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January 27, 2023

Subject: Comments on Public Wireless Supply Chain Innovation Fund Implementation

Docket No. 221202-0260

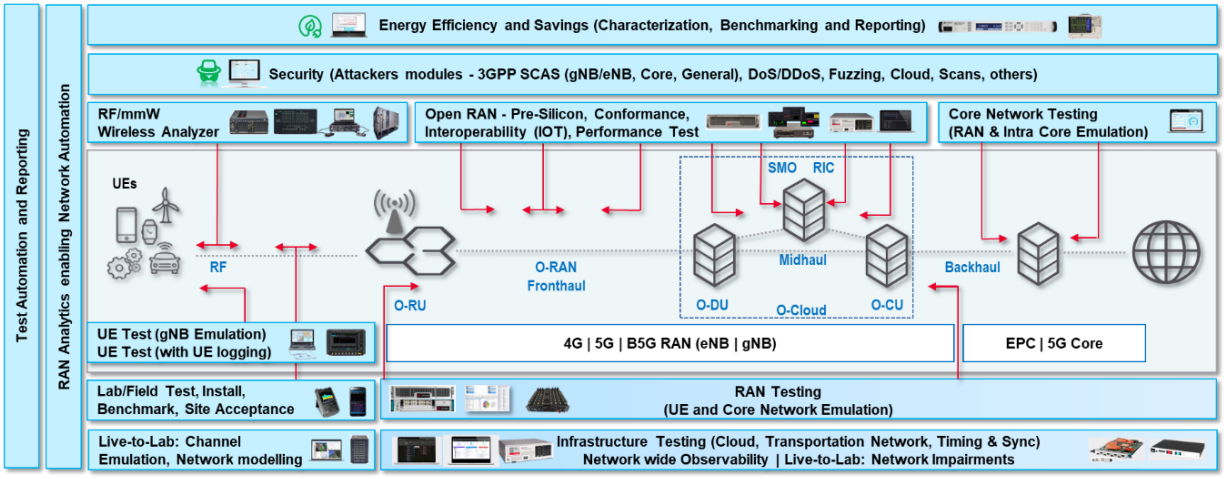
Keysight Technologies is pleased to comment on the Public Wireless Supply Chain Innovation Fund.

About Keysight

Keysight Technologies, a US company headquartered in Santa Rosa, California, is a market leader in 5G, Next G, and Open RAN test solutions, with the industry's most complete portfolio of prototyping, test, measurement, and security solutions. Keysight achieved this position by partnering early with standards-setting leaders to understand and master the complexities of 5G. By leveraging our leading end-to-end 5G test solutions, we allow our customers to break through complexity and accelerate 5G innovations, in the following ways:

- Design, test, and deliver 5G-compliant and high-performance systems with early access to insights that speed development and reduce risk
- Use our integrated solutions to streamline workflows and ensure reliable results
- Run secure and connected 5G services that work in the real world using end-to-end insight from the device to the edge to the core of your network

Keysight's edge-to-core Open RAN test solutions enable conformance, interoperability, performance, security, and energy efficiency testing across the entire lifecycle, with suites specifically tailored for chipset makers, software stack developers, network equipment manufacturers, mobile operators, test houses labs, and private network system integrators. Keysight is a major contributor in O-RAN ALLIANCE, co-chairing committees and leading or contributing to nine groups responsible for defining Open RAN specifications for 5G networks open interfaces, security, transport, cloud, AI/ML enabled RICs and applications, energy efficiency and savings, and B5G/6G research topics. Keysight has enabled OTICs (Open Testing and Integration Center) labs around the world with test, certification and badging capabilities and expertise. Keysight has participated in all O-RAN Global PlugFests since 2019, enabling acceleration of O-RAN technology development with our comprehensive test solutions and global expertise. The figure below shows various test and emulation touchpoints in a RAN/Open RAN where Keysight can provide solutions.



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Below are Keysight's insights to NTIA's questions.

State of the Industry

1. What are the chief challenges to the adoption and deployment of open and interoperable, standards-based RAN, such as Open RAN? Are those challenges different for public vs. private networks?

