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NSC SUPPORT OF THE DOD'S 5G INITIATIVE

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<u>Executive Summary</u>

The National Spectrum Consortium (NSC) prepared the attached white paper to address challenges related to 5G technology in support of the U.S. Department of Defense (DoD). The paper is designed to provide Federal executives with an overview of 5G and its potential impacts on military operations. It provides descriptions of 5G and identifies the technologies that will be most important as America develops its own 5G capabilities; it discusses some of the opportunities for and threats to our economy; and it offers Military leadership specific examples of 5G technologies as they relate to the Joint Warfighting Functions. Additionally, it offers recommendations on how the National Spectrum Consortium could assist DoD in meeting these challenges – a similar approach can be used to support other Federal Agencies in addressing their 5G technology challenges and needs.

The National Spectrum Consortium (NSC) is available to assist you in achieving the desired outcomes of your 5G initiatives. The NSC provides a sanctioned and ethical "meeting place" where Government can discuss requirements, and U.S. industry and academia can share the state of technology and the art of the possible. This engagement and conversation is the key to success and timely implementation of 5G-enabling technologies.

The NSC is a research and development organization that incubates new technologies to revolutionize the way in which spectrum is utilized. Through collaboration between industry partners, academia and Government agencies, we solve the toughest problems the nation faces to enable spectrum co-existence and sharing. Technologies created by the NSC will make bi-directional and multi-directional spectrum sharing in federal and commercial bands a new norm, hence eliminating a need to relocate systems. The NSC's membership includes representatives from large businesses, small businesses, "non-traditional" companies, academic research institutions, and not-for-profit organizations. NSC members collaborate among themselves and with Government agencies to define the problems and recommend solutions; the NSC members then compete for project awards in response to Government solicitations. In short, the NSC is organized, chartered, and positioned to assist the Government in achieving the 5G desired outcomes.

The Consortium was established and awarded an initial $1.25 Billion ceiling, National Defense Authorization Act, Section 815 Prototype Other Transaction Agreement (OTA) with the Office of the Secretary of Defense in April 2015. Currently, the NSC has over 215 members from within the U.S. technology base and is executing 57 research and development projects for the DoD in support of a more effective and efficient use of spectrum.

The Section 815 OTA enables open communication between any Government member and the Consortium Membership. If the Government chooses, the NSC can organize discussions on any technical area of interest, which can take the form of large collaboration events with multiple members, industry days, one-on-one sessions with an individual member, or virtual events. The NSC intends to create a 5G Community of Interest with smaller working groups aligned with the DoD's desired outcomes or lines of effort.

In summary, the NSC has the technical expertise and 5G knowledge base readily available to assist Federal Agencies and we look forward to the opportunity to help your agency in meeting its requirements. We hope this will be the first of many engagements with your organization to position the U.S. as the world leader in 5G technology.

<u>Background</u>
The National Spectrum Consortium welcomes the opportunity to collaborate with U.S. Federal Agencies in addressing the impacts future technologies will have on their missions and the U.S. economy. This paper was originally prepared in support of the U.S. Department of Defense (DoD), specifically to infuse the voice of industry and academia as DoD investigates the opportunities and challenges presented by so-called "5G" technologies. Our NSC member organizations stand ready with the right mix of technologists from 5G industry leaders, traditional and non-traditional federal contractors, academic institutions and other industry partners that can bring relevant expertise to help solve complex issues.

The NSC offers this paper to provide all parties with a common understanding of 5G technologies -- it examines the opportunities for and vulnerabilities to DoD systems; suggest ways in which DoD might consider operational employment of 5G; suggests a method where NSC and DoD can partner to address DoD interests; and provides recommendations for moving forward. Much of this paper is analogous to and applicable for the mission challenges and technologies needed in support of many Federal Agencies.

