthiness in making its funding decisions.

G. Leveraging a Global Ecosystem to Promote Open RAN (Questions 21-26)

The Innovation Fund will benefit Open RAN technology generally and advance the Open RAN ecosystem within the United States. We respectfully submit that Nokia and other global partners with a strong presence in the U.S. market will be vital to this effort. As described above in these Comments, while not headquartered in the U.S., Nokia continues to be a U.S. innovation leader, with five R&D centers in the United States. We have over 7,300 employees in the U.S. While it is true that economic headwinds have led to industry consolidation, U.S. based network equipment jobs and U.S. located R&D hubs did not evaporate simply because they were consolidated under a new parent company.

If NTIA's goal is to advance innovation, it would be counterproductive to exclude contributions from the global ecosystem. U.S. domestic suppliers on their own cannot currently support U.S. demand for communications equipment. There is not sufficient capacity to impose an "American-made" requirement on NTIA Open RAN funding. Such capacity can be built up in the future, but the goal to facilitate near-term deployment will require leveraging the global supply chain. We further submit that many U.S. operators' consideration of Open RAN hinges on the participation by Nokia and other trusted vendors with a heritage of quality and performance in this space. Nokia urges the NTIA to recognize the importance of established trusted vendors, such as Nokia, to U.S. innovation and the U.S. economy, which will continue to

play a critical role even as Open RAN creates an environment for new entrants into the RAN equipment market.

IV. CONCLUSION

Nokia thanks NTIA for the opportunity to comment in this proceeding and looks forward to continuing to work with the U.S. Government and commercial partners to advance the Open RAN ecosystem.

Respectfully submitted,

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