Some of the chief challenges to adoption and deployment of open and interoperable standards are:

1) **Open RAN specifications and standardization development is still in progress in the O-RAN ALLIANCE** – the level of completeness and maturity differ across open interfaces (Open fronthaul being the most matured and deployment ready), cloudification, RAN Intelligent Controllers (RIC) Artificial Intelligence / Machine Learning (AI/ML) platforms (near and non-RT RICs) and multi vendors xApps and rApps, Service Management and Orchestration (SMO) zero touch automation, sustainability needing energy efficient and AI/ML enabled energy savings Open RAN specifications.
2) **Open RAN network functions implementations are still maturing** as such "plug & play" interoperability between multi-vendor devices does not exist currently, and still require significant integration efforts to reach full operational state.
3) **Open RAN deployment readiness testing and integration strategy, test specifications and test cases are in general lacking in the industry** as these are knowledge gained through decades of experience owned by few companies (mainly the tier-1 vendors). The current set of Open RAN test specifications and test cases made available in the public domain are considered basic, and therefore insufficient for deployment readiness testing.
4) **Open RAN skillset and knowledge gap** in terms of testing, integration, and optimization throughout the entire lifecycle.
5) **Open RAN multi-vendors management and orchestration due to its complexities will be needing to move towards zero touch network management** but the industry is not ready from the standards, implementation, and testing – integration perspectives.
6) **Operators will require a single pane of glass (knobs and dials) across the installed (non-Open RAN) networks and newly added Open RAN networks** which may need to include OAM interworking and interoperability with SMO and current OAM (Operations, Administration and Maintenance) / NMS (Network Management System).
7) **Open RAN speed and cost of evolution** will need to be at least on par if not better than single vendor monolithic RAN solutions which can be challenging in a multi-vendors Open RAN system therefore will require adoption of a CI/CD/CT (Continuous Integration, Development / Deployment and Testing) pipeline.
8) **Open RAN requires more "Shift-left" testing** – needing to ensure that the conformance and interoperability will need to be tested and validated during the chipset design phase.
9) **Open RAN requires more "Shift-right" testing** – needing to ensure that the field deployment conditions are brought into the labs for "live in lab" testing to accelerate field deployments.
10) **Operators' strategy for Open RAN vary widely** as each operator plans to evaluate each of the technology enablers offered by Open RAN in terms of benefit, maturity, complexity, and total cost

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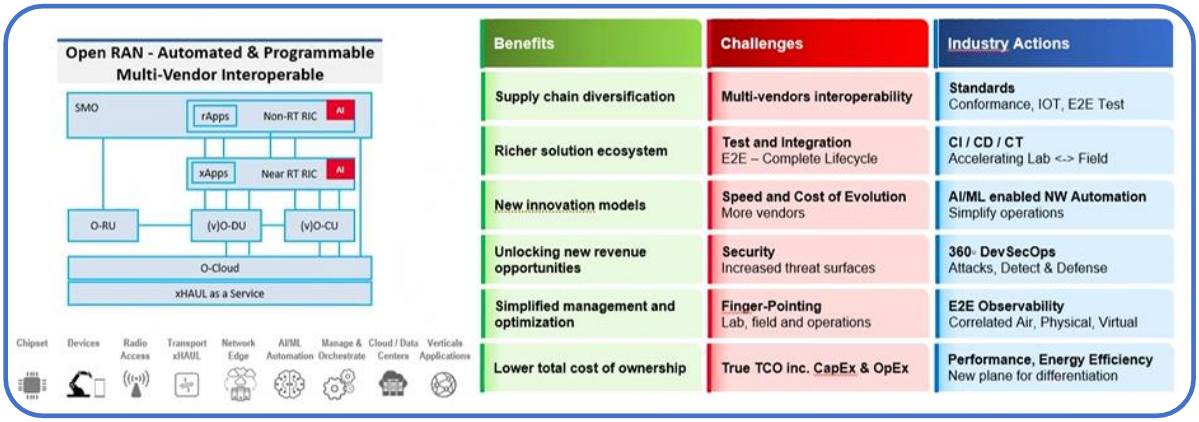
of ownership (TCO) prior to deciding to trial and eventually deploy across their own set of timelines. Operators will likely not implement all aspects of Open RAN to support multi-vendors interoperability. It is important to define and detail the high priority deployment blueprints to ensure that all components can be optimized for the prioritized deployment blueprints.