<u>What is the NSC?</u>
The National Spectrum Consortium is a research and development (R&D) organization that incubates new technologies to revolutionize the way in which spectrum is utilized. Through collaboration between industry partners, academia and Government agencies, we provide a unified voice for effectively articulating the strategically important role electromagnetic spectrum technologies play in government and industry systems. Objectives of this collaborative effort between NSC Members and the Government include:
- Rapidly maturing technologies that assist in improved electromagnetic spectrum awareness, sharing and use
- Technology demonstrations and experimentation to demonstrate how technology can be employed in increasingly contested and congested environments
- Technology analysis to inform DoD requirements and policy considerations

NSC was kick-started through a 5-year, $1.25 Billion ceiling, Section 815 Prototype Other Transaction Agreement (OTA) with the Office of the Secretary of Defense (OSD). However, the OSD allows all DoD activities (Services, agencies, systems commands, combatant commands, etc.) to use the OTA for spectrum-related collaborative purposes or competitive R&D project solutions. This OTA with DoD can also be used in support of other Federal Agencies with Statutory Other Transaction Authority; or if desired, other Federal Agencies can contract directly with the NSC using other contract instruments or their own OT Authority.

<u>What is 5G?</u>
To ensure a common understanding of what 5G is, the opportunities it offers, and the threats/vulnerabilities it may present, the NSC offers the following detailed description.

5G is more than just communications, enhanced networks ("faster 4G") or new waveforms. Instead, 5G is best described as a service delivery and innovation platform for the 2020s and beyond. It is being designed to enhance existing mobile broadband services, but more importantly, it will open new capabilities and network efficiencies not possible with today's networks. 5G will underpin the digital economy and provide the backbone for the next generation of digital technologies. The commercial investment and deployment of 5G networks and supporting technology provides both opportunities and challenges to economic security, homeland security, and national security.

5G promises greater speed, capacity, and reliability with reduced latency. The figure below shows that 5G will revolutionize communications in three dimensions: enhanced mobile broadband, ultra-reliable/ low latency communication and massive Internet of Things (IoT) connectivity.
- 5G must enable peak rates of far more than 10 Gbps on demand but more importantly more than 100Mbps even at the cell edge. This will be enabled by a dramatic increase in capacity and high spectral efficiency.

- Then it will open a new category of services known as ultra-reliable low latency communication. That means with 5G, one can steer any kind of machine, such as factory robots. It requires a predictable connection and ultra-low latency combined with 100% reliability, a challenge for today's best effort networks.

- Finally, 5G will power the vast webscale networks that interconnect billions of humans and machines.
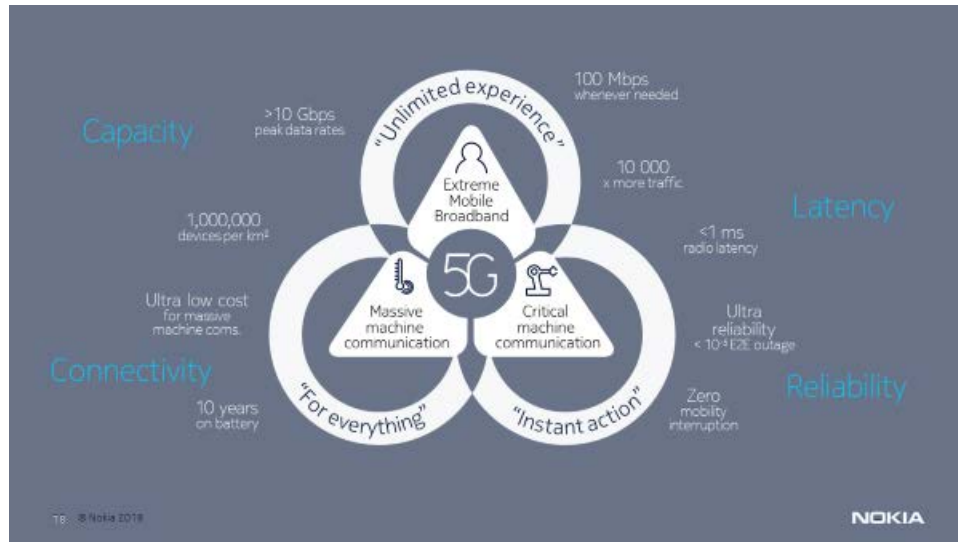
The scope of the 5G standard is far larger than a new radio. Latency and reliability will matter as much as bandwidth. IoT and emerging technologies such as Mixed Reality (comprising Virtual and Augmented Reality) enable novel application scenarios with much more stringent requirements for network latency and service level guarantees.

