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Subject: NASA Space Communications and Navigation Input to NTIA/DoD 5G NOI
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The NASA Glenn Research Center's Space Communications and Spectrum Management Project Office is pleased to submit the following response to the NTIA/DoD Notice of Inquiry on open 5G systems. This response is on behalf of the Advanced Communications and Navigation Technology (ACNT) division of NASA's Space Communications and Navigation (SCaN) program office. ACNT is led by Dr. Jason Mitchell.

NASA SCaN has a significant interest in collaboration on topics related to open 5G technology and architectures for non-terrestrial communications. This commercial technology already has substantial investment by the private sector, which reduces government investment requirements and allows government communications technology to converge towards solutions already employed successfully by industry. Recently, NASA awarded a STMD Tipping Point award to Nokia to place a 4G/LTE base station and user equipment on the Moon as part of a commercial technology demonstration. Further investment by SCaN includes the development of a Ka-band phased array leveraging commercial 5G technology for near-earth space operations. Wideband technology being developed by SCaN supports the seamless integration of civil, defense, and commercial communications relay satellites operating in Ka-band to serve space missions.

NASA encourages DoD and NTIA to pursue the development of open 5G technologies, leading to greater interoperability between government and commercial systems. We welcome the opportunity to become part of this conversation, from providing technical advice to evaluating technologies and guiding development. Our responses to the questions posed by the NOI are provided below.

Respectfully submitted,
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How to take advantage of DOD's role as an early U.S. Government adopter of 5G technology to mature the open 5G stack ecosystem faster?

One possible avenue for the government to participate with industry to help mature a commercial market is with public-private partnerships (PPP), where government and industry share costs and risks in an effort to foster new commercial markets and expertise. The NASA Communications Services Program (CSP), for example, is investigating the integration of commercial SATCOM systems

into future agency missions via a three-phase strategy with industry partners. Another example of a successful PPP was between ESA and Airbus for the development of the SpaceDataHighway, which provides high-rate laser communication services to space-based users.

How to encourage more participation in open 5G stack development including encouraging new participants and identifying any roadblocks to broader participation?

Structure the call for participation such that all businesses are encouraged to apply. Avoid barriers to entry (such as financial or labor-related) that may preclude smaller companies. Tailor the candidate evaluation criteria such that a diversity of applicants is favored.

What should be the goals of the challenge to focus on maturing the open 5G stack ecosystem?

To mature an open market, design the incentives (i.e., rewards) of the challenge to focus on areas that encourage collaboration, cooperation and interoperability between systems. Levels of collaboration/interoperability will be commensurate with reward to participants.
Also, consider partnerships between government and industry such that the government may assume some of the up-front cost/risks such that industry can establish a viable business case. Over time, the government can reduce/eliminate investment as the market matures.

How to encourage the greatest level of innovation?

Encouragement to participation comes through reward, which can include contract awards, cash prizes, partnerships, or other agreements. Structure the reward of the challenge such that participants exhibiting the greatest level of innovation achieve the greatest reward. Reference the DARPA Spectrum Collaboration Challenge (SC2).

What metrics should be used in the assessment of proposals?

Collaboration, cooperation, and interoperability are key goals to achieving an open market. DoD should weight the evaluation metrics of the challenge in such a way that participants that exhibit the greatest level of those metrics will achieve the highest evaluation scores.

How to structure the challenge such that it provides a dual benefit to both government and open 5G stack market?

Structure the challenge such that government and industry may share some of the costs/risks for maturing desired technologies through partnerships, such as public-private partnerships. In such cases, the government may assume a greater level of cost burden early in the partnership to encourage industry to work towards advancement of the technology. Once the market reaches a greater level of maturity, industry can reap the reward of enhanced market share, and the government can reduce/eliminate its involvement.

What are the incentives in open 5G stack ecosystem development that would maximize cooperation and collaboration, and promote interoperability?

DoD should weight the evaluation metrics of the challenge in such a way that the highest evaluation weights are based on participants that exhibit the greatest level of collaboration, cooperation, and interoperability.

How to include test and evaluation of security components?

DoD can evaluate security aspects of the technology by structuring a portion of the challenge such that teams will receive the greatest reward for exposing the security weaknesses of other competitors. Another option could provide for an independent "red team" that focuses on exposing competitors' security weaknesses throughout all phases of the challenge.

What software and hardware infrastructure will be needed to successfully execute this Challenge?

To ensure fair evaluation of interoperability, the government can establish an independent government testing capability (consisting of hardware and software). The evaluation may consist of 1-to-N or N-to-1 testing of user equipment and base stations to determine interoperability. NIST may be an appropriate agency to perform this testing. NASA has a strong capability, presence, and interest in satellite propagation (e.g., antennas, amplifiers) and the evaluation of networks extending beyond Earth.

What is a reasonable timeframe to structure such a Challenge? Should there be different phases for such a Challenge? If so, what are appropriate timelines for each suggested phase?

Based on the size and scope of the open 5G architecture, it seems that the challenge should be structured as a multi-year and multi-phase effort. For example, the DARPA SC2 was structured as a multi-year challenge with multiple rounds, where each round focused on different scenarios with varying obstacles. At the end of each round, the two lowest-scoring teams competed to avoid elimination.

The NASA Urban Air Mobility (UAM) Grand Challenge is another example of a multi-year and multi-phase challenge focusing on fostering the capabilities and readiness of aerial vehicles and systems for enhanced mobility around densely populated areas.

In another case, the NASA Communications Services Program (CSP) is investigating the feasibility of integrating commercial SATCOM systems into future agency missions via an approach that spans three phases and multiple years.

Could a Challenge be designed that would require participants to leverage software bill of materials design principles in the development of components for an open 5G stack?

The evaluation metrics of the challenge should be weighted in such a way that those participants that leverage the desired design principles will achieve a higher evaluation scores / higher reward. The use of a modular design already is encouraged by standard 4G/5G architecture, which

distributes components of the architecture across multiple processing elements.

Many open 5G stack organizations have developed partial implementations for different aspects of an open 5G stack. What portions of the open 5G stack has your organization successfully developed with working code? What portions of the open 5G stack does your organization believe can be developed quickly (6 months or less)? What development support would best enable test and evaluation of the different elements of an open 5G stack?

NASA is a new entrant to the 5G market. As part of its lunar architecture, LunaNet, NASA is developing 3GPP-based technologies that would enable lunar surface communications for government and commercial landers. One example of this work is the development of a LTE lunar base station and user equipment by Nokia under a 2020 Tipping Point award worth $14.1 million. Nokia is tailoring these components specifically to fit in radiation-tolerant, low-power processing elements.

A compatibility testing facility would best enable test and evaluation of the open 5G stack. To accomplish this goal, the government must establish a facility independent of the 5G developers to verify protocol, spectrum, and equipment compatibility.

What 5G enabling features should be highlighted in the Challenge, such as software defined networking, network slicing, network function virtualization, radio access network intelligent controller, radio access network virtualization?

All 5G enabling features pose an opportunity for the DoD to evolve its existing network implementation. In particular, software defined networking (SDN) provides an opportunity for rapid deployment of network routing and security policies across the DoD enterprise network. When paired with SDN, network function virtualization poses the ability for the DoD to rapidly deploy a 5G network using only minimal and limited infrastructure support in remote locations, such as a single blade server. These two features are stepping-stones to robust, reliable, and rapid deployment of communications systems in new locations.