11) **AI/ML-enabled multi-vendor network optimization and automation, leveraging O-RAN ALLIANCE-defined RIC, xApps and rApps,** require new training, evaluation, testing, and validation methodologies ensuring that AI/ML techniques can be properly designed, evaluated, tested and optimized in digital twin lab environments prior to commercial deployments from the functional, performance, security and energy efficiency standpoints.
12) **Energy Efficiency**: Radio Access Networks Energy Efficiency is one of the industries' highest priorities, caused by increasing electricity prices, sustainability concerns and traffic growth. The RAN is responsible to the main part (70%) of a mobile network Energy Consumption. Optimizing Energy Efficiency without impacting the End-User experience requires a combination of Intelligent Control, Performance and Energy monitoring, coupled with Innovative Energy Saving capabilities and standardized protocols. Energy Efficiency tests must be performed on various components of the RAN. The demand for a standardized RAN Energy Efficiency Benchmark has been growing within the entire wireless Ecosystem and standards organization.
13) **Security**: Operators have always adopted a zero-trust approach to the security aspects of the connectivity which their networks deliver to their customers. This thereby eliminates implicit trust and requires robust and continuous validation for every stage of the interaction of the end-to-end connectivity fabric between the end devices and the mobile networks, which includes the radio access, core networks, supporting edge computing servers, transport network switches/routers, cloud infrastructures and data centers. Open RAN, with its intrinsic multi-vendors interoperability support built into the O-RAN ALLIANCE specifications, has introduced, and amplified additional security threats with expanded threat surfaces with further dis-aggregation, increased number of suppliers with multi-vendors components implemented and interoperate with specifications which are still development in progress with varying levels of maturity and robustness against security threats. Increased use of AI/ML for network optimization and automation creates additional threat considerations, such as potential flaws in ML models, AI/ML applications and data sources integrity, reliability, and trust worthiness, just to name a few.

Additional benefits, challenges, and potential industry actions are shown in the figure below.



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5G and Open RAN based networks are complex systems that require attention to detail at a level beyond commercial networks, both at the system level and the network element level. The disaggregation of 5G networks using Open RAN network elements combined with the requirements for resilience, reliability and performance creates unique requirements for integration, debugging and performance validation.

On the question of private vs. public networks, here are some points to consider:

1. **Private networks depending on the use cases may have additional requirements** in terms of security, privacy, reliability, latency, resiliency such as for smart factory environments, government networks among others.
2. **Troubleshooting may be more challenging as well in private networks environment** due to sensitivity of customers data.
3. **Private networks may be needing to work in non-standalone deployment scenarios** as well which requires interworking with public networks therefore additional effort required with test and integration between the private and public networks.
4. **Private network operators from the Operational Technology (OT) industry may be less versed with network technologies** therefore requiring intent-based management and analytics as a service approach to benefit from Open RAN technology adoption.

Private networks may have more stringent requirements than commercial networks in terms of higher reliability (above five 9's), higher resilience for a wide variety of RF propagation environments and cyberattacks, and the need to deliver higher performance for a wider range of end user applications. In addition, private networks under unique circumstances (e.g. tactical) may need to be created ad hoc, forcing runtime integration of network elements that have been tested independently but not necessarily together. Another key challenge is that while commercial network operators typically have the luxury of having teams of people to drive test their networks to do optimization, private network users may require their networks to work the first time while maintaining these more stringent reliability, resilience and performance requirements placed on them.

Where private networks may be potentially easier to deploy than commercial networks are in the cases where the private networks are of smaller size and user capacity. Also, billing/roaming may not be a concern.

a. What are the challenges for brownfield deployments, in which existing networks are upgraded to incorporate open, interoperable, and standards-based equipment?

One challenge of brownfield deployments is to ensure that customer experience is not adversely impacted during the addition of Open RAN solutions to interoperate seamlessly with the existing single vendor networks from the features, functional, performance and security perspectives.