For example, mixed reality (MR) headsets in combination with motion sensors and haptic feedback mechanisms enable embodied physical interaction with virtual and remote real-world objects. As a result, timing requirements for human sensorimotor and vistibulo-ocular interaction loops have to be taken into account. Bandwidth-efficient delivery of MR 360-degree video (and Free Viewpoint video in the future), cloud rendering of MR games, multi-user manipulation of 3D objects in MR collaboration and teleoperation of remote vehicles and robots require networking latencies in the order of 10ms.

Mass deployment of connected sensors and actuators enable the creation of mission-critical cyber-physical control systems like automation of manufacturing processes, large-scale traffic coordination of autonomous vehicles, and logistics and smart electrical grids. Proper functioning of such distributed autonomous systems depends on network latencies in the order of a few milliseconds.

Cloud applications today are generally served from large centralized data centers – efficient from a cloud infrastructure perspective but limiting with respect to latency and transport efficiency for performance sensitive and high bandwidth applications. In order to deliver these new types of augmented reality (AR), virtual reality (VR), and 'tactile Internet' services, these global Internet content providers (ICPs) will need to be able to leverage localized compute/storage and connectivity services. Local network providers, with extensive distributed networking and real estate assets, are quite naturally well positioned to fill this local delivery partner role.

To enable these advances and functionalities within the same network architecture, 5G must be very flexible and adaptable based on the use cases required. The figure below illustrates the overall scope of 5G, with the new radio being critical, but just a small part of the architecture and impact to our communications infrastructure.
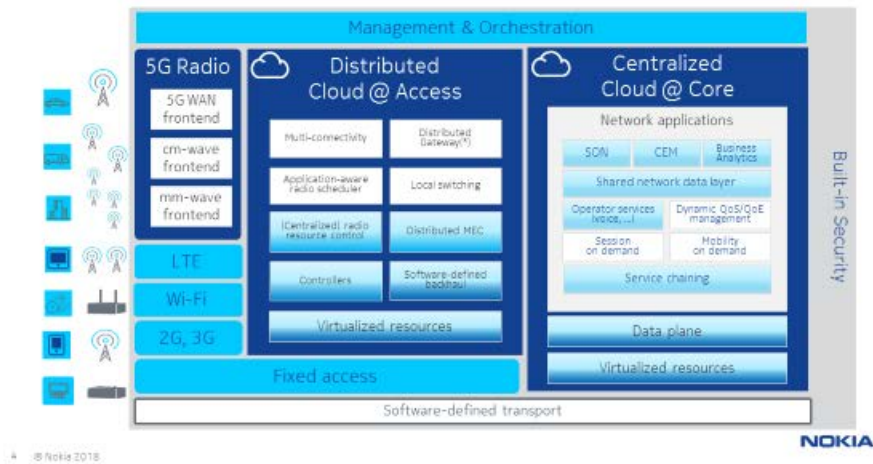
With ground breaking upgrades at the radio layer, the New Radio (NR) standard implements an advanced physical layer that supports millimeter wave communications and antenna arrays for massive multiple-input, multiple-output (MIMO) systems. In parallel, the 5G core network (5GC) has been redesigned for enhanced flexibility and service versatility. The goal of 5G networks is to provide ubiquitous, high-speed, and low-latency connectivity for enhanced mobile broadband, massive machine type communication and real-time control.

5G ubiquitous connectivity will enable massive sensor deployment, creating an ideal environment for artificial intelligence applications in areas like healthcare. This includes individual monitoring, data collection, and telemedicine. Low latency will improve augmented and virtual reality (AR/VR) to the point of supporting virtual physicians and surgeons. Or instead of healthcare, the application could be maintenance, logistics, transportation, energy, agriculture, robotics, first responders, or military operations – leveraging 5G speeds and capacity to collect and move massive amounts of data and generate improved operational efficiency across highly netted, distributed, intelligent systems.

Beamforming, multi-in multi-out (MIMO), and modulation techniques (e.g. – 256 QAM) are key technologies for 5G. Commercial scale of investment will drive down cost and size while proliferating these technologies beyond what was primarily a military application space. Nation-states and non-nation-states alike will have access to software-defined virtualized networks with highly compact, agile, and directional sensors and communication nodes. Line-of-sight (LOS) networking would allow connectivity independent of satellite communications and the ability to operate in a GPS-denied environment. LOS could be extended by using a combination of manned and/or unmanned aerial systems (UAS) as part of a massive MIMO system.

It is also important to understand that who makes 5G technologies, who sets the standards, and who owns the intellectual property (IP) has implications for security, innovation, and employment in an increasingly competitive technological environment. According to Jim Lewis at CSIS, "There are no longer any U.S. manufacturers for core telecommunications network equipment. Four companies dominate the market for the core network technologies needed for 5G networks. None of these companies are American. The choices for core network equipment are between European security partners (Ericsson and Nokia) and China (Huawei and ZTE). Samsung, with its substantial chip-making and equipment-making capabilities, has also entered the 5G race but still has a relatively small share of the market. 5G networks depend on specialized semiconductors, and American companies dominate this market. Semiconductors are a strategic industry, essential to security and growth. Chinese companies are strong in simpler microelectronics, but these pose a lower risk to security. Western companies routinely outspend their Chinese competitors in 5G R&D and hold 10 times as many 5G patents. Chinese companies still depend on the Western companies for the most advanced 5G component technologies, such as radio frequency processing or FGPAs (a specialized semiconductor essential for software defined networks)."

Defining global 5G standards will produce immense economic advantage. Chinese companies are attempting to dominate standards development to mandate the use of Chinese technologies. Patents implement standards. Patents provide ownership of the intellectual property required to make or use a technology based on a standard and create a revenue stream. For 5G, this revenue stream will be measured in the billions of dollars. The companies that patent technologies that meet 5G standards will gain larger shares of revenue and have an important advantage in further innovation.

From its annual report released in Nov 2018, the U.S.-China Economic and Security Review Commission states "The scale of Chinese state support for the IoT, the close supply chain integration between the United States and China, and China's role as an economic and military competitor to the United States creates enormous economic, security, supply chain, and data privacy risks for the United States…The lax security protections and universal connectivity of IoT devices creates numerous points of vulnerability that hackers or malicious state actors can exploit to hold U.S. critical infrastructure, businesses, and individuals at risk." As an example, although security has been improved from previous generations, unrealistic 5G system assumptions and protocol edge cases can render 5G communication systems vulnerable to adversarial attacks. Several critical security and key management functions are left outside of the scope of the 5G specifications. The comparison with known 4G Long-Term Evolution (LTE) protocol exploits reveals that the 5G security specifications do not fully address the user privacy and network availability challenges. Some of these concerns will be addressed by leveraging increased 5G speed and bandwidth to allow use of improved encryption without performance loss.

5G+ Enabled Operational Capabilities
The tie between 5G and IOT offers insights into potential opportunities for military applications. Certainly, the most obvious benefits can be drawn from direct parallels in "smart" healthcare, logistics, and maintenance, where 5G enables massive instrumentation, data collection, and the potential for applying AI to maximize complex pattern analysis and predictive/preventive operations. Advances in IOT architectures that support low power sensors and edge devices will also benefit the military where previously it was not practical to deploy long-endurance massive sensor fields or dynamically collect, analyze, and act upon the massive amounts of data generated in real time. Examining the 5G ecosystem through the lens of Joint Warfighting Functions exposes other interesting potentials such as:

- Fires – netted, distributed kill chains; battle management, third party targeting, automated weapon target pairing; swarms; multi-function arrays, visualization
- C2 – secure, LPI/LPD, resilient, high capacity, high speed ubiquitous networks, node deployment for optimized coverage (USAF MDC2), Naval Tactical Grid
- Intel – analytics, AI, cloud, red course of action (COA) prediction, dynamic collection tasking, sensor fusion
- Maneuver – vehicle-vehicle "smart transport", mobile edge computing, distributed operations, TACSIT management (USN/USMC DMO, EABO, LOCE)
- Protect – monitoring individual/collective biometrics for dynamically managing human performance, CBRNE exposure
- Sustainment – smart just-in-time (predictive/preventive) logistics/maintenance/base infrastructure (USA MDO)
- Information – cyber security

The same low latency that will benefit the entertainment community (in particular, mobile gaming) could also be applied to improving the Live Virtual Constructive (LVC) training environment and perhaps even applied to developing mixed reality operational interfaces, overlaying multi-INT, multi-layer security data with red/blue COA simulations and cued alerts to identify predicted or actual deviations from the plan and options to execute Commander's intent.