Operators will require a single pane of glass (knobs and dials) across the installed (non-Open RAN) networks and newly added Open RAN networks which may need to include OAM interworking and interoperability with SMO and current OAM/NMS.

2. What ongoing public and private sector initiatives may be relevant to the Innovation Fund?

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Some ongoing public and private sector initiatives that may be relevant to the Innovation Fund are the O-RAN Global PlugFests and TIP (Telecom Infra Project) events, which are semi-annual events where Open RAN ecosystem vendors are able to test and integrate their implementations to ensure openness and interoperability of Open RAN interfaces. Also, OTICs (Open Testing and Integration Center) labs conduct standards conformance, components IOT (Interoperability tests) and end-to-end tests for the disaggregated Open RAN components, ensuring that the components can work together from the functional, performance, security and energy efficiency standpoints. In the private sector, system integrators deploy Open RAN based End-to-End solutions for Private Networks and serve as consultants for the Public Network Service Providers. Perhaps the Innovation Fund can be used to support these events and entities.

a. What gaps exist from an R&D, commercialization, and standards perspective

One gap that currently exists in the marketplace is the ability to have high-fidelity multi-domain digital twin simulation capability. This is essential because as the 5G and 6G standards are evolving, so too are the application demands for each of these respective standards. This results in a need to be able to do digital twin simulations to accurately reflect functional operation in each of those domains from a physical layer perspective, protocol perspective and networking perspective. Another layer on top of all this is the Open RAN architecture that is very disaggregated. There is also a need to look at implementation details and instrumentation opportunities to check the performance and health of a network at run-time. One of the key technologies to address the gap of seamless simulation across these domains is hybrid digital twin simulation technology combining 5G, Open RAN, packet and radio physics digital twins with hardware and software in the loop technologies. This delivers a scalable environment with targeted fidelity allowing teams to do system level simulation and focus on innovations both within and across these domains.

In addition, enabling multi-vendor Open RAN interoperability without compromise on end-to-end performance and energy efficiency is one key challenge that would benefit from additional R&D development, as Open RAN deployments will only happen when performance and Energy efficiency (TCO) are equal or better than single vendor-based solutions

The deployment and commercialization tend to be light in testing during the product R&D lifecycle. With disaggregation being central to Open RAN, testing of conformance, interoperability and End-to-end is vital to the success of Open RAN. Perhaps Innovation funds can be used to support thorough vendor testing of Open RAN to reach a mature commercialization phase.

Keysight can provide conformance testing, interoperability testing, and end-to-end testing with a number of solutions that are being used today by customers around the world.

b. How might NTIA best ensure funding is used in a way that complements existing public and private sector initiatives?

To best ensure funding is used in a way that complements existing public and private sector initiatives, NTIA could consider challenging teams of Open RAN vendors to construct an End-to-End network based on Open RAN components from different vendors, for both public and private network end use. With NTIA direction to construct real networks, there will be a real goal with real results. Plugfests do not have such an “innovation fund” and could not move forward as NTIA potentially could.

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3. What kind of workforce constraints impact the development and deployment of open and interoperable, standards-based RAN, such as Open RAN? How (if at all) can the Innovation Fund help alleviate some of these workforce challenges?

The Open RAN standard opens the internal structure of a base station and increased the number of interfaces and protocols that the deployment engineers must learn to turn on a mobile network. The huge amount of knowledge is overwhelming for any individual. The Innovation Fund can alleviate this workforce challenge by supporting the development of AI/ML orchestration software for deploying Open RAN networks. The type of AI/ML that is needed here is unsupervised learning, which needs data and data access points (e.g., tap points) to feed the AI/ML. Keysight can provide such solutions with virtual tap points and packet brokers to feed the AI/ML engine with data.

4. What is the current climate for private investment in Open RAN, and how can the Innovation Fund help increase and accelerate the pace of investment by public and private entities?

Private Industry has invested significantly in the past few years in developing RU, DU, CU, RIC and management software, however, the major service providers have not adopted the Open RAN solutions, mainly due to the complexity of the Open RAN and risk for serving their existing customers. The Innovation Fund could focus on enabling Open RAN deployments on a smaller/regional scale to replace non-US equipment. Starting with trial deployments of Open RAN in regional/smaller networks will validate Open RAN solutions and accelerate the pace of Investment by Public and private entities.