Challenges to Military Operations and Intelligence Gathering

The learning curve for 5G is quite large, larger than previous generations of communications technology. While 5G technologies will provide warfighters with broad new operational capabilities, many threats and vulnerabilities will be discovered as DoD understands and applies 5G technologies over time. For illustration purposes, one example is presented here that demonstrates the challenges 5G may present to DoD, Homeland Security and intelligence gathering activities.

Current 4G Base Stations (BS) use sectored antennas, whereas 5G BSs will have tens of antenna elements. The antenna elements may be used to serve thousands of new devices in Multi-User MIMO configurations, or they can also allow formation of pencil beams that can provide dedicated network slices to users who are willing to pay higher subscription charges. 5G systems are also likely to cater to the autonomous vehicle market where they may be used for vehicle command and control. While these applications may be great for consumers, conducting signals intelligence or electronic warfare operations to protect US forces or perform homeland security functions against them becomes quite challenging. A few examples include:

- Detecting, separating, identifying and geo-locating individual users signature in a Massive-MIMO scenario
- Detecting the pencil beam that is allocated to a fast-moving user (e.g., in a truck or a train)
- Creating purposeful interference (i.e., conducting electronic warfare) to an individual user without disrupting friendly communications or other spectrum usages

The Need for Speed

As described above, America's adversaries and U.S. commercial wireless carriers have been working on 5G technologies for years, so action is required to put DoD on the leading edge of these advances. Once the technology is understood, developing a 5G strategy, incorporating 5G-based requirements into current and future DoD systems, and investing in government-sponsored R&D projects will be critical to ensuring that DoD can fight and win in future 5G-enabled environments.

Support for DoD's 5G Initiative

NSC members have the technological expertise and vast resources to provide DoD with comprehensive education, requirements definition, R&D, red teaming, and other 5G-related activities. To support this initiative, the NSC will stand-up a "5G Community of Interest" (COI). The NSC 5G COI will include as many participants as are interested from within the NSC membership, with no limit to the number of interested participants from each company or university. The NSC 5G COI will be asked to populate working groups (WGs) with subject matter experts (SMEs) based on specific "Outcomes" and/or "Lines Of Effort (LOEs)" to be determined by DoD. While participation in the COI and WGs is voluntary, the NSC will endeavor to staff each WG with SMEs from across our broad membership, identifying any gaps in our current membership and actively pursuing additional companies/institutions to ensure the right mix of technical 5G expertise needed to support the COI, its WGs and DoD LOEs. Ideally, each WG will be fully integrated with DoD-led teams that may be formed to ensure synchronized actions and common outcomes between government and NSC SMEs. The WGs will select a WG Lead to serve as the primary point of contact between DoD leadership, the NSC Executive Committee (ExCom), and the broader NSC membership. This COI approach can be further adapted to provide even greater support to DoD as the department develops responses to the President's October 25, 2018 Memorandum for "Developing a Sustainable Spectrum Strategy for America's Future."

Recommendations

As garnering the necessary SME support from our COI participants will require us to poll members and organize into WGs, we look forward to early and often engagement with DoD's LOE leads. To further these efforts, the NSC recommends:

- Expeditious establishment of DoD and NSC working groups based on lines of effort, focus areas, or desired outcomes. To accomplish this, the NSC recommends an organizational meeting between NSC members and DoD leadership in early January 2019. Based on timelines provided by DoD, WGs could then meet through the 1st Quarter of 2019 and report outcomes to DoD in March 2019.
- Establish recurring educational meetings, face-to-face exchanges with multiple stakeholders, webinars, tele-conferences, workshops, or other collaborative interactions.

- Conduct visits by DoD leaders to NSC labs and research facilities.
- Establish forums for defining DoD needs that will ensure DoD requirements are included in future 5G standards.
- Communicate with existing DoD-sponsored or industry-sponsored activities to ensure cohesive and efficient lines of effort.

The NSC stands ready to support your Agency. We would welcome the opportunity to address your Agency's challenges and capability needs, much like we have done above for the DoD.

Should you have any questions or wish to engage, the NSC Executive Director, Mr. Tony Melita, is our point of contact: Mr. Tony Melita, (703) 338-0294, tony@spectrumconsortium.org.

For the NSC,

Tony Melita

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