In addition, the Innovation Fund can help to co-fund projects focusing on the following areas for 5G and Next G:

1. Indoor and outdoor test labs focusing on deployment readiness testing (beyond O-RAN ALLIANCE specified basic conformance, interoperability, and system test cases – certification and badging schemes)
2. AI/ML enabled Near and non-RT RIC and Applications (xApps, rApps) developments
3. Security for all Open RAN network functions and entire Open RAN system
4. Energy efficiency and savings for all Open RAN network functions and entire Open RAN system

5. How do global supply chains impact the open, interoperable, and standards-based RAN market, particularly in terms of procuring equipment for trials or deployments?

With the exception of the RU, Open RAN components are mainly software running on COTS servers and in the cloud. From a hardware perspective, the global supply chain will not hugely impact Open RAN. From a software perspective, open source code and protection of code from non-US involvement will be an issue. Programmable hardware (e.g. FPGA) could also be an issue if there is underlying open source code.

Technology Development and Standards

6. What open and interoperable, standards-based network elements, including RAN and core network elements, would most benefit from additional research and development (R&D) supported by the Innovation Fund?

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7. Are the 5G and open and interoperable RAN standards environments sufficiently mature to produce stable, interoperable, cost-effective, and market-ready RAN products?

Below are a few candidate areas of open and interoperable standards-based network elements that would benefit from additional R&D:

1. Open fronthaul including Massive and MU-MIMO support
2. Cloudification
3. AI/ML enabled RICs and applications
4. SMO including potential integration and interworking with current NMS/OAM systems.
5. AI/ML based automated Orchestration software, because the complexity Open RAN cannot be easily deployment manually.

Open RAN specifications and standardization are still a development in progress, and the level of completeness and maturity differ across open interfaces. Open fronthaul is the most mature and deployment ready as compared to other areas listed below for which specifications are still being developed. Vendors are to develop their commercial products based on a set of minimal viable requirements to be market and deployment ready. Even in the case for open fronthaul, enhancements are still required to support efficiency for MU-MIMO deployments.

1. Cloudification
2. RIC AI/ML platforms (near and non-RT RICs) and multi vendors xApps and rApps
3. SMO zero touch automation
4. sustainability needing energy efficient and AI/ML enabled energy savings Open RAN specifications.

Some additional points to note:

- Both 5G and Open RAN are not fully mature yet because they have not been fully stress tested enough with real-world examples to see how well they actually work. Some examples are position tracking features, ultra-reliable low latency in terms of the number of factory hours 5G/Open RAN products have been running with corresponding meantime to failure for the networks in terms of factory up time and statistical quality metrics, health care and other emergency type applications, first responder and defense applications. We don't have enough runtime hours for any one of those use cases.

- Between 5G and Open RAN, each of these protocol stacks have been evolving on their own in a way, but the interoperability and interworking functions between them is lagging behind the pace of the development of each of these protocol stacks. Features like network slicing in terms of how it is represented and managed between the Open RAN and 5G protocol stacks and the constructs and entities you can use for looking at whether or not you have good a quality network slice. Also, cybersecurity and detecting rogue Open RAN elements, how do we detect, mitigate and manage these scenarios? These are some key areas that need to be addressed.

Plugfests are a reasonable starting point for market-readiness. They can be improved to help accelerate trial system deployments and larger scale feature testing. Also, there have been minimal end-to-end testing at Plugfests to demonstrate that a network is ready for deployment.

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b. What is required, from a standards perspective, to improve stability, interoperability, cost effectiveness, and market readiness?

c. What criteria should be used to define equipment as compliant with open standards for multivendor network equipment interoperability?

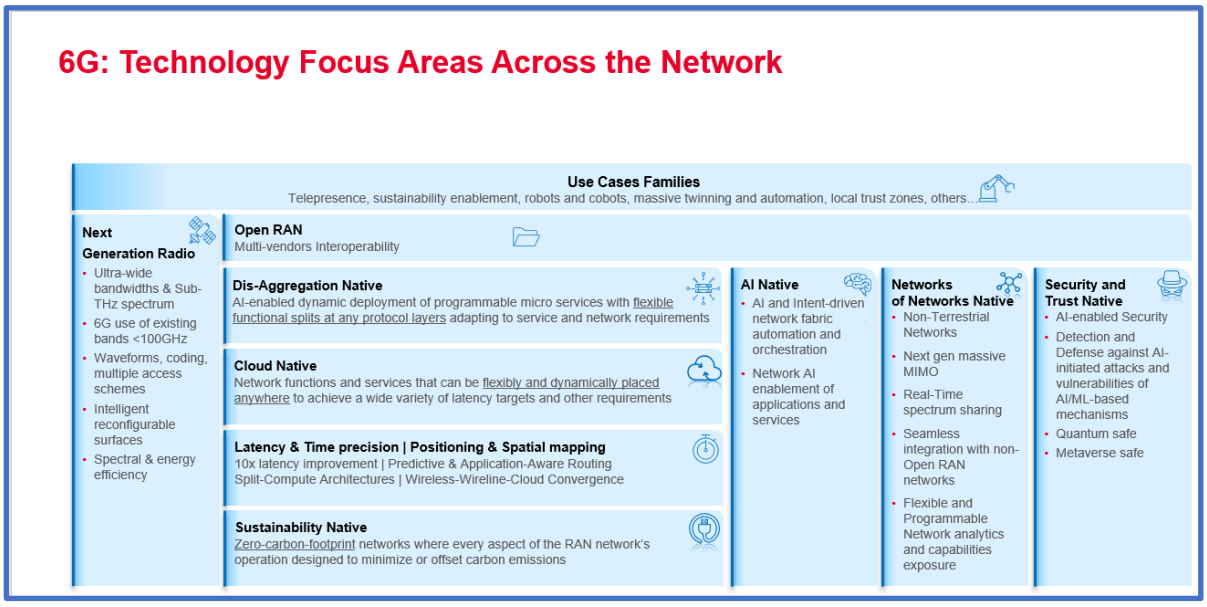
To improve stability, interoperability and market readiness, we propose that instead of adding more features to the standard, focus on a simple set of requirements, and a serving segment of customers. Once the Open RAN solutions are deployed/commercialized, more features can be added later.

Equipment should be deemed interoperable with a number of complementary network elements from different equipment manufacturers. The goal would be to have enough test coverage with different vendor implementations over some minimally required set of features.

8. What kinds of projects would help ensure 6G and future generation standards are built on a foundation of open and interoperable, standards-based RAN elements?

Some projects to help ensure 6G build on open and interoperable RAN are: 1) System level plugfests and 2) application specific testbeds developed using off the shelf rapid prototyping products. Use cases are good for driving requirements and business justification for customers but they are also great for exploring interoperability and interoperability quality between 5G and Open RAN. Having these use cases would help accelerate the testing of the interworking between 5G and Open RAN and help accelerate and discover new feature requirements. There are a very rich set of feature roadmap requirements that can be discovered – this would benefit the 5G and 6G communities and help accelerate innovations.

A variety of other candidate projects are shown in the slide below to ensure 6G and future generation standards are built on a foundation of open and interoperable, standards-based RAN elements.



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Integration, Interoperability, and Certification

9. How can projects funded through the Innovation Fund most effectively support promoting and deploying compatibility of new 5G equipment with future open, interoperable, and standards-based equipment?
a. Are interoperability testing and debugging events (*e.g.*, "plugfests") an effective mechanism to support this goal? Are there other models that work better?

10. How can projects funded through the program most effectively support the "integration of multi-vendor network environments"?

Plugfests are good solutions for testing interoperability across standard interfaces for 5G and Open RAN. These plugfests are good for looking at interoperability and adherence to these protocols and standards across vendors from a device perspective and a network perspective however, they fall short of testing a large number of permutations of how those networks are actually used. A good complement to these plugfests is to incorporate use case application testing in trial networks. In use case application testing, you could select a number of vendors, both from the device side and the network side, and instrument the network, and look to see how the network is performing, and then accelerate innovation in terms of optimizing the performance for specific use cases, discovering novel ways to get KPIs out of the network that can be used to assess the performance for specific use cases. This also provides the opportunity for standards essential contributions and adding KPIs and tap points in the protocol stacks for inspecting performance of the end-to-end applications for these use cases.

Another model of interoperability testing is to deploy and operate Open RAN on actual small-scale regional or private networks.

Project funds can most effectively support multi-vendor integration by encouraging common interface points and access points to allow for instrumentation of the network for integration and test. It would also help if government-furnished test and integration labs were available for multi-vendor integration use.

11. How do certification programs impact commercial adoption and deployment?
a. Is certification of open, interoperable, standards-based equipment necessary for a successful marketplace?
b. What bodies or fora would be appropriate to host such a certification process?

12. What existing gaps or barriers are presented in the current RAN and open and interoperable, standards-based RAN certification regimes?

Certification programs will help to drive and accelerate commercial adoption and deployment; however this can only be helpful if:

1. Certification is based on test cases which are well designed and documented to ensure consistent and repeatable testing and test results across all the global labs.
2. There will still be a gap for deployment readiness testing, as the current certification mechanism is based on basic, functional, and sunny day scenario test cases which are not representative of real-world test scenarios. Deployment readiness tests will need to include performance, robustness,

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resilience, security, stability testing in both the labs and field-testing conditions and testing in the labs with non-ideal channel and network conditions bring live environment back to the labs.

3. A Zero Touch Minimal Functionality Certification or Badge guaranteeing functional interoperability for a minimal subset of Open RAN functionality between all Open RAN elements would help address issues where conformance test cases pass but functional operation is not guaranteed even when the network elements pass those conformance test cases.

Certification helps to validate smaller vendors' Open RAN solutions - when the solutions are standardized, and interchangeable, the buyer will have less concern to buy solutions from less well-known vendors. Certification programs could also add delay in getting a network up and running.

We believe certification is necessary for a successful marketplace to minimize the amount of integration testing and validation. The number of vendors is so large that the permutations of 1:1 testing is very large, so there must be certification. Further to certification is the need to have an expanded, exhaustive amount of automated certification testing.

Current certification testing as determined by O-RAN ALLIANCE are based on test cases which focuses on functional, sunny day scenarios test cases. There is still a gap between certified Open RAN network functions and deployment readiness which will involve a lot more robust testing.

OTIC (Open Testing and Integration Center) test labs are one such forum to host such a certification process. OTIC labs would need to work closely with Open RAN test vendors.

The market for Open RAN, whether through public service providers, or private networks, has not grown to a point that demands open and interoperable standards-based RAN. Here in the US, there are only 2 certified OTICs for end-to-end testing.

Trials, Pilots, Use Cases, and Market Development

13. What are the foreseeable use cases for open and interoperable, standards-based networks, such as Open RAN, including for public and private 5G networks? What kinds of use cases, if any, should be prioritized?

14. What kinds of trials, use cases, feasibility studies, or proofs of concept will help achieve the goals identified in 47 U.S.C 906(a)(1)(C)(vi), including accelerating commercial deployments?
    a. What kinds of testbeds, trials, and pilots, if any, should be prioritized?

15. How might existing testbeds be utilized to accelerate adoption and deployment?

Here are some foreseeable use cases for open and interoperable networks:

1) Use cases where Open RAN can be leveraged to check health of the network, at run-time, at various points inside the network, for mission-critical applications. Very high reliability applications such as Vehicle-to-anything, and telesurgery, where human life is at stake

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2) Disaggregation of Non-terrestrial networks where the DU is in space, and the CU is on the ground
3) Hybrid terrestrial and non-terrestrial networks
4) Private networks to replace or complement Wi-Fi in large enterprises.
5) Public networks for smaller/regional service provider.
6) First responder use cases, where Open RAN software can be easily customized for different missions, equipment types, locales and others. This is because of the simplicity of Open RAN in customization, since it entails a simple hardware (RU) and the rest is software.

Resilience testing on test beds and prototype trial networks will help accelerate commercial acceptance. This testing would be in the context of performance resilience for RF environment quality and network operating quality and cybersecurity resilience for RF and Network cyber-attacks. Furthermore, end-to-end testbeds should be prioritized to make sure the Open RAN solutions work with a wide variety of applications.

Adoption for deployment will be accelerated when 5G/6G operational confidence can be measured in the form of quality metrics measured both at pre-deployment and on live systems. Instrumenting the networks to provide correlated metrics between application-level performance and network quality metrics vs time for a wide range of use cases can also be used to build confidence metrics showing how quickly runtime anomalies (which will occur) are contained and mitigated.

Security

17. "Promoting and deploying security features enhancing the integrity and availability of equipment in multi-vendor networks," is a key aim of the Innovation Fund (47 U.S.C 906(a)(1)(C)(vi)). How can the projects and initiatives funded through the program best address this goal and alleviate some of the ongoing concerns relating to the security of open and interoperable, standards-based RAN?

As mentioned earlier in our comments, a zero-trust approach must be adopted on the security aspects of the E2E connectivity which operators offer to their customers which includes the radio access, core networks, supporting edge computing servers, transport network switches/routers, cloud infrastructures and data centers.

The need for continuous integration, development / deployment, and testing (CI/CD/CT) for both the devices and networks from the security aspects have accelerated for 5G and B5G networks leading into 6G requirements with

1. The emergence of industry verticals and enterprise use cases which are needing increased requirements for security, privacy, and reliability of the E2E connectivity fabric.
2. Networks are going through the virtualization, cloudification and dis-aggregation transformation increasing security threats and potential vulnerability of the networks to the evolving threats applicable for both monolithic single vendor networks and Open RAN.
3. Open RAN with its intrinsic multi-vendors interoperability support built into the O-RAN ALLIANCE specifications has introduced and amplified additional security threats with expanded threat surfaces with further dis-aggregation, increased number of suppliers with multi-vendors

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components implemented and interoperate with specifications which are still development in progress with varying levels of maturity and robustness against security threats.

4. Increased use of AI/ML for network optimization and automation creates additional threats considerations such as potential flaws in ML models, AI/ML applications and data sources integrity, reliability, and trust worthiness, just to name a few.

Potential funding areas may include research and investments into cyber ranges into these topics

1. Assess, qualify, and quantify impacts to commercial scale live networks subscribers, devices and services experiences (emulated in a digital twin framework) through highly parameterized mimicking real world attacks on multi-vendors Open RAN systems which may include distributed denial-of-service (DDoS) attacks, fuzzing attacks, cloud attacks, vulnerability scanning, and attempt penetrations based on up-to-date threats and vulnerability databases.
2. Complete visibility and threat detection: one will need to have the virtual machines and containers, taps and access points, that gives you the framework in which you can deploy security features. One of the objectives will be to detect rogue elements on the network. This will require test equipment and test software that is capable of instrumenting the protocol stack to look for protocol stack anomalies both in 5G-NR and Open RAN. Another objective will be to detect security attack events as they are happening and defend against them in real time.
3. DevSecOps continuous integration, development / deployment, and testing (CI/CD/CT) pipeline design and application to Open RAN architecture and systems.

Program Execution and Monitoring

21. Transparency and accountability are critical to programs such as the Innovation Fund. What kind of metrics and data should NTIA collect from awardees to evaluate the impact of the projects being funded?

Success of the use of innovation funds should be measured, at the highest level, by success (in the form of application performance and reliability) of *actual* deployment of Open RAN networks. For more detailed metrics and data, it will depend on what is being tested. Keysight has a large number of tests and metrics for conformance, interoperability, end-to-end testing, and run-time analytics.

22. How can NTIA ensure that a diverse array of stakeholders can compete for funding through the program? Are there any types of stakeholders NTIA should ensure are represented?

23. How (if at all) should NTIA promote teaming and/or encourage industry consortiums to apply for grants?

NTIA could sponsor and reward novel innovations providing unique features and insights into the operational quality of the Open RAN/5G network. Also, NTIA can have vendors compete in end-to-end test challenges, whereby NTIA can then sponsor regional service providers to purchase Open RAN solutions from the successful vendors of these challenges. These end-to-end challenges should require vendors team with an array of vendors, to promote multi-vendor integration. It is also important to have participation by an entity that can test and evaluate the goodness of the challengers.